Closing the Psychological Distance: The Effect of Social Interactions on Team Performance

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Abstract

Social interactions in the workplace can generate reciprocal peer effects and narrow the psychological distance for team prosociality among coworkers. Incorporating such a psychological interdependence into a team production model, we investigate how the optimal social interactions characterized by the type of task the team is performing (complementary or substitutable tasks) and the vertical and horizontal structure of the team (with or without leadership). We find that in the case of complementary tasks, social interactions can enhance team performance not only for horizontal teams but also for vertical teams led by more prosocial leaders, by narrowing the prosociality gap among members and resolving task bottlenecks. On the other hand, in the cases of horizontal and vertical teams performing substitutable tasks and vertical teams performing complementary tasks supported by a more prosocial follower, social interactions can actually decrease team performance. Our results provide important implications for organizations in considering when, for what type of team, by whom, and to what extent to promote social interaction within teams that bring members' personal (psychological) distances closer, as a means of enhancing organizational effectiveness.

Keywords: team production; social interaction; prosociality; reciprocity; team leadership; peer effects;
JEL Classification: M50; D21; C72;

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1 Introduction

Interpersonal relationship-building among coworkers through social interaction is crucial in teams and organizations, not only in sports teams with clear role allocation to achieve victory, but also in corporate project teams striving to complete business tasks. In the increasingly complex and dynamic business environment, effective communication and collaboration between team members and across different departments are essential for achieving organizational goals. Social interactions, which refers to the exchange of information, ideas, emotional support between individuals, and friendship opportunities in the workplace plays a critical role in fostering trust, building relationships, generating co-worker solidarity, and creating a sense of belonging among team members. In various types of teams, "team altruism" (Li et al., 2014) or "team prosociality," which encompasses the feeling of team cohesion and belongingness, is also crucial for team members to experience job satisfaction and achieve higher team performance, in addition to material motivations such as monetary compensation and the effort they put is.

Many studies have highlighted the importance of social interaction in workplace in enhancing team performance, increasing job satisfaction, and promoting creativity and innovation (e.g., Riordan and Griffeth, 1995; Hodson, 1997; Nielsen et al., 2000; Krueger and Schkade 2008; Masum et al., 2015; Penconek et al., 2021; Delfgaauw et al., 2022, among many others). Despite its significance, there are some downsides to social interaction in the workplace that should not be overlooked. One of the main disadvantages is that it can lead to a decrease in prosociality among more prosocial employees when they interact with less prosocial colleagues. As many studies have shown, the sense of camaraderie fostered by social interaction can generate both positive and negative "peer effects." In addition, given the nature of human reciprocity (Rabin, 1993; Fehr and Scdmidt, 1999), it is reasonable to assume that interacting with colleagues who are less prosocial (altruistic) towards the teammates might have a negative impact on one's own team prosociality, while interacting with highly prosocial colleagues could have a positive impact.

Social interaction at work leads to the development of social relationships among employees and can result in various positive or negative peer and reciprocal effects. Prior studies have documented positive effects (Johnson, 2008; Mas and Morretti, 2009; Volmer, 2012; Sparks et al., 2019; Ching et al., 2021), negative effects (Carrell et al., 2008, 2011; Robert and Arnab, 2013; Dimmock et al., 2018; Cardella et al., 2019), and mixed effects (Johnson 2009; Kramer et al., 2014). The peer effects and reciprocity among these members would naturally be stronger as social interaction in the workplace is promoted, that is, workers are more affected by their peers, especially those with whom they frequently interact.

This paper incorporates reciprocal peer effects resulting from social interaction into a model of team production by two members with different levels of "team prosociality," and theoretically examine the effectiveness of social interaction in various types of team structures and project tasks. Team prosociality refers to the level of involvement, commitment, and enthusiasm that team members have towards their work and the team's goal. This can include considering the well-being and success of the team and its members and valuing the benefit of teammates. Two types of project tasks are considered: complementary tasks, where team members' efforts have a synergistic effect and play a complementary or supportive role in the team's overall performance, such that a lack of effort from one member becomes a bottleneck for the task, and substitutable tasks, where team members' efforts are substitutable, with the greatest effort exerted greatly impacting overall task performance.

Two types of team structures are examined: horizontal and vertical teams. In a horizontal team, team production occurs in a flat structure without hierarchy, modeled as a simultaneous-move game. In a vertical team, one member acts as a Stackelberg leader, indirectly motivating the follower by committing to their own effort level before the follower. We assume that social interaction within a team has reciprocal effects on the prosociality of its members, leading to an increase in prosociality for the less prosocial member but a decrease in prosociality for the more prosocial member, resulting in a narrowing of the difference in prosociality levels.

Within the framework of the model, we investigate the impact of promoting social interaction on team performance across different team structures and project tasks, as well as the asymmetric effects on team members' materialistic payoffs (defined as the difference between monetary rewards and effort costs) and psychological payoffs (defined to include prosociality towards teammates). Furthermore, we examine the extent to which upper-level managers overseeing teams should promote social interaction within teams.

We find the following results: For a horizontally structured team without leadership, social interaction enhances team performance for complementary tasks by narrowing the prosociality gap among members and resolving task bottlenecks. This results in Pareto improvement, benefiting all members in terms of material and psychological payoffs when the effort synergy (complementarity) is high. When the synergy is low, social interaction improves the material payoff of highly prosocial members and the psychological payoff of less prosocial members.

In a vertical team with a hierarchical structure, we find that social interaction improves team performance for complementary tasks only when the team is led by a leader with relatively high prosociality. In the case of complementary tasks with strategic complementarity in effort, if the prosociality of the team members is equal, the leader will exert more effort than the follower, and the follower's lack of effort becomes a bottleneck to task efficiency. Social interaction between a more prosocial leader and a follower contributes to team efficiency by increasing the prosociality of the bottlenecked followers. However, when the team is supported by a more prosocial follower, social interaction may reduce their effort contribution by lowering their prosociality, which could in turn lead to a decrease in the leader's effort, potentially having a negative impact on team performance. In the case of substitutable tasks, social interaction leads to a decrease in team performance regardless of the team's horizontal or vertical structures. This is because the equalization of prosociality among team members reduces the effort of members with larger effort, leading to a decrease in team efficiency.

Our findings contribute to a series of studies on team production and leadership in the following ways. Firstly, we present a simple model framework that shows how social interactions within a team that generate reciprocal peer effects among members can either enhance or diminish team performance in various situations. Secondly, we qualitatively clarify the effects of social interaction within a team on both the material payoff composed of the rewards and efforts perceived by agents and the psychological (mental) payoff. Thirdly, we reveal the diverse effects of social interaction on team performance based on the team's horizontal and vertical structures, i.e., whether the team has leadership or not, and the type of task, whether complementary or substitutable.

We analyze three important extensions to our basic model. The first extension considers what kind of team should be built if a manager can observe the prosociality of team members and allocate roles optimally based on that information. The second extension is to analyze situations in which the team's structure (horizontal or vertical) and roles (leader and follower) are endogenously determined by team members using the framework of endogenous timing games. These two extensions show that optimal team structure and leadership allocation can be achieved by assigning a more prosocial member to the role of follower in vertical teams performing complementary tasks, which can also be an endogenous choice of team members themselves. This implies that social interaction can mitigate inefficiencies in situations where external factors lead to suboptimal team structures, such as assigning a prosocial person as leader or a company culture that favors horizontal teams.

Our third extension utilizes an infinitely repeated game framework with a grim-trigger strategy to investigate the impact of social interaction on the sustainability of long-term cooperation among team members in situations where team production is repeatedly performed by the same members over the long term. Given that asymmetric prosociality among team members hinders cooperation, social interaction promoting convergence in prosociality plays a facilitating role in promoting cooperative behavior in teams. In a horizontal team, social interaction facilitates team cooperation regardless of the type of task being performed. In contrast, in a vertical team with a leadership hierarchy, social interaction plays a facilitating role in promoting team cooperation only when the leader initially exhibits higher prosociality than the follower, irrespective of the task type.

This paper is structured as follows. Section 2 reviews related research. Section 3 presents the basic structure of the model, and Section 4 investigates the effect of social interaction in horizontal teams. Section 5 analyzes the same in vertical teams. Section 6 discusses the obtained results, mainly regarding the possibility of voluntary social interaction by team members, the optimal duration of teams, and their relation to psychological safety in organizations. Section 7 provides three extensions of the model, optimal team design by a manager, endogenous leadership selection between members, and the effect of social interaction on the sustainability of cooperation.

Finally, Section 8 presents remaining research questions and concludes the paper.

2 Related Literature

In this section, we will provide a thorough review of literature related to various topics, including the influence of peers, the psychological impact of leaders on their followers, the significance of communication and social interaction within organizations, and the economic theories of team production, emphasizing the importance of prosociality and reciprocity.

2.1 Peer Effects in Various Situations

Individuals within the same organization or community experience various peer effects, whether positive or negative, and there is an accumulation of empirical research on this phenomenon. For instance, Mas and Moretti (2009) show a positive peer effect in the workplace, where the relative ability differences among coworkers affected their productivity. They find that the presence of high-ability coworkers leads to improvements in productivity, and that productivity further increases as coworker relationships strengthen. Jarosch et al. (2021) also report a positive peer effect, specifically analyzing the impact of learning from coworkers on individual productivity, and demonstrating that such learning improves individual productivity.

In contrast, some studies shows that associating with peers engaged in illicit behavior, such as illegal drug use by professional baseball players (Gould and Kaplan, 2011), financial fraud by employees (Dimmock et al., 2018), and cheating by peers (Carrell et al., 2008), has negative peer effects. Emotional contagion is also present, with peer behavior in greed and selfishness being contagious (Cardella et al., 2019) and dishonesty being contagious among peers (Robert and Arnab, 2013). Kramer et al. (2014) conduct a large-scale experiment using Facebook and demonstrated the spread of positive and negative emotions through social media.

2.2 Social Interaction in Teams with/without Leadership

Extensive research in economics, psychology, sociology, and business studies has demonstrated that building personal relationships, friendships, and fostering communication through social interaction is beneficial for enhancing team cohesion and performance in various types of teams, including those in companies and educational institutions. For instance, a close communication and improved intimacy among teammates can enhance team performance (Büyükboyacıand Robbett, 2017; Battiston et al., 2021; Ching et al., 2021). Even geographically dispersed teams can improve performance through voluntary communication among members (Hinds and Mortensen, 2005). Van den Bulte and Moenaert (1998) find that co-location of multiple teams increased communication among R&D teams, marketing, and manufacturing departments, leading to improved speed of product development and manufacturing. The co-location in their study can be seen as an example of the investment that promotes social interaction in our theory. Pearce (2004) also notes that "shared vision" within a team is key to enhancing performance by promoting members' altruism and teamwork.

A series of studies on team leadership examines the communication between a leader and team members, as well as the contagion of leader emotions to team members (Clarkson et al., 2020, for a meta-analysis on leadership and emotional contagion). The positivity or negativity of a leader's psychological characteristics is contagious to followers (Johnson, 2008, 2009), and it is evident that teams led by leaders with a positive mood perform better (Volmer, 2012). Additionally, research shows that opportunities for communication with leaders who possess strong communication skills (Lu et al., 2022) and opportunities for communication with leaders chosen by followers (Brandts et al., 2015) have a positive impact on teams. Our theory suggests that interaction with more prosocial leaders enhances team performance in complementary tasks, and this mechanism provides insight into the results of these empirical and experimental studies.

2.3 Prosociality and Psychological Safety in Teams

Numerous studies have highlighted the importance of prosociality (altruism) among team or organizational members in enhancing performance. For instance, the socialization processes within a team can influence the levels of prosociality among new members, which may foster greater cohesion and better performance outcomes (Moreland and Levine, 1982; O'Reilly and Chatman, 1986). Li et al. (2014) propose a model of work team altruism, which shows that it enhances team cooperation and trust, leading to better team performance. Furthermore, altruistic motives within teams promote tacit knowledge-sharing within the team (Obrenovic et al., 2020). Data from the National Hockey League shows that higher team altruism scores are associated with higher playoff and winning percentages, and that team altruism contributes more to success than individual skills (Stevens et al., 2020). Furthermore, Hekman et al. (2009) shows that having a higher organizational identification leads employees to reciprocate towards organizational support and achieve high performance. Our findings indicate that reciprocal prosociality between team members through social interaction can enhance the performance of complementary tasks, offering a mechanism for why team prosociality is associated with improved group cohesion and performance outcomes.

Our study is also relevant to a series of previous studies that have shown that ensuring psychological safety within an organization leads to better organizational performance (Kahn, 1990; Edmondson, 1999; Carmeli et al., 2010; Gu et al., 2013). If a team has psychological safety, employees feel safe to express their opinions and ideas without fear of negative consequences, which could result in more communication and opportunities to learn about their teammates' prosociality. In this sense, the investment in social interaction in our model can be viewed as an investment in ensuring psychological safety of the team.

2.4 Economics Theory and Experiment for Team Production and Leadership

When team members are rewarded based on the team's collective output, the non-excludable nature of the rewards can incentivize individual members to under-contribute voluntarily, resulting in inefficient team performance.[1] This feature is captured by the team production model, which is based on the theory of private provision of public goods pioneered by Bergstrom et al. (1986). Within the framework, Varian (1994) examines a sequential contribution game with leadership and shows that the underprovision problem (or inefficient team performance) is further exacerbated because the leader free rides on the follower's effort. This situation is similar to our results for substitutable tasks.

Optimal leadership and team formation problems have been analyzed in various studies within the theory of team production. Huck and Rey-Biel (2006) investigate endogenous leadership in teams where members dislike effort differentials among members. Kempf and Rota-Graziosi (2010) examine endogenous leadership with varying properties of public goods or team production. Bose et al. (2010) and Hattori and Yamada (2020) focus on designing rewards based on team members' roles and leadership selection in teams with or without leadership. Gregor (2015) analyzes task allocation between leaders and followers for multiple tasks. Hattori and Yamada (2018) explore members' incentives for skill improvement in horizontal and vertical teams with substitutable tasks. Rahmani et al. (2018) consider "participatory" and "directive" team leadership and find that the contributions of a leader and followers are aligned for tasks with complementary efforts. While our paper shares similarities with these previous studies in terms of the model's setting, none of these studies have considered the significant role of prosociality in enhancing teamwork and its reciprocal effects.

There are many theoretical and experimental studies that demonstrate the importance of "social norms" based on prosociality (altruism) and reciprocity among team members for team efficiency (e.g., Fehr and Gachter, 2000; Fehr and Schmidt, 2006). Carpenter et al. (2009) demonstrate, through theory and experiments, that agents with unconditional altruism and reciprocity motives can achieve high levels of cooperation by willingly

[1] There are many studies that use principal-agent theory, such as Lazear and Rosen (1981) and Holmström (1982), to consider the moral hazard problem in teams and the optimal compensation design under it, including studies by McAfee and McMillan (1991), Itoh (1991), Che and Yoo (2001), and Rayo (2007) among others. Our study focuses on analyzing how social interaction affects the strategic effort decision of team members under a common reward based on team performance, so there is little relevance to studies using these contract-theory approaches.

bearing costs to punish non-contributing members when reciprocity is strong. While we also assume the presence of agents with intrinsic prosociality, our focus is on the reciprocal effect among members brought about by endogenous social interaction. Baldassarri (2015) conducts a lab-in-the-field experiment in Uganda and shows that reciprocity among teammates is more important for promoting cooperative behavior than consideration for others such as altruism and group solidarity. Our research differs from theirs in that we consider the efficiency of team production with reciprocity as a two-way peer effect and its relation to leadership.[2]

Our prosociality function, which represents how social interaction equalizes prosociality among members through the strengthening of the reciprocal peer effect, is based on Levine's (1998) definition of "fairness," wherein individuals are more willing to be altruistic towards opponents who exhibit higher levels of altruism towards them. In this sense, our conception of social interaction in the workplace can be interpreted as increasing each employee's fairness concerns through their interactions with one another. Several studies provide indirect evidence that the promotion of interpersonal relationships and building cooperative environment strengthens fairness concerns. For instance, when individuals are treated fairly, they are more likely to reciprocate with fairness towards others, and in cooperative environments, people tend to demand more fairness than in competitive environments (Fehr and Schmidt, 1999). Furthermore, reciprocal individuals exhibit greater trust towards others compared to selfish individuals (Altmann et al., 2008).

2.5 Endogenous Altruism in Teams

Perhaps the most relevant papers to our research are Rotemberg (1994) and Dur and Sol (2010), which consider the endogenous altruism of team members and demonstrate the importance of human relations in the workplace. Rotemberg's (1994) considers altruistic agents receive psychological rewards not only from their own material payoffs, but also from those of their teammates and shows that committing to altruism is a rational decision when there is strategic complementarity between actions, meaning that "complementarity breeds altruism." He also demonstrates that opportunities for socializing that encourage altruistic behavior are beneficial for the team. Dur and Sol's (2010) study, on the other hand, develops a multi-agent principal-agent model in which intrinsic altruism is fostered through social interactions with colleagues. Instead of allowing agents to choose their own level of altruism as Rotemberg (1994) does, Dur and Sol (2010) considers the optimal contract in situations where agents can enhance their teammates' altruistic feelings towards them by showing kindness, respect, and attention.

Our study, like these previous studies, examines the impact of team members' endogenous altruism and the efficiency of organizational social interaction and human relationships in the workplace. However, our study differs from these studies in the following ways. First, Rotemberg (1994) and Dur and Sol (2010) take a behavioral approach where it is possible to increase one's own level of altruism or the level of altruism of others, but they do not account for peer effects that may be influenced by others' low or high levels of altruism. Our study focuses on the emotional aspect of human behavior, where individuals are influenced by others' feelings and motivation, and endogenize their prosociality through social interaction, which promotes assimilation and strengthens peer effects. Second, we show that the type of task, the horizontal and vertical structure of the team, and the type of leader serve as boundary conditions for social interaction to enhance team performance.

3 The Model

Consider a team consisting of two members (Members 1 and 2) and one upper manager who oversees the team. The two team members engage in a common task, and their team performance is given by $G(g_1, g_2; \beta)$, where

[2] Regarding the examination of reciprocity between principals and agents, rather than among team members, Itoh (2004) considers agents' altruism and inequity aversion, Bassi et al. (2014) investigate reciprocal altruism between principal and agent, and Dur et al. (2010) analyze optimal incentive contracts for agents who reciprocate to the principal's attention.

$g_1 \in \mathbb{R}_+$ and $g_2 \in \mathbb{R}_+$ are respectively Member 1's and 2's effort to team production. We assume

$$\partial G/\partial g_i > 0,\ \partial^2 G/\partial g_i^2 \leq 0,\ \text{and}\ \frac{\partial^2 G}{\partial g_i \partial g_j} = \beta$$

for $i, j \in \{1, 2\}$, where $\beta \in \mathbb{R}$ represents the degree of effort complementary/substitutability. In some parts of the paper, we use the following specific team production function:

$$G(g_1, g_2; \beta) = \sum_{i=1,2} g_i + \beta \prod_{i=1,2} g_i. \tag{1}$$

In the team production function, $\beta > 0$ indicates that the efforts of two individuals play complementary roles in team production. We refer to the task with $\beta > 0$ as "complementary tasks," which corresponds to a situation where even if one team member exerts a greater effort, team performance will not improve unless the other team member's effort is also substantial. In other words, increasing the effort level of the member who exerts the lowest effort leads to a more significant improvement in team performance.[3]

On the other hand, we call the case of $\beta < 0$ as "substitutable tasks," which indicates that the efforts of two individuals play substitutive roles in team production. A substitutable task can be handled by multiple team members, allowing another member to take over if the original member is unable to complete it. For example, this could refer to a situation where one team member takes a vacation and another team member substitutes for their role, allowing for the task to proceed seamlessly. This type of task is considered "routine" (as defined by Rahmani et al. (2018)), and can be performed by any team member, with the level of performance primarily dependent on the effort exerted by the team member who exerts the greatest amount of effort.[4] For example, this could happen when team members share limited resources, such as production facilities, or when a superstar member's exceptional performance substantially enhances the team's overall evaluation.[5] As we will see later, when β is positive (negative), the efforts of the two members are strategic complements (strategic substitutes).

Member i entails the following "materialistic" utility, π_i:

$$\pi_i(g_i, g_j) = \frac{\alpha}{2} \gamma\, G(g_i, g_j; \beta) - C(g_i), \tag{2}$$

where $\alpha \in [0, 1]$ is the labor share, $\gamma \in \mathbb{R}_+$ is the team productivity parameter that converts team performance into revenues, and $C(\cdot)$ is the effort cost function. The labor share α represents the proportion of rewards generated from team production that are allocated to the two workers as labor income. We use the specific functional form for the effort cost as $C(g_i) = c\, g_i^2$, where $c > 0$ is the effort cost parameter.

The material utility is defined as the common reward determined by team performance minus the effort cost, not including psychological factors such as a sense of belonging to the team, cohesiveness, and prosociality. These psychological factors are included by the following "psychological" utility, u_i:

$$u_i(g_i, g_j, \phi_i) = \pi_i + \phi_i\,(\lambda; a_i, a_j)\, \pi_j, \tag{3}$$

[3]For example, if we consider the function $G(g_1, g_2; 1)$ with $\beta = 1 > 0$ in (1), the marginal product for Member i's effort is $\partial G/\partial g_i = 1 + g_j$. This implies that if $g_i > g_j$ holds, increasing g_j further leads to a higher team performance than increasing g_i further. The production function with $\beta > 0$ can be described as team performance being a "weaker-link" type of public good, according to the terminology introduced by Hirshleifer (1983).

[4]For example, if we consider the function $G(g_1, g_2; 1)$ with $\beta = 1 > 0$ in (1), the marginal product for Member i's effort is $\partial G/\partial g_i = 1 + g_j$. This implies that if $g_i > g_j$ holds, increasing g_i further leads to a higher team performance than increasing g_j further. This can also be described as a "better-shot" type, in Hirshleifer's (1983) terminology, where increasing the effort level of the member who exerts the highest effort leads to a more significant improvement in team performance.

[5]In a team production function defined by (1), complementary tasks are those for which a smaller difference in efforts between the two players results in a larger team output, while substitute tasks are those for which a larger difference leads to a larger team output. For example, if we assume that the sum of efforts of both players is 1 (i.e., $g_1 + g_2 = 1$), in a complementary task where $\beta = 1 > 0$, we have $G(0.5, 0.5; 1) = 0.5 + 0.5 + (1)(0.5)(0.5) = 1.25 > G(0.8, 0.2; 1) = 0.8 + 0.2 + (1)(0.8)(0.2) = 1.16 > G(1, 0; 1) = 1 + 0 + (1)(1)(0) = 1$, while in a substitute task where $\beta = -1$, we have $G(0.5, 0.5; -1) = 0.5 + 0.5 + (-1)(0.5)(0.5) = 0.75 < G(0.8, 0.2; -1) = 0.8 + 0.2 + (-1)(0.8)(0.2) = 0.84 > G(1, 0; -1) = 1 + 0 + (-1)(1)(0) = 1$. Also, in (1), the marginal product of each member's effort is $1 + \beta g_j$, and this should be non-negative.

where $\phi_i(\lambda; a_i, a_j) \in [0,1]$ is Member i's degree of team prosociality, which represents how Member i values the utility of Member j, $a_i \in [0,1]$ is Member i's intrinsic level for team prosociality, $a_j \in [0,1]$ is the teammate j's intrinsic level for team prosociality, and $\lambda \in [0,1]$ is the degree of social interaction within the team.

We assume that the team prosociality of each member is mutually influenced through social interactions, resulting in a convergence of the prosociality levels. The function $\phi_i(a_i, a_j, \lambda)$ is assumed to have the following properties:

$$\phi_i(0; a_i, a_j) = a_i,\ \ \phi_i(1; a_i, a_j) = \phi_j(1; a_i, a_j), \tag{4}$$

$$\frac{|\phi_i(\lambda; a_i, a_j) - \phi_j(\lambda; a_i, a_j)|}{\partial\lambda} < 0, \tag{5}$$

$$\frac{\phi_i(\lambda; a_i, a_j)}{\partial\lambda} = -\frac{\phi_j(\lambda; a_i, a_j)}{\partial\lambda}. \tag{6}$$

The properties in (4) indicate that members possess their intrinsic team prosociality in the absence of social interaction, while with full interaction at $\lambda = 1$, their team prosociality perfectly aligns (i.e., maximum reciprocity). The property in (5) represents that social interaction continuously reduces the gap in team prosociality between individuals, and (6) represents that this effect is symmetric. In other words, as social interaction between team members becomes deeper, team prosociality among members tends to equalize, meaning that members with higher prosociality will decrease their prosociality through interaction with those with lower prosociality, while members with lower prosociality will increase their prosociality. That is, social interaction strengthens peer effects, resulting in the contagion of team prosociality among members

As one of the specific functional forms that satisfies the properties of (4), (5), and (6), we sometimes use the following:

$$\phi_i(\lambda; a_i, a_j) = \frac{a_i + \lambda\, a_j}{1 + \lambda}. \tag{7}$$

The variable λ in (7) is based on the formulation by Levine (1998) of the degree of "fairness" in individuals, wherein individuals are more willing to be prosocial towards opponents who exhibit higher levels of prosociality towards them. In our study, λ is an endogenous variable determined by the manager, representing both the level of social interaction and the strength of peer effects among team members.

We examine two types of team structures. One is a horizontal team structure in which there is no leader-follower (or superior-subordinate) relationship between two members in each team. This team structure is represented by a game in which each member takes the effort of the other as given and simultaneously determines their own effort level. The other is a vertical team structure represented by a Stackelberg-type game, where one member acts as a leader and decides their effort level first, while the other member acts as a follower and determines their effort level after observing the leader's effort level. In team production models, the Stackelberg leader captures important features of real-world leaders, including the power to commit workload, the ability to motivate followers through their workload commitment, and an informational advantage in predicting followers' reactions.

In exchange for receiving $1 - \alpha$ fraction of the rewards earned by the team, the manager who manages a team holds the authority and responsibility for determining the team's social interaction level and bearing the associated costs. The manager's payoffs, $\pi_M(G, \lambda)$ are defined by:

$$\pi_M(G, \lambda) = (1 - \alpha)\gamma G - \omega(\lambda), \tag{8}$$

where $\omega(\cdot)$ is the cost for establishing social interaction with $\omega' > 0$, $\omega'' > 0$, $\omega(0) = 0$, and $\omega(1) = \infty$.[6] For

[6]We do not distinguish between psychological and physical payoffs for managers. This is because we focus on team prosociality, that is, altruistic preferences towards the same team members, which operates only within the team.

Table 1: Summary of Notations

Notation	Definition
Parameters	
α	Labor share (employee compensation share)
β	Degree of effort complementary/substitutability
γ	Team productivity parameter
c	Effort cost parameter of contributing effort
a_i	Intrinsic degree of team prosociality for Member i
h	Cost parameter for promoting social interaction
Variables and functions	
g_i	Member i's effort
λ	Degree of Social interaction
$G(g_i, g_j; \beta)$	Team performance
$C(g_i)$	Effort cost function for Member i
$\pi_i(g_i, g_j)$	Material payoffs for Member i
$\pi_M(G, \lambda)$	Payoffs for manager
$u_i(g_i, g_j, \phi_i)$	Psychological payoffs for Member i
$\phi_i(\lambda; a_i, a_j)$	Member i's team prosociality
$\omega(\lambda)$	Cost function for social interaction
$R_i(g_j, \phi_i)$	Best response of Member i against Member j's effort

some results, we use the specific form of the cost function as

$$\omega(\lambda) = \frac{h\lambda^2}{1-\lambda}, \tag{9}$$

where $h \in \mathbb{R}_+$ is cost parameter. We assume that the cost of social interaction is borne by the manager or the organization instead of the team members. Possible costs include expenses for designing institutional arrangements to facilitate social interactions among members, co-locating members' workplaces, providing facilities such as bars, coffee counters, and recreational facilities to encourage workplace communication, organizing social events within the company, and the expected opportunity costs of time allocated to social interactions. However, as discussed in Section 6.1, there may be situations where team members themselves voluntarily bear the costs of social interaction.

The game has two stages. In Stage 1, the manager determines the level of social interaction, λ, in order to maximize their own payoffs. Each member's team prosociality will be equalized depending on the level of social interaction. In Stage 2, each team member voluntarily determines the amount of effort to the team task, which is complementary or substitutable tasks. In the case of a vertical team, the leader decides their contribution to the team task first, and then the follower determines their contribution. In the case of a horizontal team, each member determines their contribution simultaneously. Table 1 summarizes the basic notations used throughout the paper.

4 Social Interaction in Horizontal Teams

This section derives the impact of social interaction on the effort levels, team performance, and member utilities in equilibrium, as well as the optimal level of social interaction for a team with a horizontal structure.

4.1 Team Production in Stage 2

We derive the equilibrium of Stage 2 in horizontal teams. Given the level of social interaction λ, each member in horizontal teams simultaneously decides their effort to maximize their psychological utility. We have the following first-order conditions for $i = \{1, 2\}$:

$$\frac{\partial u_i}{\partial g_i} = \frac{\alpha}{2}\gamma\left(1+\phi_i\right)\frac{\partial G}{\partial g_i} - C' = 0. \tag{10}$$

The second-order condition is $SOC_i \equiv \partial^2 u_i/\partial g_i^2 = \frac{\alpha}{2}\gamma(1+\phi_i)\frac{\partial^2 G}{\partial g_i^2} - C'' < 0$, which necessarily holds.

The first-order condition (10) implicitly defines the reaction function of Member i against Member j's effort, $R_i(g_j, \phi_i)$. By utilizing the implicit function theorem, the property is given by

$$\frac{\partial R_i}{\partial g_j} = -\frac{\frac{\alpha}{2}\beta\gamma(1+\phi_i)}{SOC_i}, \quad \frac{\partial R_i}{\partial \phi_i} = -\frac{\frac{\alpha}{2}\gamma\frac{\partial G}{\partial g_i}}{SOC_i}. \tag{11}$$

The sign of $\partial R_i/\partial g_j$ depends only on the sign of β, which confirm that both members' efforts are strategic complements for complementary tasks with $\beta > 0$ and are strategic substitutes for substitutable tasks with $\beta < 0$.

When applying the specific functional forms, we have the following reaction functions:

$$g_i = R_i(g_j, \phi_i) \equiv \frac{\alpha\gamma(1+\phi_i)(1+\beta g_j)}{4c}, \tag{12}$$

where $\partial R_i/\partial g_j > 0$ if $\beta > 0$ and $\partial R_i/\partial g_j < 0$ if $\beta < 0$.

To ensure the uniqueness and stability of Nash equilibrium, we assume $\frac{\partial^2 u_i}{\partial g_i^2}\frac{\partial^2 u_j}{\partial g_j^2} - \frac{\partial^2 u_i}{\partial g_i \partial g_j}\frac{\partial^2 u_j}{\partial g_i \partial g_j} > 0$. When we apply the specific production function of (1), we assume the following.[7]

Assumption 1.

$$4c - \alpha|\beta|\gamma\sqrt{1+\phi_i}\sqrt{1+\phi_j} > 0 \tag{13}$$

For the sake of computational simplicity, we impose the following slightly stricter condition instead of the above one:

$$4c - \alpha|\beta|\gamma\left(1+\max[\phi_i, \phi_j]\right) > 0. \tag{14}$$

Solving for R_i and R_j in (12), we have the equilibrium effort level of Member i:

$$g_i^H = \frac{\alpha\gamma(1+\phi_i)\xi_j}{\Gamma}, \tag{15}$$

where

$$\xi_i \equiv 4c + \alpha\beta\gamma(1+\phi_i) > 0 \;\text{ and }\; \Gamma \equiv 16c^2 - \alpha^2\beta^2\gamma^2(1+\phi_1)(1+\phi_2) > 0,$$

hold from (14), and the superscript H refers to the 2nd-stage equilibrium value in horizontal team. Substituting the equilibrium effort to G, u_i, and u_j, we characterize the 2nd-stage equilibrium as G^H, π_i^H, and u_i^H.

We now derive the impact of changes in one member's team prosociality on their own effort and the effort

[7] Following Vives (1999), the stability of the equilibrium require

$$\left|\frac{\partial^2 u_i}{\partial g_i^2} \cdot \frac{\partial^2 u_j}{\partial g_j^2}\right| > \left|\frac{\partial^2 u_i}{\partial g_i \partial g_j} \cdot \frac{\partial^2 u_j}{\partial g_i \partial g_j}\right|,$$

which reduces to the condition in Assumption 1.

of other team member. From (10), we have

$$\begin{pmatrix} dg_i^H \\ dg_j^H \end{pmatrix} = -\frac{1}{D}\begin{bmatrix} \frac{\partial^2 u_j}{\partial g_j^2} & -\frac{\partial^2 u_i}{\partial g_i \partial g_j} \\ -\frac{\partial^2 u_j}{\partial g_j \partial g_i} & \frac{\partial^2 u_i}{\partial g_i^2} \end{bmatrix}\begin{bmatrix} \frac{\alpha\gamma}{2}\frac{\partial G}{\partial g_i} \\ 0 \end{bmatrix}(d\phi_i),$$

where the determinant $D \equiv (\partial^2 u_i/\partial g_i^2)(\partial^2 u_j/\partial g_j^2) - (\partial^2 u_i/\partial g_i \partial g_j)(\partial^2 u_j/\partial g_i \partial g_j) > 0$. Therefore, we find

$$\begin{aligned} \frac{dg_i^H}{d\phi_i} &= -\frac{1}{D}\left(\frac{\partial^2 u_j}{\partial g_j^2}\right)\frac{\alpha}{\gamma}\frac{\partial G}{\partial g_i} > 0 \\ \frac{dg_j^H}{d\phi_i} &= -\frac{1}{D}\left(-\frac{\partial^2 u_j}{\partial g_i \partial g_j}\right)\frac{\alpha}{\gamma}\frac{\partial G}{\partial g_i} \gtreqless 0 \quad \Leftrightarrow \quad \frac{\partial^2 u_j}{\partial g_i \partial g_j} \gtreqless 0 \quad \Leftrightarrow \quad \beta \gtreqless 0. \end{aligned}$$

The two equations above show that (i) an increase in one's own prosociality leads to an increase in one's own effort and (ii) in the case of substitutable tasks, an increase in one's own prosociality leads to an increase (decrease) in the effort of other members.[8]

Then, we explore the effect of social interaction on each member's effort. Differentiating g_i^H in λ, we have

$$\begin{pmatrix} dg_i \\ dg_j \end{pmatrix} = -\frac{1}{D}\begin{bmatrix} \frac{\partial^2 u_j}{\partial g_j^2} & -\frac{\partial^2 u_i}{\partial g_i \partial g_j} \\ -\frac{\partial^2 u_j}{\partial g_j \partial g_i} & \frac{\partial^2 u_i}{\partial g_i^2} \end{bmatrix}\begin{bmatrix} \frac{\alpha\gamma}{2}\frac{\partial G}{\partial g_i}\phi_i'(\lambda) \\ \frac{\alpha\gamma}{2}\frac{\partial G}{\partial g_j}\phi_j'(\lambda) \end{bmatrix}(d\lambda).$$

Using (6) and (11), we have

$$\frac{dg_i}{d\lambda} = -\frac{1}{D}\frac{\alpha\gamma}{2}\phi_i'\left(\frac{\partial^2 u_j}{\partial g_j^2}\frac{\partial G}{\partial g_i} + \frac{\partial^2 u_i}{\partial g_i \partial g_j}\frac{\partial G}{\partial g_j}\right) = -\frac{SOC_j}{D}\frac{\alpha}{2}\gamma\phi_i'\zeta_i^H, \tag{16}$$

where

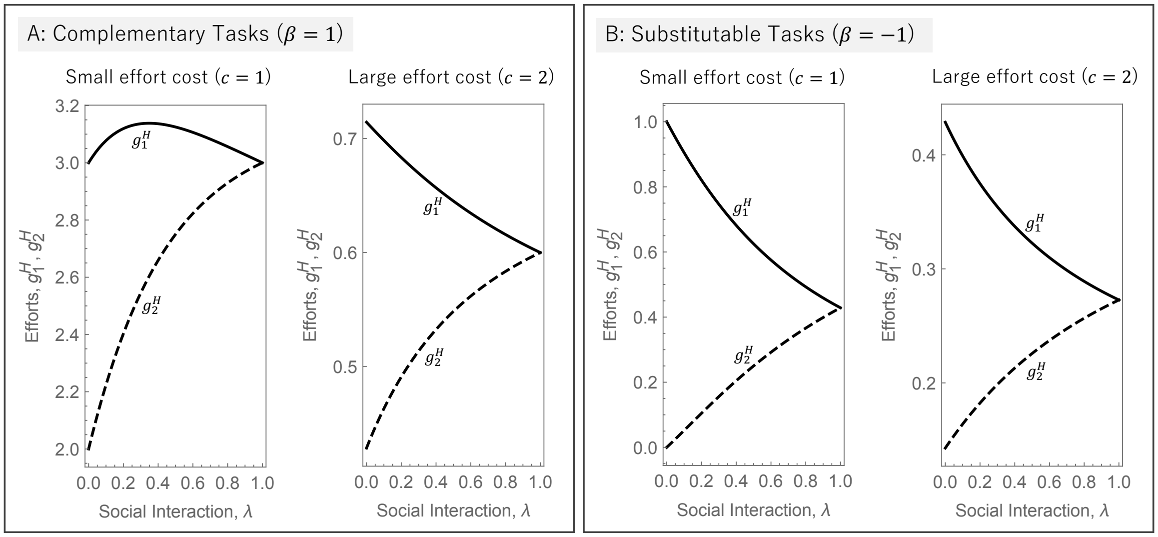
$$\zeta_i^H \equiv \frac{\partial G}{\partial g_i} - \frac{\partial R_j}{\partial g_i}\frac{\partial G}{\partial g_j}\frac{1+\phi_i}{1+\phi_j}. \tag{17}$$

The sign of (16) is equal to the sign of $\phi_i'\zeta_i^H$. When $\beta < 0$, we have $\partial R_j/\partial g_i < 0$, implying that $\zeta_i^H > 0$ must hold. Therefore, the sing of $dg_i/d\lambda$ coincides with the sign of ϕ_i'. This means that if $a_i > a_j$ (or equivalently $\phi_i > \phi_j$), then $dg_i^H/d\lambda < 0$, and if $a_i < a_j$, then $dg_i^H/d\lambda > 0$: social interaction reduces the effort of more prosocial members and increases the effort of less prosocial members.

On the other hand, in the case of complementary tasks with $\beta > 0$, there may be cases where $\zeta_H < 0$ due to $\partial R_j/\partial g_i > 0$. Considering that $\partial R_j/\partial g_j < 1$ is a necessary condition for the existence of a Nash equilibrium, in the case where $a_i \leq a_j$ ($\phi_i \leq \phi_j$), ζ_i^H is always positive due to $\partial G/\partial g_i > \partial G/\partial g_j$. However, when strategic complementarity is strong ($\partial R_j/\partial g_j$ is large) and $\phi_i > \phi_j$, there is also a tendency for $\partial G/\partial g_i < \partial G/\partial g_j$, resulting in $\zeta_i^H < 0$. In this case, the sign of $dg_i^H/d\lambda$ is opposite to the sign of ϕ_i'. This means that if $a_i > a_j$, there may be a case where both $dg_i^H/d\lambda > 0$ and $dg_j/d\lambda > 0$ hold. In other words, when strategic complementarity is strong, there is a region where social interaction increases the effort of both members. As the level of social interaction increases, the level of prosociality of each member becomes equalized, and ζ_i^H eventually becomes positive. If both members have $\zeta_i^H > 0$, then social interaction reduces the effort of more prosocial members and increases the effort of less prosocial members, similar to the case of substitutable tasks. Now, we have the following proposition.

Proposition 1. *For a horizontal team performing complementary tasks, if strategic complementarity is strong enough ($\zeta_i^H < 0$), social interaction can increase the effort of all members. However, for teams performing*

[8] These effects can be confirmed by applying (1): $\frac{dg_i^H}{d\phi_i} = \frac{16c\alpha\gamma\xi_j}{\Gamma^2} > 0$ and $\frac{dg_i^H}{d\phi_j} = \frac{4c\alpha^2\gamma^2(1+\phi_i)\xi_i}{\Gamma^2} \cdot \beta \gtreqless 0 \Leftrightarrow \beta \gtreqless 0$.



Note. Parameters: $\alpha = .5$, $\gamma = 4$, $\{a_1, a_2\} = \{1, 0\}$.

Figure 1: Equilibrium Effort and Social Interaction in Horizontal Teams

substitute tasks or with weak strategic complementarity, social interaction can reduce the effort of more prosocial members and increase the effort of less prosocial members.

The intuition behind the results is straightforward: social interaction has a direct effect on the effort of a member with high prosociality by lowering their prosociality and an opposite effect on a member with low prosociality by increasing their prosociality. In the case of complementary tasks, there is a strategic complementarity of effort, whereby the increase in effort of the latter can lead to a strategic effect that increases the effort of the former, leading to social interaction raising the efforts of both.

Applying the specific functional form (1), (16) can be obtained as follows.

$$\frac{dg_i^H}{d\lambda} = \frac{4c\alpha\gamma\xi_j}{\Gamma^2}\phi_i'\left(4c - \alpha\beta\gamma(1+\phi_i)\frac{\xi_i}{\xi_j}\right). \tag{18}$$

In (18), we readily find that when $\beta < 0$, $dg_i^H/d\lambda < 0$ for $\phi_i > \phi_j$ and $dg_i^H/d\lambda > 0$ for $\phi_i < \phi_j$ hold. When $\beta > 0$, $dg_i^H/d\lambda > 0$ holds for $\phi_i > \phi_j$, provided that the following conditions are met:

$$4c - \alpha\beta\gamma(1+\phi_i)\frac{\xi_i}{\xi_j} < 0, \tag{19}$$

which corresponds to $\zeta_i^H < 0$. In the condition (19), if $\phi_i > \phi_j$, $\xi_i/\xi_j > 1$ holds, and therefore, even within parameter ranges that satisfy Assumption 1, it is possible for the condition to hold when c is small and α, β, and γ are large. For example, if $\alpha = .5$, $\beta = 1$, $\gamma = 4$, $a_1 = 1$, and $a_2 = 0$, condition (19) reduces to $c < \frac{1+\sqrt{17}}{4} \approx 1.28$, and in this case, social interaction would raise effort levels for both members. In the following, we will refer to cases with low effort cost or high complementarity as the case of small c.

In Figure 1, the 2nd-stage equilibrium effort of each member is depicted as a function of λ for horizontal teams performing complementary and substitutable tasks with $\alpha = .5$, $\gamma = 4$, and $\{a_1, a_2\} = \{1.0\}$. In the case of complementary tasks ($\beta = 1$), there exists a range of λ that satisfies the condition (19) when $c = 1$, but not when $c = 2$. As can be seen from this figure, in the case of complementary tasks, there is a region where social interaction increases the efforts of both members when the effort cost is small. However, when the effort cost is high or in the case of substitutable tasks, social interaction reduces the effort of more prosocial members and increases the effort of less prosocial members.

Next, we investigate how social interaction affects the equilibrium team performance, G^H.

$$\frac{dG^H}{d\lambda} = \frac{SOC_1 \cdot SOC_2}{D}\phi_1' \left(\frac{\partial R_i}{\partial \phi_i}\zeta_i^H - \frac{\partial R_j}{\partial \phi_j}\zeta_j^H\right). \tag{20}$$

The derivations are given in Section S1 of Supplementary Materials.

The sign condition for (20) is simple: when $\beta > 0$, $\phi_i > \phi_j$ implies $\phi_i' < 0$, $\frac{\partial R_i}{\partial \phi_i} < \frac{\partial R_j}{\partial \phi_j}$, and $\zeta_i^H < \zeta_j^H$, which leads to $dG^H/d\lambda > 0$. In addition, $\phi_i < \phi_j$ implies $\phi_i' > 0$, $\frac{\partial R_i}{\partial \phi_i} > \frac{\partial R_j}{\partial \phi_j}$, and $\zeta_i^H > \zeta_j^H$, which also leads to $dG^H/d\lambda > 0$. In contrast, when $\beta < 0$, $\phi_i > \phi_j$ implies $\phi_i' < 0$, $\frac{\partial R_i}{\partial \phi_i} > \frac{\partial R_j}{\partial \phi_j}$, and $\zeta_i^H > \zeta_j^H$, which leads to $dG^H/d\lambda < 0$. Also, $\phi_i < \phi_j$ implies $\phi_i' > 0$, $\frac{\partial R_i}{\partial \phi_i} < \frac{\partial R_j}{\partial \phi_j}$, and $\zeta_i^H < \zeta_j^H$, which leads to $dG^H/d\lambda < 0$. Now, we have the following main proposition.

Proposition 2. *Social interaction necessarily enhances performance for horizontal teams performing complementary tasks and necessarily lowers performance for horizontal teams performing substitutable tasks. The effect becomes stronger as the difference in team prosociality among members increases.*

The result is highly intuitive. In cases where tasks are complementary, the synergy effect in production is strengthened when the difference in effort among team members is small, resulting in higher team performance. However, when there is a difference in team prosociality among members, the smaller effort of the less prosocial member becomes a bottleneck for the task. In such situations, social interaction can reduce the prosociality gap and narrow the effort difference, thereby resolving the bottleneck and improving team performance.

On the other hand, when tasks are substitutable, the team performance is higher when the difference in effort is greater, as long as the total effort is held constant. This means that social interaction aimed at reducing prosociality gap can actually lower team performance. Moreover, as Proposition 1 shows, the effort of the highly prosocial member not only decreases due to social interaction resulting in decreased their prosociality, but also to exploit the increased prosociality of other team member. This can significantly reduce team performance.

By specifying the team production function as (1), we can confirm Proposition 2. After some manipulations, we have

$$G^H = \frac{\alpha\gamma(4c(1+\phi_1)\xi_2^2 + (1+\phi_2)\xi_1\Gamma)}{\Gamma^2}.$$

The effect of social interaction on equilibrium team performance is given by

$$\frac{dG^H}{d\lambda} = \frac{16c^2\alpha^2\gamma^2(2\xi_i\xi_j + \Gamma)}{\Gamma^3} \cdot (\phi_j - \phi_i)\phi_i'(\lambda) \cdot \beta. \tag{21}$$

Since the term $(\phi_j - \phi_i) \cdot \phi_i' \geq 0$ holds for all $a_i \in [0,1]$ and $a_j \in [0,1]$, we find that the sign of (21) is positive (negative) for $\beta > 0$ ($\beta < 0$), which confirms Proposition 2.

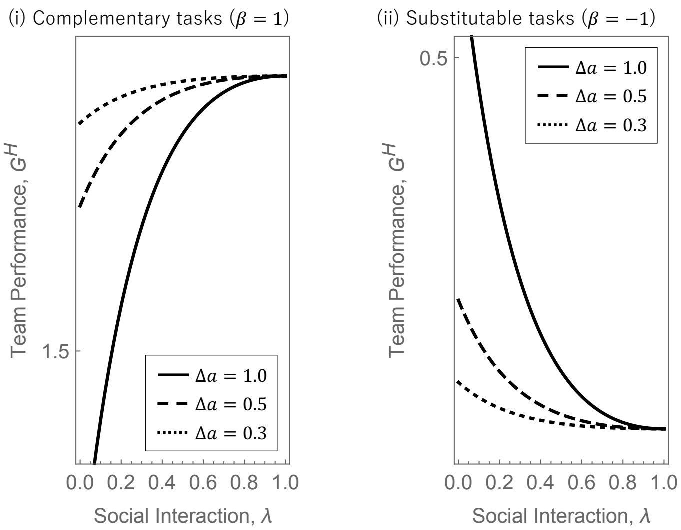
Figure 2 depicts the relationship between the degree of social interaction and equilibrium team performance for various combinations of a_1 and a_2 in the case of $\alpha = .5$, $\gamma = 4$, and $c = 2$. We depict three different case in which member's average prosociality are the same but its variances are different, i.e., $\{a_1, a_2\} = \{1, 0\}, \{0.75, 0.25\},$ and $\{0.65, 0.35\}$.

Before deriving the optimal level of social interaction by a manager, let us examine the effects of social interaction on the material and psychological payoffs of team members. Applying the envelope theorem, the marginal impact of λ on the material and psychological payoffs of each member in 2nd-stage Nash equilibrium can be expressed as follows:

$$\frac{d\pi_i^H}{d\lambda} = \frac{\alpha\gamma}{2}\frac{dG^H}{d\lambda} - \frac{dg_i^H}{d\lambda}C', \tag{22}$$

$$\frac{du_i^H}{d\lambda} = \frac{dg_j^H}{d\lambda}\frac{\partial u_i}{\partial g_j} + \phi_i'\pi_j^H \tag{23}$$

In (22), the first term represents the common influence of social interaction on rewards for both members, while



Note. Parameters: $\alpha = .5$, $\gamma = 4$, $c = 2$, $\{a_1, a_2\} = \{1, 0\}$ in $\Delta a = 1.0$, $\{a_1, a_2\} = \{.75, .25\}$ in $\Delta a = 1.0$, and $\{a_1, a_2\} = \{.65, .35\}$ in $\Delta a = 1.0$.

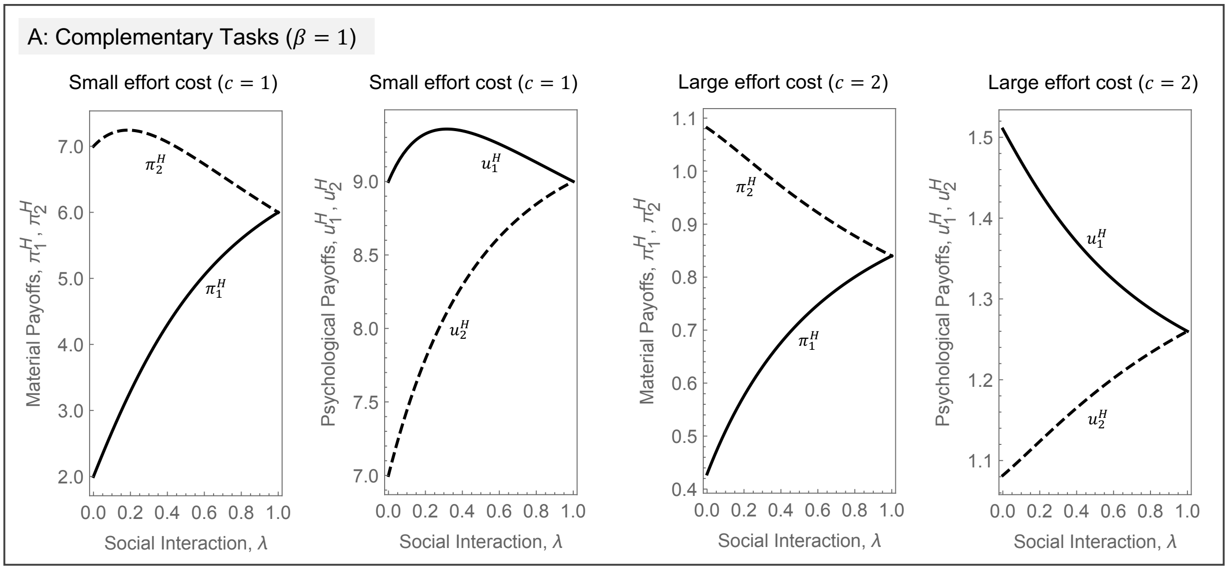
Figure 2: Team performance for complementary (left) and substitutable (right) tasks

the second term represents the individual impact on effort costs. In the case of complementary tasks ($\beta > 0$), from Propositions 1 and 2, social interaction increases rewards and increases the effort of both members when effort costs are low, while decreasing the effort of the more prosocial member and increasing the effort of the less prosocial member when effort costs are high. Therefore, it can be seen that the material payoff of the more prosocial member is more likely to be improved by social interaction. The payoff of the less prosocial member may also be improved by social interaction when effort costs are low, due to the reward increase resulting from increased effort by both members. On the other hand, in the case of substitutable tasks ($\beta < 0$), social interaction reduces rewards and the effort of the more prosocial member is just replaced by the effort of the less prosocial member, making it impossible for both members' material payoffs to improve.

Equation (23) captures the impact of social interaction on the psychological payoffs of team members. The first term on the right-hand side represents the indirect effect of social interaction through changes in other member' efforts on one's own psychological payoffs, while the second term represents the direct effect of changes in one's own team prosociality on psychological payoffs. In the case of the complementary tasks, if $\phi_i < \phi_j$, the indirect effect is positive (negative) when effort costs are small (large), and the direct effect is positive. Conversely, if $\phi_i > \phi_j$, the indirect effect is positive, but the direct effect is negative. It is worth noting that even when the indirect effect is negative, its impact is not as strong as the direct effect due to the strategic complementarity of effort. Therefore, less prosocial members are more likely to improve their psychological payoffs through social interaction than those with higher prosociality. More importantly, as shown graphically later, social interaction may lead to Pareto improvements, that is, improvement of the psychological payoffs for both members when effort costs are low.

In the case of substitutable tasks, if $\phi_i < \phi_j$ ($\phi_i > \phi_j$), the indirect effect is negative (positive) while the direct effect is positive (negative). Therefore, as in the case of complementary tasks, less prosocial members are more likely to experience improved psychological payoffs through social interaction. However, social interaction may lower the psychological payoffs of both members, especially when the effort cost is low, as it can lead to a decrease in team rewards.

The material and psychological payoffs of each member are illustrated as a function of social interaction in Figures 3 and 4, where the complementary and the substitutable tasks cases are depicted, respectively. In all graphs of Figures 3 and 4, it can be observed that in the situation of "maximal reciprocity" of $\lambda = 1$, the



Note. Parameters: $\alpha = .5$, $\gamma = 4$, $c = 1$ (small effort cost), $c = 2$ (large effort cost), and $\{a_1, a_2\} = \{1, 0\}$.

Figure 3: Material/Psychological Payoffs in Horizontal Teams with Complementary Tasks

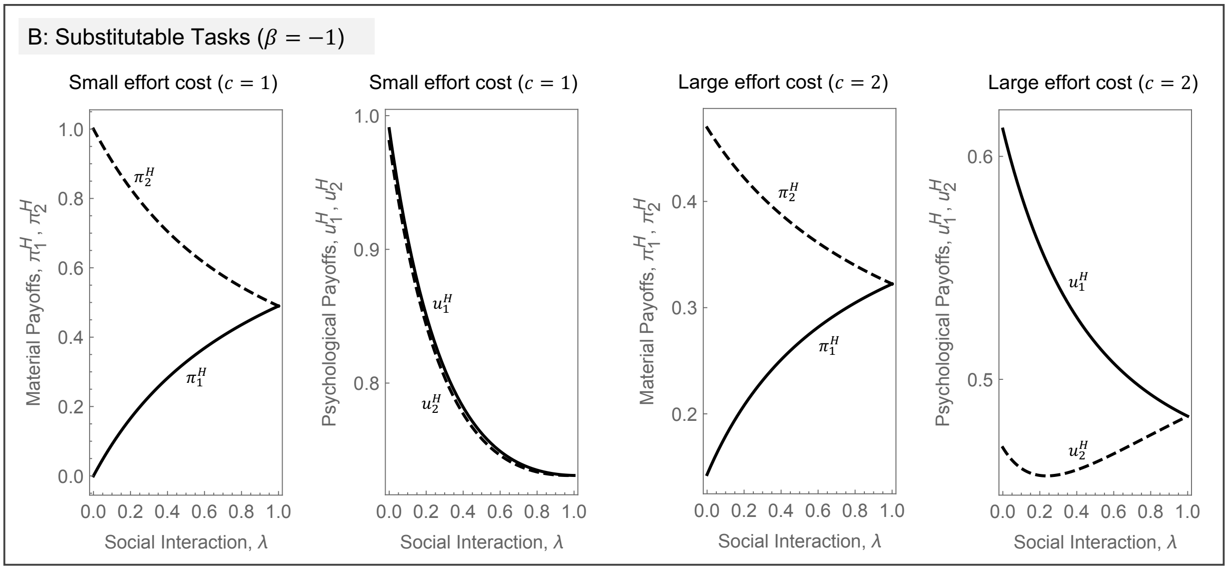
prosociality of both members is equal, and thus the payoffs of both members are also equal.

We can see from Figure 3 that, in the case where effort costs are high ($c = 2$), social interaction enhances the material payoffs of more prosocial members by reducing their own effort and increasing their common rewards, but lowers their psychological payoffs due to the negative direct effect of decreased prosociality. On the other hand, for members with lower prosociality, social interaction increases rewards but decreases their material payoffs due to increased effort on their part and decreased effort from other members, while increasing their psychological payoffs due to the positive direct effect of increased prosociality. However, in the case where effort costs are low ($c = 1$), there exists a region where social interaction can improve both material and psychological payoffs for both types of members. Furthermore, as social interaction enhances team performance in complementary tasks, it can increase the manager's profits. Thus, it shows that social interaction can lead to Pareto improvement, benefiting all members of the organization.

Figure 4 illustrates the payoffs for team members performing substitutable tasks, where social interaction reduces team performance and member rewards. Due to the strategic substitutability of their efforts, social interaction can lead to a more prosocial member free-riding on the increased efforts of a less prosocial member. As a result, while the rewards decrease, the more prosocial member's material payoffs improve. However, their psychological payoffs decrease due to the decrease in prosociality. On the other hand, a less prosocial member increase their effort through social interaction, which always reduces their material payoffs. When effort cost is high ($c = 2$), the free-riding effect induced by social interaction is not as significant, resulting in an increase in team prosociality and an improvement in their psychological payoffs. However, when the effort cost is low ($c = 1$), the diminishing effect of rewards through social interaction becomes stronger, potentially leading to a decrease in psychological payoffs for both members involved.[9]

Proposition 3. *Social interaction can increase psychological payoffs for both members of complementary task teams with low effort costs, but decrease payoffs for substitutable task teams with low effort costs. With high effort costs, social interaction reduces the psychological payoffs of a more prosocial member and increases that*

[9] In the case of $c = 1$ in Figure 4, the psychological payoffs of both players become exactly equal for all λ. This is due to the fact that with $a_1 = 1$ and $a_2 = 0$, player 1's material payoff happens to be 0 and player 2's material payoff happens to be 1 when $\lambda = 0$, resulting in their psychological payoffs being equal as well. As a result, the psychological payoffs of both players move in the same direction in response to changes in λ.



Note. Parameters: $\alpha = .5$, $\gamma = 4$, $c = 1$ (small effort cost), $c = 2$ (large effort cost), and $\{a_1, a_2\} = \{1, 0\}$.

Figure 4: Material/Psychological Payoffs in Horizontal Teams with Substitutable Tasks

of a less prosocial member, regardless of task type.

Proposition 3 indicates that social interaction can enhance the payoff of all team members performing complementary task while it may decrease the payoff of all team members performing substitutable tasks. However, in our model, it is the responsibility of the manager to determine the level of social interaction to be employed. In the next subsection, we will examine the optimal social interaction determined by the manager and shed light on the relationship between their decision and the characteristics of the organization or team.

4.2 Manager's Choice on Social Interaction

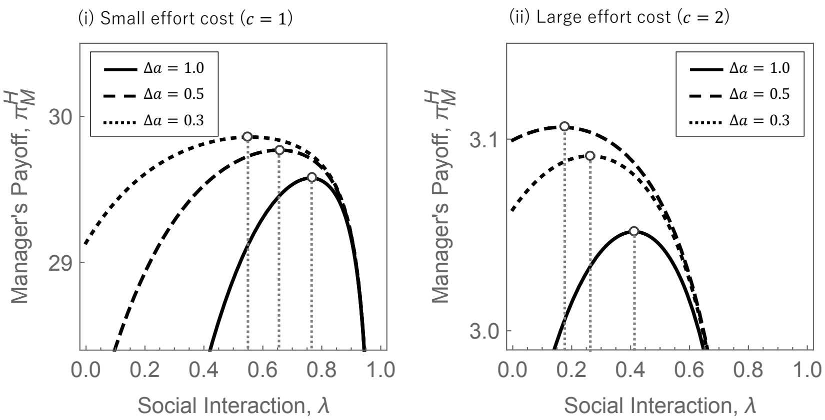
The manager determines the level of $\lambda \in [0, 1]$ to maximize their own payoffs. As in Proposition 2, in the case of substitutable tasks, social interaction always decreases team performance, so the manager will choose $\lambda = 0$. Therefore, in the following analysis, we will focus on the case of complementary tasks with $\beta > 0$.

The optimal level of social interaction in horizontal teams, λ^H, is obtained by the first-order condition

$$(1-\alpha)\gamma \frac{dG^H}{d\lambda} - \omega'(\lambda^H) = 0.$$

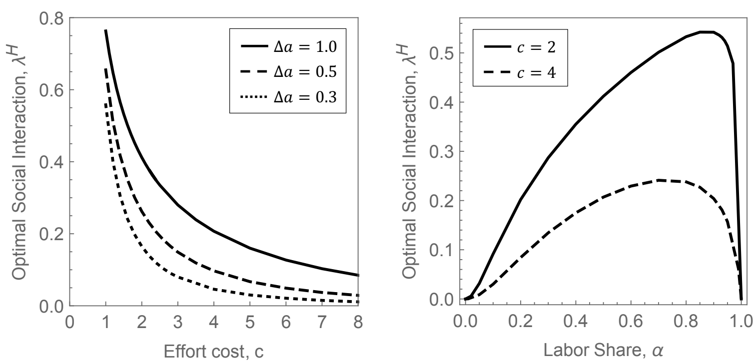
Given that $G^H > 0$ when $\lambda = 0$, $dG^H/d\lambda > 0$, $\omega' > 0$, $\omega'' > 0$, $\omega(0) = 0$ and $\omega(1) = \infty$, we necessarily have an interior solution for $\lambda^H \in (0, 1)$.

Firstly, we can immediately confirm that λ^H is decreasing with respect to the marginal cost of social interaction ω' (or with respect to parameter h in (9)), implying that the manager will be reluctant to engage in social interaction when it is costly. By applying specific cost function for social interaction (9), Figure 5 depict the manager's payoffs as a function of the level of social interaction. From the figure, we can find the optimal social interaction for complementary tasks for small effort cost ($c = 1$) in the left panel and for large effort cost ($c = 2$) in the right panel. When the difference in team prosociality among members is significant (the solid curve: $a_1 = 1.0$ and $a_2 = 0$), the optimal level of social interaction becomes $\lambda^H = .76$ for the case with small effort costs and $\lambda^H = .41$ for the case with large effort costs. We can also observe that when the gap in intrinsic prosociality among teammates is smaller and the effort costs are greater, the manager opts for lower levels of social interaction.



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$, $h = 0.1$, $\{a_1, a_2\} = \{1, 0\}$ in $\Delta a = 1.0$, $\{a_1, a_2\} = \{.75, .25\}$ in $\Delta a = 1.0$, and $\{a_1, a_2\} = \{.65, .35\}$ in $\Delta a = 1.0$.

Figure 5: Optimal Social Interaction for Horizontal Teams with Complementary Tasks



Note. Parameters: $\alpha = .5$ (left), $\beta = 1$, $\gamma = 4$, $h = 0.1$, $\{a_1, a_2\} = \{1, 0\}$ in $\Delta a = 1.0$, $\{a_1, a_2\} = \{.75, .25\}$ in $\Delta a = .5$, and $\{a_1, a_2\} = \{.65, .35\}$ in $\Delta a = .3$.

Figure 6: The Effect of Effort Cost and Labor Share on Optimal Social Interaction

Figure 6 illustrates the relationship between the optimal social interaction and the effort cost in the left panel, and the labor share in the right panel. When the complementary task performed by the team requires more effort from its members, the complementary effect, i.e., synergy effect, of the members' efforts decreases. Therefore, the manager selects a lower level of social interaction. Furthermore, when the labor share is low, increasing the share leads to an increase in team members' effort. In this case, the manager aims to leverage the synergy effect by encouraging more social interaction. However, under excessively high labor share, the manager's own share of the rewards diminishes, leading to a decrease in the incentive to bear the cost of social interaction. Thus, the optimal social interaction level with respect to the labor share follows an inverted U-shaped relationship. These observations are summarized as the following proposition.

Proposition 4. *A manager supervising teams performing complementary tasks engages in positive social interaction, whereas a manager supervising a team performing substitutable tasks does not. The optimal social interaction towards teams performing complementary tasks increases with a larger difference in prosociality among members, a smaller cost of social interaction, and a smaller effort cost for the task. Furthermore, the relationship between optimal social interaction and the labor share follows an inverted-U shape.*

In summary, our Propositions 1 through 4 provide not only positive answers on how social interaction affects horizontal teams with tasks of different natures and who benefits from them, but also normative answers on how much social interaction should be conducted for teams with tasks of different natures.

5 Social Interaction in Vertical Teams

In the previous section, we examined the effects of social interaction in horizontal teams where there is no specific hierarchy among team members. Next, our focus is on examining the effects of social interaction in vertical teams consisting of a leader and a follower. This analysis will enable us to examine the effects of social interaction based on the type of prosocial gap between the leader and the follower.

In this section, we use the notation of members L and F (where L denotes the leader and F denotes the follower) instead of Members 1 and 2, to refer to the two members that constitute a team. All the expressions previously presented with $i \in \{1, 2\}$ are replaced with $i \in \{L, F\}$ as indicated in the preceding section.

As is commonly observed in leaders of real-world organizations and teams, they are believed to possess the authority to commit their own workload, the ability to motivate followers through their actions, and an information advantage in predicting follower responses. Therefore, in our analysis of vertical teams, we consider a Stackelberg-type team production in which the leader commits their effort first while anticipating the responses of the subsequent follower. Similar to the previous section, in Stage 1, the manager decides on the social interaction level within the teams (specifically, between the leader and the follower) to maximize their own payoff. In Stage 2, a two-stage Stackelberg-type team production is played between the leader and the follower.

5.1 Team Production in Stage 2

First, we derive 2nd-stage equilibrium. The reaction function of the Stackelberg follower F is given by replacing the variable subscript i in (10) with F and, specifically, $R_F(g_L, \phi_F)$ as in (12). Then, the utility maximization of the leader L is given by $\max_{g_L} u_L(g_L, R_F(g_L, \phi_F))$, which yields the following first-order condition:

$$\begin{aligned} \frac{\partial u_L\left(g_L, R_F\left(g_L\right)\right)}{\partial g_L} &= \left[\frac{\alpha}{2}\gamma(1+\phi_L)\frac{\partial G}{\partial g_L} - C'(g_L)\right] + \frac{\partial R_F}{\partial g_L}\left[\frac{\alpha}{2}\gamma(1+\phi_L)\frac{\partial G}{\partial g_F} - \phi_L C'(g_F)\right] \qquad (24) \\ &= \left[\frac{\alpha}{2}\gamma(1+\phi_L)\frac{\partial G}{\partial g_L} - C'(g_L)\right] + \frac{\partial R_F}{\partial g_L}\frac{\alpha}{2}\gamma\frac{\partial G}{\partial g_F}(1-\phi_L\phi_F) = 0 \qquad (25) \end{aligned}$$

When evaluating in (25) at $g_L = g_i^H$, then the terms in the first square bracket become zero from the first-order conditions for horizontal teams (10). Therefore, we have

$$\left.\frac{\partial u_L}{\partial g_L}\right|_{g_{Li}=g_i^H} = \frac{\partial R_F}{\partial g_L}\frac{\alpha}{2}\gamma\frac{\partial G}{\partial g_F}(1-\phi_L\phi_F),$$

where g_{Li} represents the effort level of Member i when the member is a leader in the team. If $\partial R_F/\partial g_L > 0$ (i.e., $\beta > 0$), then the sign of the above becomes positive, indicating $g_{Li}^V > g_i^H$. If $\partial R_F/\partial g_L < 0$ (i.e, $\beta < 0$), then the sign of the above becomes negative, indicating $g_{Li}^V < g_i^H$. Due to the strategic complementarity or substitutability, we have $g_{Fi}^V > g_i^H$ for both $\partial R_F/\partial g_L > 0$ and $\partial R_F/\partial g_L < 0$. That is, for complementary tasks, both leaders and followers in a vertical team will exert more effort than they would in a horizontal team with the same members. For substitutable tasks, leaders will exert less effort and followers will exert more effort in a vertical team than they would in a horizontal team with the same members. These are summarized as the following lemma:

Lemma 1. *For $\beta > 0$, $g_{Li}^V > g_i^H$ and $g_{Fi}^V > g_i^H$ hold. For $\beta < 0$, $g_{Li}^V < g_i^H$ and $g_{Fi}^V > g_i^H$ hold.*

Specifying the team production functional as (1), we have

$$g_L^V = \frac{\alpha\gamma\,[4c(1+\phi_L)+\alpha\beta\gamma[2+\phi_L(1-\phi_F)](1+\phi_F)]}{\Theta} \tag{26}$$

$$g_F^V = \frac{\alpha\gamma\xi_L(1+\phi_F)}{\Theta}, \tag{27}$$

where $\Theta \equiv 16c^2 - \alpha^2\beta^2\gamma^2[2+\phi_L(1-\phi_F)](1+\phi_F) > 0$ from the following assumption, $\xi_L \equiv 4c+\alpha\beta\gamma(1+\phi_L) > 0$ from Assumption 1, and the superscript V denotes equilibrium variable at Stage 2 in vertical teams. To avoid corner solutions, we assume the following:

Assumption 2.

$$4c - \alpha|\beta|\gamma\sqrt{2+\phi_L(1-\phi_F)}\sqrt{1+\phi_F} > 0 \tag{28}$$

Assumption 2 imposes stricter conditions compared to Assumption 1, which was assumed in the case of a homogeneous team. This is because in addition to the asymmetry of prosociality among team members, there is now an asymmetry based on their roles (leader or follower). Moreover, as can be seen from (26), in the case of substitutable tasks, it is more likely that the leader's effort will become zero, i.e., they becomes a complete free rider.

Comparing g_L^V with g_F^V, we obtain

$$g_L^V - g_F^V = \frac{\alpha\gamma\,[4c(\phi_1-\phi_2)+\alpha\beta\gamma(1+\phi_2)(1-\phi_1\phi_2)]}{\Theta}. \tag{29}$$

First, when $\phi_1 = \phi_2$, we have $g_L^V > g_F^V$ for $\beta > 0$ and $g_L^V < g_F^V$ for $\beta < 0$, implying that, in complementary (substitutable) tasks, the leader contributes greater (smaller) effort compared to the follower, and this difference becomes larger as the absolute value of β increases.

We denote team performance, material and psychological payoffs for each member $i \in \{L, F\}$ at Stage 2 as G^V, π_i^V, and u_i^V, respectively. First, we examine the impact of λ on g_L^V. Through the derivation as described in Section S2 of the Supplementary Material, we obtain the following result.

$$\frac{dg_L^V}{d\lambda} = -\frac{\frac{\alpha}{2}\gamma}{SOC_L}\phi'_L\zeta_L^V, \tag{30}$$

where

$$\zeta_L^V \equiv \frac{\partial G}{\partial g_L} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{2+\phi_F-2\phi_L\phi_F+\phi_F^2}{1+\phi_F}, \tag{31}$$

and $SOC_L < 0$ is the second derivative of the objective function for Member L.

We immediately find that if $\beta < 0$, then (31) is positive, and thus, (30) has the same sign as ϕ'_L, implying that social interaction reduces effort from the leader when $\phi_L > \phi_F$, and increases it when $\phi_L < \phi_F$. In the case of complementary tasks with $\beta > 0$, $\partial R_F/\partial g_L > 0$, implying that when there is strong strategic complementarity (i.e., $\partial R_F/\partial g_L$ is large) or high marginal productivity of the follower (i.e., when the leader's effort is relatively large), ζ_L^V may be negative. In such a case, (30) has the opposite sign as ϕ'_L, indicating that social interaction increases the leader's effort when the leader is more prosocial than the follower, but decreases it when the opposite is true. If $\zeta_L^V > 0$, then social interaction reduces the leader's effort when the leader is more prosocial than the follower, as is the case with substitutable tasks.

The effect of social interaction on follower's effort $g_F^V = R_F(g_L^V, \phi_F)$ is

$$\begin{aligned}\frac{dg_F^V}{d\lambda} &= \frac{dg_L}{d\lambda}\cdot\frac{\partial R_F}{\partial g_L} + \frac{\partial R_F}{\partial \phi_F}\phi_F' = \frac{dg_L}{d\lambda}\frac{\partial R_F}{\partial g_L} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{\phi_L'}{\beta(1+\phi_F)} \\ &= \frac{\partial R_F}{\partial g_L}\left[\frac{dg_L^V}{d\lambda} - \frac{\partial G}{\partial g_F}\frac{\phi_L'}{\beta(1+\phi_F)}\right]. \end{aligned} \tag{32}$$

The sign of (32) depends on the task type, the sign of $dg_L^V/d\lambda$, and the type of leadership (i.e., prosocial leadership or followership). The first term in parentheses represents the strategic effect of social interaction on how followers respond to changes in a leader's effort, while the second term represents the direct effect of social interaction on altering followers' prosociality.

In the case of complementary task with $\beta > 0$, if $\zeta_L^V < 0$, then both terms become positive for prosocial leadership case and negative for prosocial followership case, implying that social interaction raises the efforts of both leaders and followers under prosocial leadership, while it decreases them under prosocial followership. However, if $\zeta_L^V > 0$, although the two terms have opposite signs, the direct effect of the second term dominates the strategic effect of the first term, causing social interaction to reduce the effort of initially more prosocial member and increase the effort of initially less prosocial member. In the case of substitutable task with $\beta < 0$, the two terms have opposite signs, the direct effect dominates the strategic effect, also causing social interaction to reduce the effort of initially more prosocial member and increase the effort of initially less prosocial member. Now we have the following proposition.

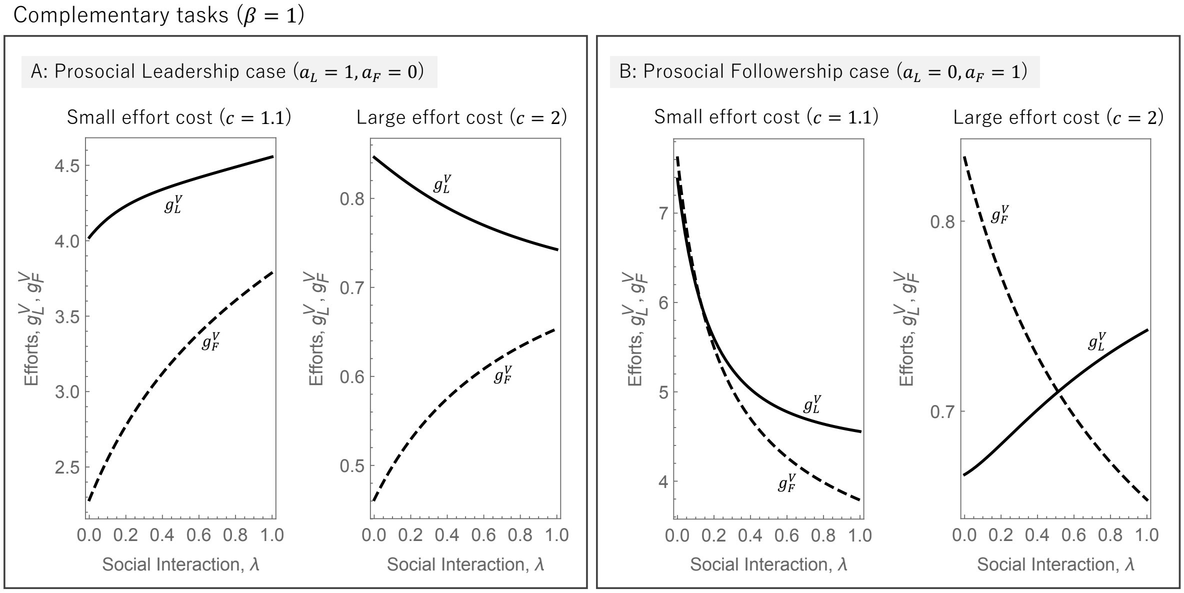
Proposition 5. *In vertical teams with complementary tasks, if $\zeta_L^V < 0$, then social interaction between more prosocial leader and less prosocial follower increases efforts for both members, and that between less prosocial leader and more prosocial follower reduces efforts for both members. Otherwise, social interaction decreases effort for initially more prosocial member and increases effort for the initially less prosocial member. In vertical teams with substitutable tasks, social interaction always reduces effort for the initially more prosocial member and increases effort for the initially less prosocial member.*

Intuitively, in the case of complementary tasks, the condition $\zeta_L^V < 0$ is more likely to hold when $\partial R_F/\partial g_L$ is large (i.e., when followers respond strongly positively to the leader's effort) or when the followers' marginal product, $\partial G/\partial g_F$, is high (i.e., when the leader's effort level is high). This corresponds to cases with larger β or smaller c, as confirmed in Section S3 in Supplementary Materials. In that case, in teams performing complementary tasks led by more prosocial leaders, social interaction enhances everyone's effort, while in teams supported by more prosocial followers, social interaction decreases everyone's effort.

Figure 7 depicts the equilibrium efforts by a leader and a follower in vertical teams performing complementary tasks in various situations. Firstly, in all four panels, it can be observed that in the case of maximal reciprocity where the level of prosociality among members is equal (i.e., when $\lambda = 1$), as shown in (29), the leader's effort g_L^V is greater than the follower's one g_F^V, reflecting the difference in position.

In the case of complementary tasks with strategic complementarity, the effect of social interaction varies greatly depending on which member, leader or follower, has higher prosociality. When the leader's prosociality level surpasses that of the follower (which we hereafter call it as the "prosocial leadership" case), the leader can make the decision with expecting that the interaction with the follower will lead to an increase in the follower's prosociality level, influenced by the leader's high prosociality, which will prompt the follower to exert more effort. When effort costs are low (or equivalently $\zeta_L^V < 0$), this positive complementary effect is stronger than the negative effect of the leader's decreased prosociality, and thus, social interaction is likely to increase the effort of both members. Such situation is depicted by the leftmost panel of Figure 7.

However, when the follower's prosociality is higher than the leader's (which we hereafter call it as the "prosocial followership" case), social interaction reduces follower prosociality, and the leader may make decisions anticipating a decrease in follower effort, potentially having a negative incentive effect that reduces the leader's own effort, despite the positive effect of increased prosociality. When effort costs are low (or $\zeta_L^V < 0$), this



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$.

Figure 7: Equilibrium Efforts in Vertical Teams Performing Complementary Tasks

negative effect is stronger, and social interaction may decrease the effort of both the leader and follower. Such situation is depicted by the panel second from the right of Figure 7.

In the case of substitutable tasks with strategic substitutability of effort, social interaction equalizes member prosociality, which results in an increase in effort from the less prosocial member and a decrease in effort from the more prosocial member. This is consistent with the results of horizontal teams performing substitutable tasks. Figure S1 in Supplementary Materials provides the numerical simulations for substitutable task case.

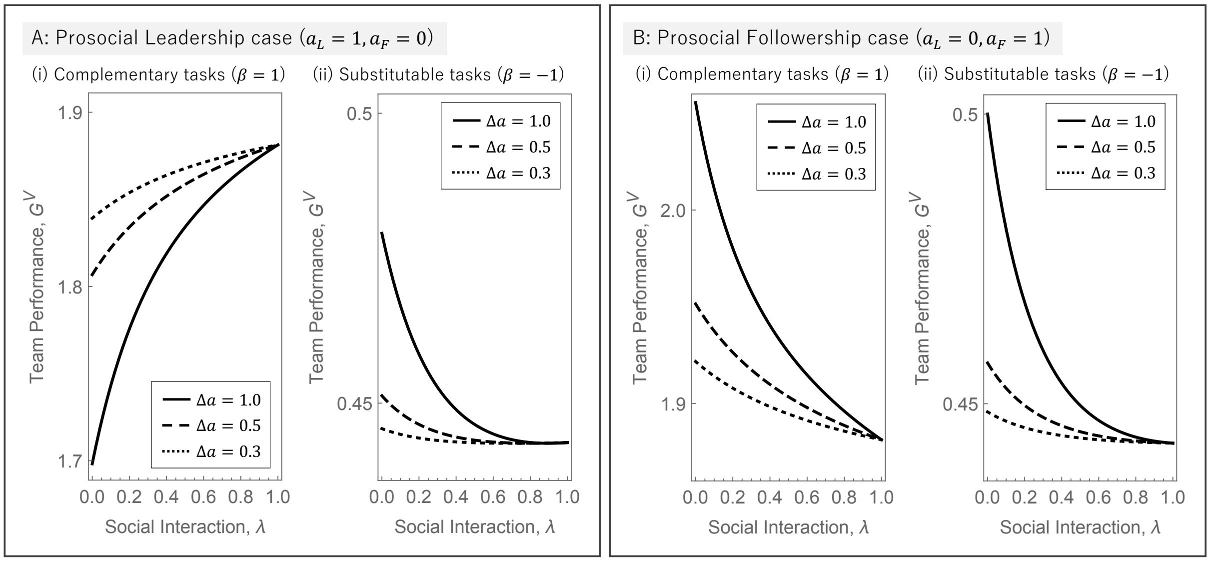
Next, we investigate the effect of social interaction on team performance at the 2nd-stage equilibrium. We have the derivative of $G^V \equiv G(g_L^V, g_F^V; \beta)$ with respect to λ as follows:

$$\frac{\partial G^V}{\partial \lambda} = \frac{\partial G}{\partial g_L}\frac{\partial g_L^V}{\partial \lambda} + \frac{\partial G}{\partial g_F}\frac{\partial g_F^V}{\partial \lambda}. \tag{33}$$

In the case of complementary tasks, if $\phi_L > \phi_F$ and $\zeta_L^V < 0$, then both $dg_L^V/d\lambda$ and $dg_F^V/d\lambda$ are positive, which unambiguously implies that $dG^V/d\lambda > 0$. Even if $\zeta_L^V > 0$, the negative effect of the leader's effort reduction on team performance (that is represented by the first term) is lower that the positive effect of the follower's effort increase (that is represented by the second term) because, as the leader's effort significantly exceeds that of the follower when $\phi_L > \phi_F$, the marginal productivity of the leader's effort ($\partial G/\partial g_L$) is much smaller than that of the follower's effort ($\partial G/\partial g_F$).

On the other hand, if $\phi_L < \phi_F$ and $\zeta_L^V < 0$, then both $dg_L^V/d\lambda$ and $dg_F^V/d\lambda$ are negative, leading to $dG^V/d\lambda < 0$, and even if $\zeta_L^V > 0$, there exists a unilateral negative strategic effect where the leader reduces their own effort, anticipating the decrease in follower's prosociality caused by social interaction. Thus, in the case of complementary tasks, it holds that $dG^V/d\lambda > 0$ if $\phi_L > \phi_F$, and $dG^V/d\lambda < 0$ if $\phi_L < \phi_F$.

In the case of substitutable tasks, the sign of $dG^V/d\lambda$ is somewhat ambiguous and depends on the magnitudes of ϕ_L, ϕ_F, and the strategic effects. Nonetheless, the following tendencies can be identified: when $\phi_L > \phi_F$, a leader's negative strategic effect, anticipating an increase in follower prosociality through social interaction, results in $dG^V/d\lambda < 0$. On the other hand, when $\phi_L < \phi_F$, the strategic effect is positive, but reducing the prosociality and efforts of the follower, who exerts significant effort due to their position and large prosociality, would lead to a significant decline in team performance, resulting in $dG^V/d\lambda < 0$.



Note. Parameters: $\alpha = .5$, $\gamma = 4$, and $c = 2$.
Panel A: $\{a_L, a_F\} = \{1, 0\}$ in $\Delta a = 1.0$, $\{a_L, a_F\} = \{.75, .25\}$ in $\Delta a = .5$, and $\{a_1, a_2\} = \{.65, .35\}$ in $\Delta a = .3$.
Panel B: $\{a_L, a_F\} = \{0, 1\}$ in $\Delta a = 1.0$, $\{a_L, a_F\} = \{.25, .75\}$ in $\Delta a = .5$, and $\{a_1, a_2\} = \{.35, .65\}$ in $\Delta a = .3$.

Figure 8: Social Interaction on Team Performance: prosocial leadership vs. prosocial followership

In what follows, we verify the above discussion by specifying the team production function as (1) and the prosociality function as (7). We derive the derivative of G^V with respect to λ by evaluating it at $\{a_L, a_F\} = \{1, 0\}$ and $\{a_L, a_F\} = \{0, 1\}$, respectively. In this case, we have

$$\left.\frac{dG^V}{d\lambda}\right|_{\{a_L,a_F\}=\{1,0\}} = \frac{4c\alpha^2\gamma^2\left[4c + 7\alpha\beta\gamma\cdot\dfrac{16c^2-\alpha^2\beta^2\gamma^2}{48c^2-\alpha^2\beta^2\gamma^2}\right]}{\Theta^3(1+\lambda)^2}\cdot\beta, \tag{34}$$

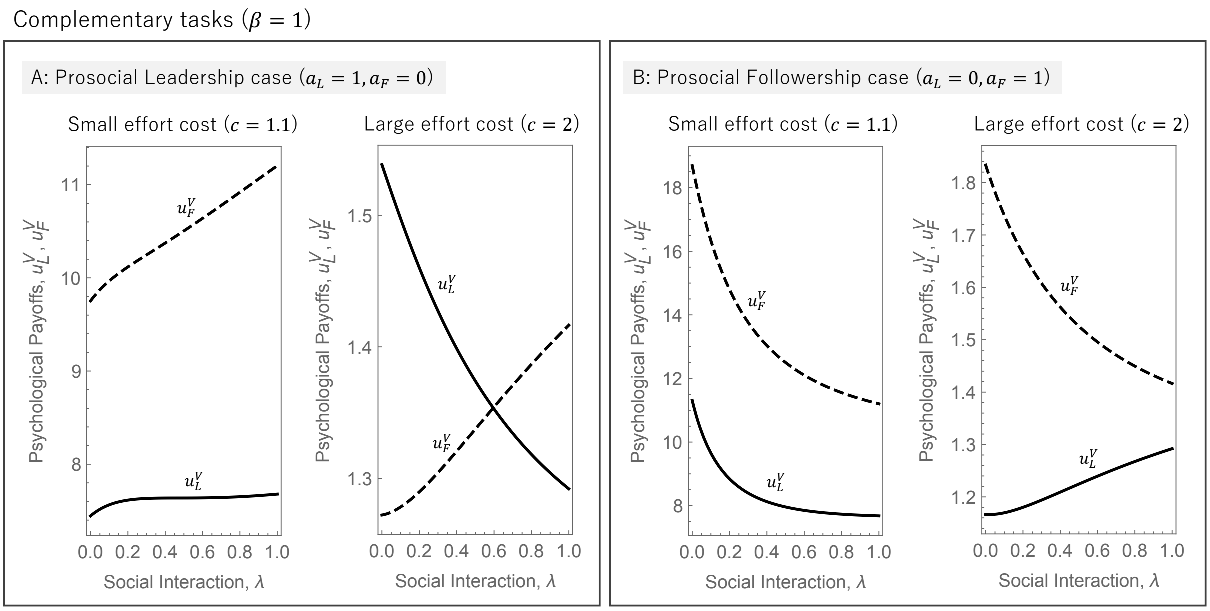
$$\left.\frac{dG^V}{d\lambda}\right|_{\{a_L,a_F\}=\{0,1\}} = -\frac{c\alpha^3\beta^2\gamma^3\left[\Theta + 4c(10c+\alpha\beta\gamma)\right]}{\Theta^3(1+\lambda)^2}. \tag{35}$$

When $\beta > 0$, the sign of (34) is positive, indicating that social interaction enhances team performance for complementary tasks under prosocial leadership. However, the sign of (35) is negative, indicating that social interaction reduces team performance for complementary tasks under prosocial followership. In contrast, when $\beta < 0$, both (34) and (35) have negative signs, suggesting that social interaction impairs team performance for substitutable tasks, regardless of whether the team is under prosocial leadership or prosocial followership.[10] Figure 8 depict the simulation results, indicating that social interaction enhances team performance only for the teams performing complementary tasks with prosocial leadership.

Proposition 6. *Consider two members who have $\{a_1, a_2\} = \{1, 0\}$. In vertical teams performing complementary tasks, social interaction improves team performance if it involves a more prosocial leader and a less prosocial follower, but it lowers team performance if it involves a less prosocial leader and a more prosocial followers. In vertical teams performing substitutable tasks, social interaction lowers team performance.*

In a horizontal team, social interaction enhances team performance for complementary tasks but diminishes it for substitutable tasks. In contrast, the boundary condition for whether social interaction enhances team

[10]When $\beta < 0$, the sign of the parentheses in the numerator of (34) is obviously positive if c is large, since the first term becomes larger and the second germ becomes smaller. When c takes the minimum value that satisfies Assumption 2, that is, when $16c^2 = 3\alpha^2\beta^2\gamma^2$, the expression inside the parentheses reduces to $2\alpha^2\beta^2\gamma^2(16c + 7\alpha\beta\gamma)$, which is confirmed to be positive because $2c + \alpha\beta\gamma = \xi_L|_{a_L=1,a_F=0} > 0$.



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$.

Figure 9: Psychological Payoffs in Vertical Teams with Complementary Tasks

performance in vertical teams performing complementary tasks is whether the team is led by a relatively high-prosociality leader: social interaction only enhances performance for complementary tasks led by a leader with higher team prosociality than its follower. In vertical team performing complementary tasks, when both have same team prosociality, the leader will put in more effort than the follower. If the leader's prosociality is higher than that of the follower, this tendency becomes stronger, indicating that the follower' lack of effort becomes a serious bottleneck in their task accomplishment. In such a situation, social interaction brings about a change in effort to alleviate the serious bottleneck.

On the other hand, in teams supported by the follower with higher prosociality than their leader, social interaction exacerbates the bottleneck problem by lowering the prosociality of the follower who is already the bottleneck, leading to a more serious problem. Therefore, in the case of prosocial followership, social interaction lowers team performance. In addition, for vertical teams performing substitutable tasks, similar to the results of horizontal teams, the disparity in prosociality between members has a positive impact on team performance, and social interaction lowers team performance by reducing the difference in effort between members.

In summary, for vertical teams with a hierarchical structure, social interaction can improve performance by resolving the bottleneck of followers' lack of effort in complementary tasks only when the teams are led by a more prosocial leader. This interesting result aligns with the discussion on transformational (inspirational) leadership in a series of literature (e.g., Burns, 1978; Bass, 1990; Avolio, 1999; Bass and Riggio, 2006; among many others).

Next, we examine the impact of social interaction on the payoffs of members in vertical teams. As Proposition 6 confirms, in the case of substitutable tasks, social interaction will lower team performance, leading the manager to choose $\lambda = 0$. Therefore, we provide the numerical results of the influence of social interaction on the payoffs of each member, particularly the psychological payoffs, in vertical teams performing complementary tasks.

Figure 9 illustrates the impact of social interaction on psychological payoffs of members in vertical teams performing complementary tasks. Panel A shows the prosocial leadership case, and panel B shows the prosocial followership case. In all four plots, in the case of maximal reciprocity where $\lambda = 1$, the leader and follower are symmetric in all aspects except for their roles, which leads to a higher psychological payoff for the follower than the leader, reflecting second-mover advantages.[11]

Unlike the case of horizontal teams, social interaction can improve the payoff of all team members only when effort costs are small (or effort complementarity is strong) enough to satisfy $\zeta_L^V < 0$ and when the team is led by a relatively prosocial leader. In the case of high effort costs, as with horizontal teams, social interaction lowers the psychological payoff of an initially more prosocial member and raises that of an initially less prosocial member.

As one may notice from the figure, social interaction may lower the payoffs of both leader and follower in the prosocial followership case, but their payoffs are at a higher "level" than those in the prosocial leadership case. If managers are able to observe employee prosociality levels and use them to organize teams, this has important implications for team formation, which we will discuss in detail in Section 7.1.

5.2 Manager's Choice of Social Interaction in Stage 1

As in the analysis of horizontal teams, the manager determines the level of $\lambda \in [0, 1]$ to maximize their own payoffs. The first order condition is given by $(1-\alpha)\dfrac{dG^V}{d\lambda} - \omega'(\lambda) = 0$. With $\omega(0) = 0$ and $\omega(1) = \infty$, we have an interior solution for $\lambda^V \in (0, 1)$ as long as $dG^V/d\lambda > 0$.

Firstly, we find, from Proposition 6, that a manager will choose positive social interaction for vertical teams only when they perform complementary tasks and are led by a more prosocial leader. Thus, the following proposition is immediate.

Proposition 7. *A manager supervising vertical teams performing complementary tasks engages in social interaction if the teams composed of a more prosocial leader and a less prosocial follower, but does not engage in social interaction if the teams composed of a less prosocial leader and a more prosocial follower. For vertical teams performing substitutable tasks, a manager does not engage in social interaction.*

To compare the optimal level of social interaction for a team with prosocial leadership performing complementary tasks with the optimal level for a horizontal team consisting of the same members, we hereby present (33) again:

$$\frac{dG^V}{d\lambda} = \frac{dg_L^V}{d\lambda}\frac{dG^V}{dg_L} + \frac{dg_F^V}{d\lambda}\frac{dG^V}{dg_F}.$$

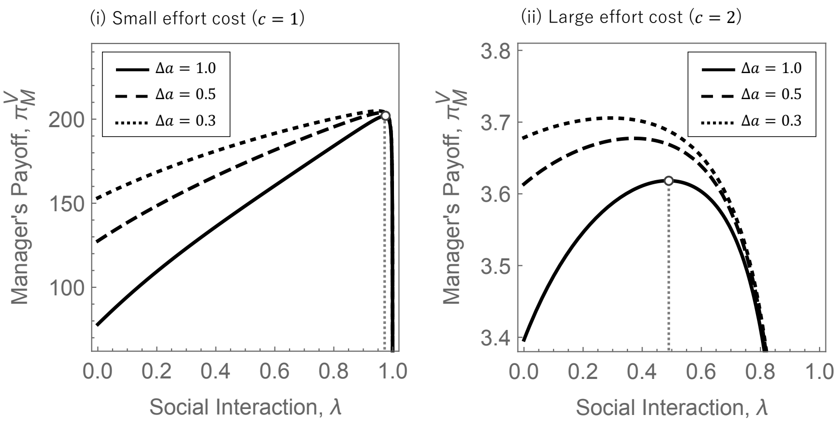
When $\beta > 0$, even if $\phi_L = \phi_F$, $g_L^V > g_F^V$ holds true, which leads to $dG^V/dg_F > dG^V/dg_L$. Therefore, in the case of prosocial leadership with $\phi_L > \phi_F$, g_L^V becomes even larger than g_F^V, further enhancing the effect of $dG^V/dg_F > dG^V/dg_L$. Consequently, $dG^V/d\lambda$ is larger than $dG^H/d\lambda$, implying that, in the case of complementary tasks, all else being equal, the optimal level of social interaction for a vertical teams led by a more prosocial leader is higher than the optimal level of social interaction for a horizontal team composed of the same members.

Proposition 8. *Consider a team performing complementary tasks consisting of two members with different levels of initial prosociality. The optimal level of social interaction for a vertical team with the more prosocial member as leader is higher than the optimal level for a horizontal team.*

Social interaction plays a significant role in the performance of complementary tasks led by highly prosocial leaders. Since $g_{Li}^V > g_i^H$ and $g_{Fj}^V > g_j^H$ hold, vertical teams outperform horizontal teams in complementary tasks, leading to greater payoffs for the manager.[12] In addition, in vertical teams with a more prosocial leader, social interaction has a positive effect on both narrowing the prosociality gaps between the leader and the follower,

[11] If the leader and the follower have equal prosociality, in complementary tasks, the less effortful follower enjoys a higher psychological payoff than the more effortful leader due to the second-mover advantage, while in substitutable tasks, the less effortful leader enjoys a higher psychological payoff than the more effortful follower due to the first-mover advantage (Gal-Or, 1985; Bulow et al., 1985).

[12] Bose et al. (2010) and Hattori and Yamada (2020) also show that vertical teams have higher performance than horizontal teams in models of complementary effort in team production.



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$, $h = 0.1$, $\{a_L, a_F\} = \{1, 0\}$ in $\Delta a = 1.0$, $\{a_L, a_F\} = \{.75, .25\}$ in $\Delta a = .5$, and $\{a_L, a_F\} = \{.65, .35\}$ in $\Delta a = .3$.

Figure 10: Optimal Social Interaction for Vertical Teams with Complementary Tasks

thereby generating more synergy, and improving the insufficient effort of the follower that can be a bottleneck for the team. Therefore, it is optimal for the manager to choose higher levels of social interaction.

By applying specific cost function for social interaction (7), we numerically obtain the optimal level of social interaction for vertical teams performing complementary tasks with initial prosociality level $\{a_L, a_F\} = \{1, 0\}$. Using the same parameter set as the horizontal team case analyzed in Section 4.2, we obtain $\lambda^V = .97$ for the case with low effort cost ($c = 1$) and $\lambda^V = .49$ for the case with high effort cost ($c = 2$). These values exceed the optimal social interaction $\lambda^H = .76$ for $c = 1$ and $\lambda^H = .41$ for $c = 2$, respectively, that the same members would have had if they were hypothetically formed into horizontal teams, as illustrated in Figure 5. This implies that, all other things equal, a manager should invest in promoting social interaction within a team performing complementary tasks under prosocial leadership.

6 Discussion

In this section, we will discuss our qualitative findings obtained so far regarding (i) who should promote and pay for social interaction in teams, (ii) how long a team should continue with the same members, and (iii) how our results relate to team psychological safety in organizations.

6.1 Voluntary Social Interaction among Members

In the main body, we assumed that upper management (the manager) outside the team introduces social interaction within the team and bears its cost. However, as shown in Figures 3 and 9, in the case of complementary tasks, there exists a range of λ for which social interaction improves the psychological payoffs of all members for both horizontal teams and vertical teams with prosocial leadership. That is, in that cases, social interaction may be promoted voluntarily by the members themselves at their own expense. On the other hand, in the case of substitutable tasks, social interaction cannot improve the psychological payoff of all members, so they will not voluntarily interact socially within the team. Our results offer an explanation for the circumstances under which members will voluntarily engage in social interaction, based on the task and team conditions.

6.2 Optimal Duration of Teams

Our findings also suggest that the optimal duration of a team depends on the nature of the tasks and the team structure. In the main body, we considered short-term investments to promote social interaction within the team. However, it is natural to assume that as the same team members continue to work together over a long period, they will gradually influence each other, and λ will increase from 0 to 1 over time. For horizontal teams performing complementary tasks, a long-term team is desirable because members gradually influence each other through work, and this reduces prosociality disparities, which has a positive effect on resolving task bottlenecks. On the other hand, in the case of substitutable tasks, a long-term team would reduce the prosociality of highly prosocial members, which is important for team performance.

In vertical teams, in the case of complementary tasks, a short-term team is desirable if led by a low-prosociality, self-centered leader, to avoid decreasing follower prosociality due to peer effects. On the other hand, in the case of a highly prosocial leader, a long-term team is desirable to allow their high prosociality to permeate the follower. For substitutable tasks, as shown later in Section 7.1, vertical teams are either not desirable or, if so, social interaction will always reduce team performance.

6.3 Psychological Safety in Organization

Our findings may also shed light on the significant concept of "psychological safety" in contemporary workplaces, and offer one explanation for why psychologically safe organizations may lead to higher performance. Psychological safety refers to the belief that the workplace is safe for interpersonal risk taking (Kahn, 1990; Edmondson, 1999).[13] Under a psychologically safe organizational or team culture, individuals with different levels of prosociality will be able to express their opinions and ideas without hesitation. The ease of communication and its high frequency will promote the propagation of prosociality among team members. In other words, psychologically safe teams are likely to be more susceptible to the influence of others' prosociality, both positively and negatively, than teams that are not psychologically safe.

There have been numerous studies on the impact of psychological safety on job performance. Gu et al. (2013) found that effective social interaction, through trust and mutual understanding among team members, fosters innovation in R&D teams by mediating psychological safety. Carmeli et al. (2010) found through a survey that inclusive leadership enhances psychological safety, and psychological safety promotes employees' creative participation. Given that innovative tasks requiring creativity demand complementary efforts, as classified by Rahmani et al. (2018), our results suggest that a psychologically safe environment could reduce team prosociality gaps and potentially lead to the success of creative tasks. In particular, for complementary tasks where there is a synergy effect between members' efforts, a psychologically safe team environment is predicted to enhance performance by contributing to the resolution of task bottlenecks in horizontal teams or vertical teams led by prosocial leaders.

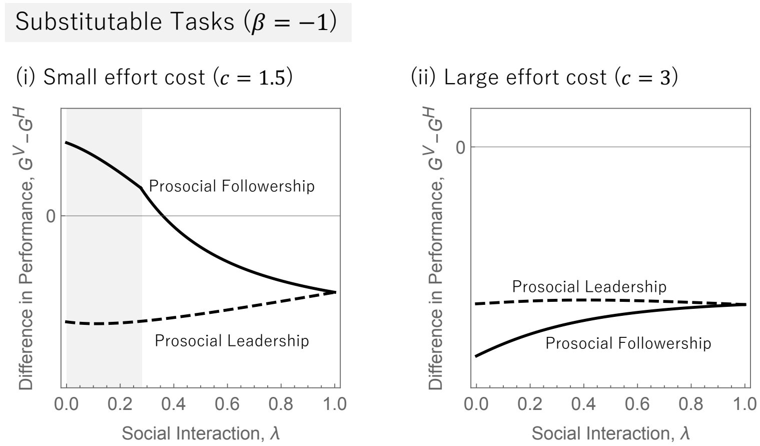
7 Extensions

In this section, we extend the basic model in three directions. First, we analyze the team design that a manager would employ when they are able to determine the team's structure (horizontal or vertical) and assign roles to its members (leader or follower). Second, we analyze how a team is designed when team members can determine the team structure by themselves. Third, applying a simple repeated-game framework, we investigate how social interaction affects the sustainability of cooperation among team members.

7.1 Optimal Team Structure

Here, we consider the optimal team structure that a manager should select, assuming they can hypothetically have the ability to choose not only the level of social interaction but also the team's structure, whether it is

[13] For more on psychological safety, see Edmondson (1999, 2003), and Franzier et al. (2017) for meta-analysis.



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$, $\{a_L, a_F\} = \{1, 0\}$ for Prosocial Leadership case, and $\{a_L, a_F\} = \{0, 1\}$ for Prosocial Followership case.

Figure 11: Comparison of Team Performance for Substitutable Tasks

horizontal or vertical, and who should lead.

Naturally, from the manager's perspective, it is desirable to have a team structure that maximizes team performance. Therefore, we first investigate how the desirable team structure, whether horizontal or vertical, depends on the type of task.

From Lemma 1, we immediately find that, in the case of complementary tasks with $\beta > 0$, $G^V > G^H$ necessarily holds. Hence, regardless of the distribution of initial prosociality among team members, the manager should form vertical teams to perform complementary tasks. Then the next issue to consider is whether to select a more or less prosocial member as the team leader. In a vertical team, when prosociality levels are equal, the leader tends to exert more effort, which implies that the follower's lack of effort becomes a bottleneck for the task. Hence, we can easily confirm that assigning the more prosocial member to the follower position instead of the leader can lead to higher team performance. Figure S3 in Supplementary Materials illustrates the numerical results. The key point is that in prosocial followership, team performance is high, but social interaction lowers it, while in prosocial leadership, performance is lower but social interaction can boost it. Therefore, if the manager can establish an optimal team formation, social interaction is not required.

In the case of substitutable tasks with $\beta < 0$, $g_{L1}^V < g_1^H$ and $g_{F2}^V > g_2^V$ hold, and thus the relative magnitudes of G^H and G^V cannot be uniquely determined. Since the efforts are strategic substitutes, the team performance of vertical teams may lower than that of horizontal teams by strategic effect. However, team performance increases as the difference in effort levels among team members becomes greater. Therefore, by placing a more prosocial member in follower's position where effort levels tend to be higher in vertical teams, it may be possible for vertical teams to surpass the team performance that would have been achieved if the same members had formed a horizontal team.

In support of this properties, Figure 11 presents two panels that plot the difference in team performance achieved by vertical and horizontal teams performing substitutable tasks (i.e., $G^V - G^H$) as a function of social interaction. When effort costs are low, in prosocial followership teams, there exists a situation where the leader becomes a complete free-rider (the gray area in the figure), causing the prosocial followers to contribute all effort, resulting in higher team performance than horizontal teams with the same members due to this specialization. A leadership style in which a leader exerts little effort and instead motivates their more prosocial followers to put in more effort corresponds to what Rahmani et al. (2018) call "directive" team leadership. Our results indicate that this directive leadership style is desirable for a team when there is high substitutability of effort, as well as strong strategic effects. In contrast, when effort costs are high, neither leadership style can match the

		Member 2	
		moving early (Lead)	moving late (Follow)
Member 1	moving early (Lead)	u_1^H, u_2^H	u_{L1}^V, u_{F2}^V
	moving late (Follow)	u_{F1}^V, u_{L2}^V	u_1^H, u_2^H

Figure 12: Payoff Matrix of Endogenous Timing for Leadership Selection

team performance of horizontal teams.

To summarize the discussion here, if a manager can design the optimal team, then for complementary tasks, it is best to form a vertical team with prosocial followership by placing highly-prosocial members in follower roles. For substitutable tasks, when effort costs are low, it is optimal to form a vertical team with prosocial followership and when effort costs are high, it is optimal to form a horizontal team. Furthermore, if optimal team design is feasible, promoting social interaction within the team is unnecessary.

7.2 Endogenous Leadership

In our baseline model, we analyzed a situation in which the team structure, whether horizontal or vertical, is exogenously given to team members. Here, we employ the endogenous timing game developed by Hamilton and Slutsky (1990) to investigate the team structure that is most plausible when team members voluntarily determine both the team structure and their roles.

Following Hamilton and Slutsky (1990), we consider the situation in which members noncooperatively and simultaneously choose their preferred role, moving early (*Lead*) or moving late (*Follow*) in the team production stage. If both members choose *Lead* or *Follow*, a simultaneous-move horizontal team production will take place. If one member chooses *Lead* and the other chooses *Follow*, a Stackelberg vertical team production will take place. The table represents the normal-form representation of the timing game.

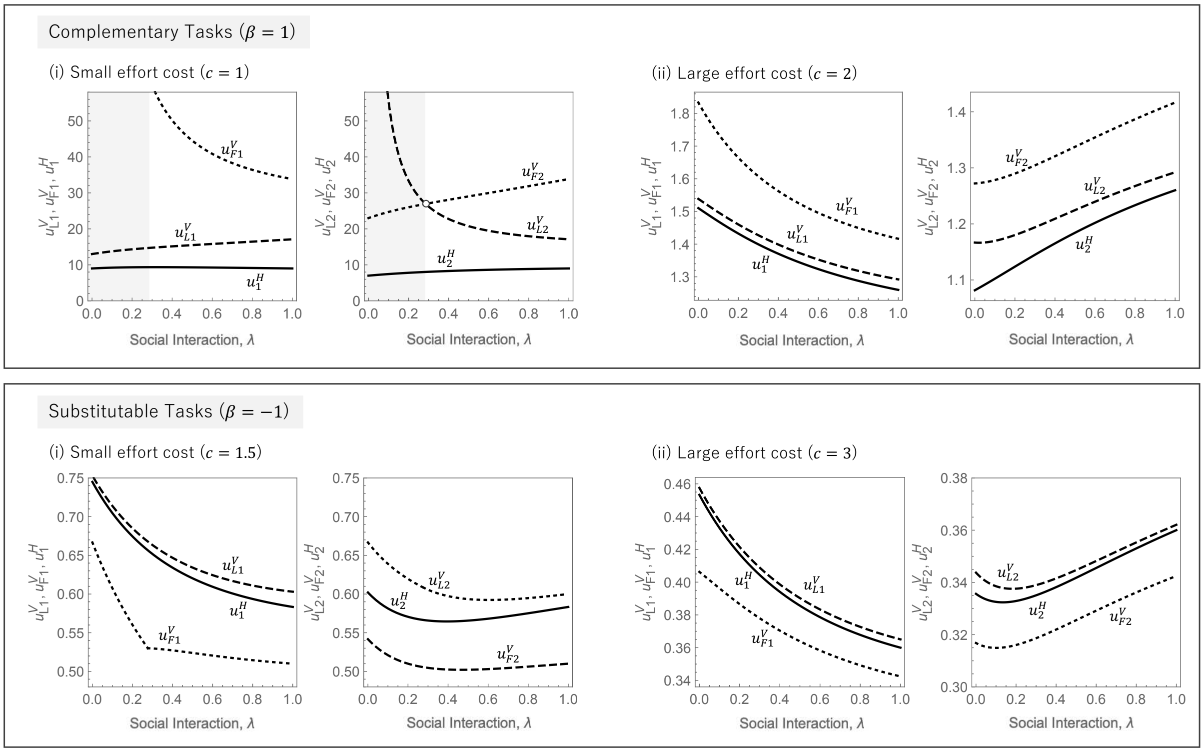
First, we consider the case where the members are symmetric with $\phi_i = \phi_j = \bar{\phi}$, which also corresponds to the case of maximal reciprocity ($\lambda = 1$). In this case, we have

$$u_{Li}^V - u_i^H \Big|_{\phi_i=\phi_j=\bar{\phi}} = \frac{c\alpha^4\gamma^4\left(1-\bar{\phi}\right)^2\left(1+\bar{\phi}\right)^4}{\left[4c-\alpha\beta\gamma\left(1+\bar{\phi}\right)\right]^2\Theta}\cdot\beta^2 > 0, \tag{36}$$

$$u_{Fi}^V - u_i^H \Big|_{\phi_i=\phi_j=\bar{\phi}} = \frac{2c\alpha^3\gamma^3\left(1-\bar{\phi}\right)^2\left(1+\bar{\phi}\right)^3\left[4c-\alpha\beta\gamma\left(1+\bar{\phi}\right)\frac{\Gamma}{2\Theta}\right]}{\left[4c-\alpha\beta\gamma\left(1+\bar{\phi}\right)\right]^2\Theta}\cdot\beta \gtreqless 0, \tag{37}$$

Since $\frac{\Gamma}{2\Theta} < 1$, we have $u_{F_i}^V > u_i^H$ for $\beta > 0$ and $u_{F_i}^V < u_i^H$ for $\beta < 0$. Therefore, we find from (36) that, when members have equal prosociality, their optimal responses are to choose *Lead* in response to the opponent's *Follow*, regardless of the nature of the task. In addition, according to equation (37), their optimal responses are to choose *Follow* for complementary tasks, and to choose *Lead* for substitutable tasks. Therefore, in the case of complementary tasks, two Nash equilibria can emerge, wherein one member takes on the role of leader, and the other becomes the follower, resulting in the formation of a vertical team. In contrast, there exists a unique Nash equilibrium for substitutable tasks where both members prefer to choose *Lead*, leading to the formation of a horizontal team.

Let us next consider a situation where the prosociality levels of team members are asymmetric with $\{a_1, a_2\} = \{1, 0\}$, i.e., Member 1 is more prosocial than Member 2. Figure 13 shows the psychological payoffs, u_i^H, u_{Li}^V, and u_{Fi}^V of Members 1 and 2 in a horizontal team, and as a leader and a follower in a vertical team, respectively.



Note. Parameters: $\alpha = .5$, $\gamma = 4$.

Figure 13: Psychological Payoffs and Social Interaction when $\{a_1, a_2\} = \{1, 0\}$

In complementary task cases, $u^V_{F1} > u^V_{L1} > u^H_1$ holds irrespective of their effort cost, implying that a more prosocial member (Member 1) favors followership. However, a less prosocial member (Member 2) prefers leadership when λ is small (i.e., with a large prosociality gap), as depicted by the gray area in panel (i). In these regions, a vertical team with prosocial followership is the unique Nash equilibrium for the endogenous timing game. In other regions, both members prefer followership for second-mover advantages, resulting in two Nash equilibria forming vertical teams: $\{1, 2\} = \{Lead, Follow\}$, $\{Follow, Lead\}$.

Next, using Harsanyi and Selten's (1988) risk-dominant criterion, we select one Nash equilibrium from these two equilibria. The equilibrium where Member 1 chooses to be the leader and Member 2 chooses to be the follower is risk-dominant if it has a larger product of deviation losses, i.e., if

$$\Omega \equiv (u^V_{L1} - u^H_1)(u^V_{F2} - u^H_2) - (u^V_{F1} - u^H_1)(u^V_{L2} - u^H_2) > 0, \tag{38}$$

and if $\Omega < 0$, then the equilibrium where Member 2 becomes a the leader is risk-dominant Nash equilibrium.

In Section 7.1, we have demonstrated that in complement task teams, appointing a member with high prosociality to a follower's position achieves higher team performance than prosocial leadership cases. From the fact, we expect that $u^V_{L1} + u^V_{F2} < u^V_{F1} + u^V_{L2}$, which can also be verified from Figure 9. This implies that the second term in (38) dominates the first term, and $\Omega < 0$ holds. Consequently, a less prosocial Member 2 becoming the leader is a risk-dominant equilibrium, representing the most desirable team structure for organizations, as demonstrated in Section 7.1.[14] Figure S4 in Supplementary Materials plots Ω as a function of the social interaction level.

This result highlights the importance of social interaction in teams performing complementary tasks. If team members can voluntarily organize efficient vertical teams with prosocial followership, social interaction is

[14]It is confirmed that Ω is always negative, regardless of the magnitude of c as long as Assumptions 1 and 2 are satisfied.

unnecessary. Thus, social interaction compensates for situations with exogenously appointed prosocial leaders or when horizontal teams form due to inadequate corporate culture and leadership selection.

For substitutable tasks with $\beta < 0$, as illustrated in parts (iii) and (iv) of Figure 13, both members prefer the leader role and dislike the follower position the most (i.e., $u^V_{Li} > u^H_i > u^V_{Fi}$ holds for $i \in \{1,2\}$).[15] Thus, the Nash equilibrium in this endogenous timing game is formed by both choosing to be a leader, resulting in the formation of a horizontal team with simultaneous moves. As demonstrated in Section 7.1, when effort costs are low, a vertical team with a more prosocial member serving as a follower can achieve higher team performance, making the voluntarily formed horizontal team an inefficient outcome from the perspective of managers or the organization.

7.3 Effect of Social Interaction on Long-term Team Cooperation

In our main analysis, we treated team production as an one-shot non-cooperative game without binding promises or norms within the team. However, in a long-term situation where the team task is repeated by the same team members, some kind of cooperative behavior within the team may occur.

In this last extension, we consider a simple infinitely repeated game of team production with grim-trigger strategies and examine the impact of social interaction on the sustainability of cooperation. As before, the team is composed of two members $i \in \{1,2\}$ with different levels of prosociality, and rewards determined only by team performance are divided equally. We here assume that the one-shot team production is infinitely repeated with perfect monitoring. Additionally, we assume that each team member has a chance for social interaction before the first team production and that their prosociality remains constant throughout subsequent team productions.

We first derive the conditions for sustaining cooperation through the use of the grim-trigger strategies in a horizontal team. In the case where both members non-cooperatively determine their effort, each Member i receives a payoff of $u^H_i \equiv u_i(g^H_i, g^H_j, \phi_i)$, as analyzed in Section 4. On the other hand, if both members cooperate, their effort levels are determined by maximizing the sum of their material payoffs:[16]

$$\max_{g_i,\, g_j} \Pi \equiv \pi_i(g_i, g_j, \phi_i) + \pi_j(g_i, g_j, \phi_j)$$

The first-order conditions are

$$\frac{\partial \Pi}{\partial g_1} = \alpha\gamma \frac{\partial G}{\partial g_1} - C'(g_1) = 0 \text{ and } \frac{\partial \Pi}{\partial g_2} = \alpha\gamma \frac{\partial G}{\partial g_2} - C'(g_2) = 0.$$

We denote the cooperative effort level of Member i as g^H_{iC}. The first-order conditions derived above imply that $g^H_{1C} = g^H_{2C} = g^H_C > g^H_i$, which suggests that all members should exert the same level of effort, which is greater than their non-cooperative level. We define Member i's psychological payoffs in cooperation as $u^H_{iC} \equiv u_i(g^H_C, g^H_C, \phi_i)$. If $\phi_1 > \phi_2$, then we have

$$\left(u^H_{1C} - u^H_1\right) - \left(u^H_{2C} - u^H_2\right) = \left[\frac{\alpha}{2}\gamma(G^H_C - G^H) - C(g^H_C)\right] + (1-\phi_2)C(g^H_1) - (1-\phi_1)C(g^H_2) > 0, \tag{39}$$

which implies that the gains from cooperation is greater for a more prosocial member. This is because initially less prosocial members are required to exert a greater increase in effort when cooperating compared to initially more prosocial members (i.e., $g^H_1 > g^H_2$ implies $(g^H_C - g^H_1) < (g^H_C - g^H_2)$).[17]

[15] In panel (iii) of Figure 13, both u^V_{F1} and u^V_{L2} exhibit noticeable kinks. This occurs because, when λ is small (prosociality gap is still large) and effort costs are low, the less prosocial member (Member 2) becomes a complete free rider who contributes no effort when taking the leader role.

[16] We consider a promise to maximize the sum of physical payoffs rather than the sum of psychological payoffs for the following reasons. First, the total sum of psychological payoffs, which includes prosociality towards team members, can far exceed the total sum of physical payoffs and is therefore unrealistic. Second, physical payoffs are more observable than prosociality and provide a clear indicator when explicitly committing to cooperative effort. However, it is worth noting that even if we had conducted the same analysis with the objective function of the total sum of psychological payoffs, the conclusion that social interaction enhances the sustainability of cooperation would still hold.

[17] It should be noted that in cases where there is a large difference in prosociality between members, a less prosocial member may

Now, we consider the sustainability of the above cooperation of $\{g_{1C}^H, g_{2C}^H\}$ in an infinitely repeated game with grim-trigger strategies. We assume that each member i maximizes its discounted stream of psychological payoffs with discount factor δ_i. When both members cooperate, Member i obtain u_{iC}^H. When unilaterally deviating from the cooperation, Member i chooses the effort level

$$g_{iD}^H \equiv \underset{g_i}{\operatorname{argmax}}\ u_i(g_i, g_C^H, \phi_i),$$

where g_{iD}^H represents the effort level of Member i when he/she deviates. The corresponding deviation payoffs are represented by $u_{iD}^H \equiv u_i(g_{iD}^H, g_C^H, \phi_i)$. We immediately find that if $\phi_1 > \phi_2$, then $g_C^H > g_{1D}^H > g_{2D}^H$ holds. If Member i deviates at period t, Member j will never cooperate and choose g_j^H after period $t+1$. Thus, the cooperation of $\{g_{1C}^H, g_{2C}^H\}$ is sustainable (i.e., a subgame perfect Nash equilibrium) if the following incentive compatibility constraint is satisfied for all $i \in \{1, 2\}$:

$$\frac{u_{iC}^H}{1-\delta_i} \geq u_{iD}^H + \frac{\delta_i u_i^H}{1-\delta_i}.$$

Thus, we find that Member i does not deviate from the cooperation if

$$\delta_i \geq \hat{\delta}_i \equiv \frac{u_{iD}^H - u_{iC}^H}{u_{iD}^H - u_i^H}.$$

where $\hat{\delta}_i$ represents the critical discount factor for Member i to favor adhering cooperation over one-time deviation.

When the gain from cooperation is high, the critical discount factor becomes smaller. Assuming without loss of generality that $\phi_1 > \phi_2$, if cooperation requires $g_{1C}^H = g_{2C}^H$ as in (39), then Member 2 is required to increase effort more when cooperating, which reduces their incentive to cooperate. On the other hand, because $g_C^H > g_{1D}^H > g_{2D}^H$, Member 2 gains more from deviation from cooperation than Member 1, i.e., $u_{2D}^H - u_{2C}^H > u_{1D}^H - u_{1C}^H$. Therefore, the less prosocial member requires a larger discount factor than more prosocial member to sustain cooperation, i.e., $\hat{\delta}_2 > \hat{\delta}_1$ if $\phi_1 > \phi_2$.

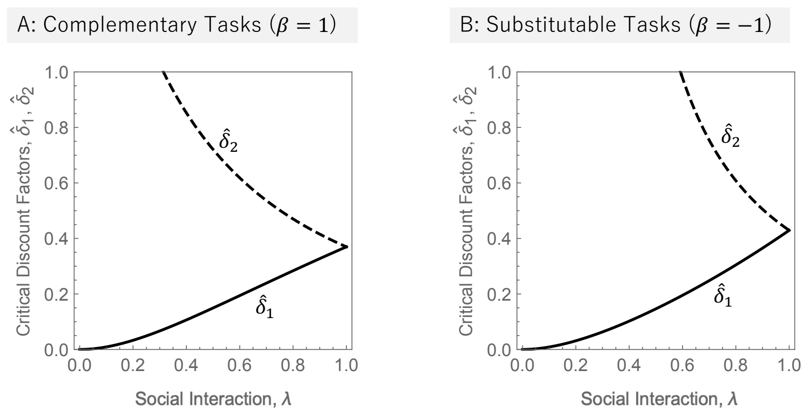
Social interaction leads to the convergence of prosociality between members, so it holds that $d\hat{\delta}_1/d\lambda > 0$ and $d\hat{\delta}_2/d\lambda < 0$ for $\lambda \in [0, 1)$ and $\hat{\delta}_1 = \hat{\delta}_2$ at $\lambda = 1$. If both members' discount factors are equal social interaction contributes to creating a team that is more likely to sustain cooperation. Importantly, this result holds regardless of the type of task (complementary or substitutable), meaning that social interaction has a positive effect on team performance by promoting cooperation among members even in substitutable tasks.

Figure 14 illustrates the relationship between the critical discount factor and social interaction for asymmetric team members in complementary tasks (panel A) and substitutable tasks (panel B). The critical discount factor of the more prosocial Member 1 ($a_1 = 1$) is depicted by a solid line, while the critical discount factor of the less prosocial Member 2 ($a_2 = 0$) is represented by a dashed line. As seen from the figure, in both types of tasks, $\hat{\delta}_1 < \hat{\delta}_2$ holds for $\lambda \in [0, 1)$ and becomes equal at $\lambda = 1$.[18] Social interaction plays a facilitative role in promoting cooperative behavior in teams, by lowering the critical discount factor of less prosocial members who hinder the continuation of cooperation.

In the case of a vertical team, as shown by Mouraviev and Rey (2011), the Stackelberg leader does not have deviation incentives because the leader's deviation is immediately punished by the follower in the period. That is, leadership indeed facilitates team cooperation by making it easier to punish deviations by the leader. This implies that social interaction within a vertical team enhances the sustainability of long-term cooperation it effectively reduces the follower's deviation incentive. In the case of prosocial leadership with $\phi_L > \phi_F$, social

even experience $u_{iC}^H - u_i^H < 0$. As we will see later, a less prosocial member may choose not to cooperate even when their discount factor is 1.

[18] In the figure, $\lambda = 0$ represents the case where $\hat{\delta}_1 = 0$, which means the deviation incentive is zero. This is because, even if deviating from the cooperation, Member 1 would choose the cooperative solution if $\phi_1 = 1$.



Note. Parameters: $\alpha = .5$, $\gamma = 4$, $c = 4$, $\{a_1, a_2\} = \{1, 0\}$.

Figure 14: Critical Discount Factors for Sustaining Cooperation in Horizontal Teams

interaction increases the prosociality of the follower, which reduces the critical discount factor necessary for the follower to sustain cooperation. Therefore, in prosocial leadership teams performing complementary tasks, social interaction not only improves short-term non-cooperative team performance but also has a long-term sustaining effect on cooperation. On the other hand, in prosocial leadership teams performing substitutable tasks, social interaction does not have a short-term performance-enhancing effect, but it does have a long-term sustaining effect on cooperation.

8 Concluding Remarks

Organizations are made up of people, and people influence each other. In particular, group consciousness and altruistic emotions towards fellow members can sometimes become a powerful driving force behind the organization. Within corporate organizations, interactions through work and other activities can inspire some individuals through the high level of group consciousness of others, while demotivating others due to the low consciousness of their peers. By incorporating such socially-driven interactions into team production theory, we have revealed what constitutes the optimal social interaction for an organization.

We found that in horizontal teams without hierarchical structures, complementarity of effort is a necessary condition for social interaction to enhance team performance and alleviate bottleneck problems associated with task completion. Furthermore, in teams performing complementary tasks led by a more prosocial leader, social interaction also serves to boost team performance. Conversely, teams led by a less prosocial leader may not experience these benefits. Social interaction can exacerbate the free-riding problem and negatively impact team performance in tasks where effort is substitutable. However, social interaction has the potential to induce long-term cooperation among team members regardless of the type of task being performed.

Our results not only provide one answer to the practical question of how much employee interaction should be encouraged in an organization, but also provide some answers to questions such as why some teams spontaneously engage in social interaction within the team, how long the optimal team composition period should be, and how ensuring psychological safety in the organization can enhance the performance of complementary task teams.

Our study has three main tasks remaining. The first task is to examine the degree to which our qualitative results from theoretical analysis are supported by empirical or experimental evidence. This involves conducting randomized controlled experiments with subjects and controlling the type of task and the amount of communication between team members. The second task is to consider the impact of social interaction between the manager (principal) and team members (agents), including the effect of the manager's altruism towards the team and the influence of rewards determined by the manager on team member prosociality. Finally, our theory hypothesizes that social interaction reduces the prosociality gap between team members. However, in certain environments, all team members' prosociality may converge to the level of the most prosocial individual, while in other environments, it may converge to the level of the least prosocial individual. For instance, Dimant (2019) finds that antisocial behavior is more contagious than prosocial behavior among peers, suggesting that social interaction may cause both members to converge towards the lower level of prosociality. Although this may require some psychological research, it remains an important future research topic.

References

[1] Altmann, S., Dohmen, T., Wibral, M., 2008. Do the reciprocal trust less? Economics Letters 99(3), 454–457.

[2] Avolio, B.J., 1999. Full leadership development: Building the vital forces in organizations. Thousand Oaks, CA: Sage.

[3] Baldassarri, D., 2015. Cooperative networks: Altruism, group solidarity, reciprocity, and sanctioning in Ugandan producer organizations. American Journal of Sociology 121(2), 355–395.

[4] Bass, B.M., 1990. From transactional to transformational leadership: Learning to share the vision. Organizational Dynamics 18(3), 19–31.

[5] Bass, B.M., Riggio, R.E., 2006. Transformational leadership. Psychology press.

[6] Bassi, M., Pagnozzi, M., Piccolo, S., 2014. Optimal contracting with altruism and reciprocity. Research in Economics 68(1), 27–38.

[7] Battiston, D., Blanes i Vidal, J., Kirchmaier, T., 2021. Face-to-Face Communication in Organizations. The Review of Economic Studies 88(2), 574–609.

[8] Bergstrom, T., Blume, L., Varian, H., 1986. On the private provision of public goods. Journal of Public Economics 29(1), 25–49.

[9] Bose, A., Pal, D., Sappington, D.E.M., 2010. Asymmetric treatment of identical agents in teams. European Economic Review 54(7), 947–961.

[10] Brandts, J., Cooper, D.J., Weber, R.A., 2015. Legitimacy, Communication, and Leadership in the Turnaround Game. Management Science 61(11), 2627–2645.

[11] Bulow, J.I., Geanakoplos, J.D., Klemperer, P.D., 1985. Multimarket oligopoly: Strategic substitutes and complements. Journal of Political Economy 93(3), 488–511.

[12] Burns, J. M. (1978). Leadership. New York: Harper & Row.

[13] Büyükboyacı, M., Robbett, A., 2017. Collaboration and free-riding in team contests. Labour Economics 49, 162–178.

[14] Carrell, S.E., Malmstrom, F.V., West, J.E., 2008. Peer effects in academic cheating. Journal of Human Resources 43(1), 173–207.

[15] Carrell, S.E., Hoekstra, M., West, J.E., 2011. Is poor fitness contagious?: Evidence from randomly assigned friends. Journal of Public Economics 95(7-8), 657–663.

[16] Cardella, E., Kugler, T., Anderson, J., Connolly, T., 2019. Is greed contagious? Four experimental studies. Journal of Behavioral Decision Making 32(5), 579–598.

[17] Carmeli, A., Reiter-Palmon, R., Ziv, E., 2010. Inclusive leadership and employee involvement in creative tasks in the workplace: The mediating role of psychological safety. Creativity Research Journal 22(3), 250–260.

[18] Carpenter, J., Bowles, S., Gintis, H., Hwang, S.-H., 2009. Strong reciprocity and team production: Theory and evidence. Journal of Economic Behavior & Organization 71(2), 221–232.

[19] Che, Y.K., Yoo, S.W., 2001. Optimal incentives for teams. American Economic Review 91(3), 525–541.

[20] Ching, K., Fortl, E., Rawley, E., 2021. Extemporaneous Coordination in Specialist Teams: The Familiarity Complementarity. Organizational Science 32(1), 1–17.

[21] Clarkson, B.G., Wagstaff, C.R.D., Arthur, C.A., Thelwell, R.C., 2020. Leadership and the contagion of affective phenomena: A systematic review and mini meta - analysis. European Journal of Social Psychology 50(1), 61–80.

[22] Delfgaauw, J., Dur, R., Onemu, O., Sol, J., 2022. Team incentives, social cohesion, and performance: A natural field experiment. Management Science 68(1), 230–256.

[23] Dimant, E., 2019. Contagion of pro- and anti-social behavior among peers and the role of social proximity. Journal of Economic Psychology 73, 66–88.

[24] Dimmock, S.G., Gerken, W.C., Graham, N.P., 2018. Is Fraud Contagious? Coworker Influence on Misconduct by Financial Advisors. Journal of Finance 73(3), 1417–1450.

[25] Dur, R., Non, A., Roelfsema, H., 2010. Reciprocity and incentive pay in the workplace. Journal of Economic Psychology 31(4), 676–686.

[26] Dur, R., Sol, J., 2010. Social interaction, co-worker altruism, and incentives. Games and Economic Behavior 69(2), 293–301.

[27] Edmondson, A.C., 1999. Psychological safety and learning behavior in work teams. Administrative Science Quarterly 44(2), 350–383.

[28] Edmondson, A.C., 2003. Speaking up in the operating room: How team leaders promote learning in interdisciplinary action teams. Journal of management studies, 40(6), 1419–1452.

[29] Fehr, E., Gächter, S., 2000. Fairness and retaliation: The economics of reciprocity. Journal of Economic Perspectives 14(3), 159–182.

[30] Fehr, E., Schmidt, K.M., 1999. A theory of fairness, competition, and cooperation. The Quarterly Journal of Economics 114(3), 817–868.

[31] Fehr, E., Schmidt, K.M., 2006. Chapter 8 The Economics of Fairness, Reciprocity and Altruism – Experimental Evidence and New Theories, in: Handbook of the Economics of Giving, Altruism and Reciprocity. Elsevier, 615–691.

[32] Frazier, M. L., Fainshmidt, S., Klinger, R. L., Pezeshkan, A., Vracheva, V., 2017. Psychological safety: A meta-analytic review and extension. Personnel psychology 70(1), 113–165.

[33] Gal-Or, E., 1985. First mover and second mover advantages. International Economic Review 26(3), 649–653.

[34] Gould, E.D., Kaplan, T.R., 2011. Learning unethical practices from a co-worker: The peer effect of Jose Canseco. Labour Economics 18(3), 338–348.

[35] Gregor, M., 2015. Task divisions in teams with complementary tasks. Journal of Economic Behavior & Organization 117, 102–120.

[36] Gu, Q., Wang, G.G., Wang, L., 2013. Social capital and innovation in R&D teams: the mediating roles of psychological safety and learning from mistakes. R&D Management 43(2), 89–102.

[37] Hamilton, J.H., Slutsky, S.M., 1990. Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. Games and Economic Behavior 2(1), 29–46.

[38] Hattori, K., Yamada, M., 2018. Skill diversity and leadership in team production. Journal of Institutional and Theoretical Economics 174(2), 351–374.

[39] Hattori, K., Yamada, M., 2020. Effective leadership selection in complementary teams. Journal of Institutional and Theoretical Economics 176(4), 620–639.

[40] Harsanyi, J.C., Selten, R., 1988. A general theory of equilibrium selection in games. Cambridge: MIT Press.

[41] Hekman, D.R., Steensma, H.K., Bigley, G.A., Hereford, J.F., 2009. Combined effects of organizational and professional identification on the reciprocity dynamic for professional employees. Academy of Management Journal 52(3), 506–526.

[42] Hinds, P.J., Mortensen, M., 2005. Understanding Conflict in Geographically Distributed Teams: The Moderating Effects of Shared Identity, Shared Context, and Spontaneous Communication. Organization Science 16(3), 290–307.

[43] Hirshleifer, J., 1983. From weakest-link to best-shot: The voluntary provision of public goods. Public Choice 41(3), 371–386.

[44] Hodson, R., 1997. Group relations at work: Solidarity, conflict, and relations with management. Work and Occupations 24(4), 426–452.

[45] Holmström, B., 1982. Moral hazard in teams. The Bell Journal of Economics 13(2), 324–340.

[46] Huck, S., Rey-Biel, P., 2006. Endogenous leadership in teams. Journal of Institutional and Theoretical Economics 162(2), 253–261.

[47] Itoh, H., 1991. Incentives to help in multi-agent situations. Econometrica 59(3), 611–636.

[48] Itoh, H., 2004. Moral hazard and other-regarding preferences. The Japanese Economic Review 55, 18–45.

[49] Jarosch, G., Oberfield, E., Rossi-Hansberg, E., 2021. Learning From Coworkers. Econometrica 89(2), 647–676.

[50] Johnson, S.K., 2008. I second that emotion: Effects of emotional contagion and affect at work on leader and follower outcomes. The Leadership Quarterly 19(1), 1–19.

[51] Johnson, S.K., 2009. Do you feel what I feel? Mood contagion and leadership outcomes. The Leadership Quarterly 20(5), 814–827.

[52] Kahn, A.K., 1990. Psychological Conditions of Personal Engagement and Disengagement at Work. Academy of Management Journal 33(4), 692–724.

[53] Kempf, H., Graziosi, G.R., 2010. Leadership in public good provision: a timing game perspective. Journal of Public Economic Theory 12(4), 763–787.

[54] Kramer, A.D., Guillory, J.E. and Hancock, J.T., 2014. Experimental evidence of massive-scale emotional contagion through social networks. Proceedings of the National Academy of Sciences 111(24), 8788–8790.

[55] Krueger, A.B., Schkade, D., 2008. Sorting in the labor market do gregarious workers flock to interactive jobs? Journal of Human Resources 43(4), 859–883.

[56] Lazear, E.P., Rosen, S., 1981. Rank-Order Tournaments as Optimum Labor Contracts. Journal of Political Economy 89(5), 841–864.

[57] Levine, D.K., 1998. Modeling Altruism and Spitefulness in Experiments. Review of Economic Dynamics 1(3), 593–622.

[58] Li, N., Kirkman, B.L., Porter, C.O., 2014. Toward a model of work team altruism. Academy of Management Review 39(4), 541–565.

[59] Lu, J.G., Swaab, R.I., Galinsky, A.D., 2022. Global leaders for global teams: Leaders with multicultural experiences communicate and lead more effectively, especially in multinational teams. Organization Science 33(4), 1554–1573.

[60] Mas, A., Moretti, E., 2009. Peers at work. American Economic Review 99(1), 112–145.

[61] Masum, A.K.M., Azad, M.A.K., Beh, L.S., 2015. Determinants of academics' job satisfaction: Empirical evidence from private universities in Bangladesh. PloS one 10(2), e0117834.

[62] McAfee, R.P., McMillan, J., 1991. Optimal contracts for teams. International Economic Review 32(3), 561–577.

[63] Moreland, R.L., Levine, J.M., 1982. Socialization in small groups: Temporal changes in individual-group relations. In Advances in experimental social psychology (Vol. 15, pp. 137-192). Academic Press.

[64] Mouraviev, I., Rey, P., 2011. Collusion and leadership. International Journal of Industrial Organization 29(6), 705–717.

[65] Nielsen, I.K., Jex, S.M., Adams, G.A., 2000. Development and validation of scores on a two-dimensional workplace friendship scale. Educational and Psychological Measurement, 60(4), 628–643.

[66] Obrenovic, B., Jianguo, D., Tsoy, D., Obrenovic, S., Khan, M.A.S., Anwar, F., 2020. The enjoyment of knowledge sharing: impact of altruism on tacit knowledge-sharing behavior. Frontiers in Psychology 11, 1496.

[67] O'Reilly, C.A., Chatman, J., 1986. Organizational commitment and psychological attachment: The effects of compliance, identification, and internalization on prosocial behavior. Journal of Applied Psychology 71(3), 492.

[68] Pearce, C.L., Ensley, M.D., 2004. A reciprocal and longitudinal investigation of the innovation process: The central role of shared vision in product and process innovation teams (PPITs). Journal of Organizational Behavior 25(2), 259–278.

[69] Penconek, T., Tate, K., Bernardes, A., Lee, S., Micaroni, S.P., Balsanelli, A.P., de Moura, A.A., Cummings, G.G., 2021. Determinants of nurse manager job satisfaction: A systematic review. International Journal of Nursing Studies 118, 103906.

[70] Rahmani, M., Roels, G., Karmarkar, U.S., 2018. Team Leadership and Performance: Combining the Roles of Direction and Contribution. Management Science 64(11), 5234–5249.

[71] Rabin, M., 1993. Incorporating fairness into game theory and economics. American Economic Review 83(5), 1281–1302.

[72] Rayo, L., 2007. Relational incentives and moral hazard in teams. The Review of Economic Studies 74(3), 937–963.

[73] Riordan, C.M., Griffeth, R.W., 1995. The opportunity for friendship in the workplace: An underexplored construct. Journal of Business and Psychology 10, 141–154.

[74] Robert, I., Arnab, M., 2013. Is dishonesty contagious?. Economic Inquiry 51(1), 722–734.

[75] Rotemberg, J.J., 1994. Human relations in the workplace. Journal of Political Economy 102(4), 684–717.

[76] Sparks, A.M., Fessler, D.M. and Holbrook, C., 2019. Elevation, an emotion for prosocial contagion, is experienced more strongly by those with greater expectations of the cooperativeness of others. PloS one 14(12), p.e0226071.

[77] Stevens, S. T., Chavarria, K., Brenya, J., Keenan, J. P., 2020. There's no "I" in team: Altruism as a predictor of team success in the National Hockey League. Bulletin of the New Jersey Academy of Science 61(1), 22–30.

[78] Van den Bulte, C., Moenaert, R.K., 1998. The effects of R&D team co-location on communication patterns among R&D, marketing, and manufacturing. Management Science 44(11-part-2), S1–S18.

[79] Varian, H. R., 1994. Sequential contributions to public goods. Journal of Public Economics 53(2), 165–186.

[80] Vives, X., 1999. Oligopoly Pricing: Old Ideas and New Tools. MIT Press.

[81] Volmer, J., 2012. Catching leaders' mood: Contagion effects in teams. Administrative Sciences 2(3), 203–220.

Supplementally Materials

S1. Derivation for $dG^H/d\lambda$

Using (16), the partial derivative of the second-stage equilibrium team performance $G^H = G(g_1^H, g_2^H; \beta)$ with regard to λ is given by

$$\begin{aligned}
\frac{\partial G^H}{\partial \lambda} &= \frac{\partial g_1^H}{\partial \lambda}\frac{\partial G}{\partial g_1} + \frac{\partial g_2^H}{\partial \lambda}\frac{\partial G}{\partial g_2} \\
&= -\frac{SOC_2}{D}\frac{\alpha}{2}\gamma\phi_1'\zeta_1^H\frac{\partial G}{\partial g_1} - \frac{SOC_1}{D}\frac{\alpha}{2}\gamma\phi_2'\zeta_2^H\frac{\partial G}{\partial g_2} \\
&= -\frac{1}{D}\frac{\alpha}{2}\gamma\phi_1'\left(SOC_2\,\zeta_1^H\frac{\partial G}{\partial g_1} - SOC_1\,\zeta_2^H\frac{\partial G}{\partial g_2}\right) \\
&= -\frac{SOC_1\,SOC_2}{D}\phi_1'\left(\frac{\frac{\alpha}{2}\gamma\frac{\partial G}{\partial g_1}}{SOC_1}\zeta_1^H - \frac{\frac{\alpha}{2}\gamma\frac{\partial G}{\partial g_2}}{SOC_2}\zeta_2^H\right) \\
&= \frac{SOC_1\,SOC_2}{D}\phi_1'\left(\frac{\partial R_1}{\partial \phi_1}\zeta_1^H - \frac{\partial R_2}{\partial \phi_2}\zeta 2^H\right),
\end{aligned}$$

where the final transformation is made using (11).

S2. Derivation for ζ_L^V

Here, we assume $\partial^2 G/\partial g_i^2 = 0$ or is small enough to ignore, as in (1), to simplify the mathematical derivations. By taking the total derivative of (24), we have

$$\left[\frac{\partial^2 u_L}{\partial g_L^2}\right] dg^V + \left[\frac{\partial^2 u_L}{\partial g_L \partial \lambda}\right] d\lambda = 0, \tag{S.1}$$

where

$$\begin{aligned}
\frac{\partial^2 u_L}{\partial g_L \partial \lambda} &= \frac{\alpha}{2}\gamma\left[(1+\phi_L)\beta\frac{\partial R_F}{\partial \phi_F}\phi_F' + \phi_L'\frac{\partial G}{\partial g_L}\right] \\
&\quad + \frac{\alpha}{2}\gamma\left[\frac{\partial^2 R_F}{\partial g_L \partial \phi_F}\phi_F'\frac{\partial G}{\partial g_F}(1-\phi_L\phi_F) - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}(\phi_L'\phi_F + \phi_L\phi_F')\right] \\
&= \frac{\alpha}{2}\gamma\phi_L'\left[\frac{\partial G}{\partial g_L} - (1+\phi_L)\beta\frac{\partial R_F}{\partial \phi_F} - \frac{\partial^2 R_F}{\partial g_L \partial \phi_F}\frac{\partial G}{\partial g_F}(1-\phi_L\phi_F) - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}(\phi_F - \phi_L)\right].
\end{aligned} \tag{S.2}$$

From (11), we have

$$\frac{\partial R_F}{\partial \phi_F} = \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{1}{\beta(1+\phi_F)}. \tag{S.3}$$

In addition, assuming $\partial^2 G/\partial g_i^2 = 0$, we have

$$\frac{\partial^2 R_F}{\partial g_L \partial \phi_F} = -\frac{\frac{\alpha}{2}\gamma\beta}{SOC_F} = \frac{\partial R_F}{\partial g_L}\frac{1}{1+\phi_F}. \tag{S.4}$$

Substituting (S.3) and (S.4) into (S.2), we have

$$\begin{aligned}
\frac{\partial^2 u_L}{\partial g_L \partial \lambda} &= \frac{\alpha}{2}\gamma\phi_L'\left[\frac{\partial G}{\partial g_L} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{1+\phi_L}{1+\phi_F} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{1-\phi_L\phi_F}{1+\phi_F} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}(\phi_F - \phi_L)\right] \\
&= \frac{\alpha}{2}\gamma\phi_L'\left(\frac{\partial G}{\partial g_L} - \frac{\partial R_F}{\partial g_L}\frac{\partial G}{\partial g_F}\frac{2+\phi_F - 2\phi_L\phi_F + \phi_F^2}{1+\phi_F}\right) = \frac{\alpha}{2}\gamma\phi_L'\zeta_L^V.
\end{aligned} \tag{S.5}$$

Substituting (S.5) into (S.1), we have

$$\frac{dg_L^V}{d\lambda} = -\frac{\frac{\alpha}{2}\gamma}{SOC_L}\phi_L'\zeta_L^V.$$

S3. Confirming Proposition 5 under the Specification of the Function G

By differentiating (26) and (27) in λ, we have

$$\frac{dg_L^V}{d\lambda} = \frac{4c\alpha\gamma\phi_L'\left[\Theta - \alpha\beta\gamma\eta\xi_L\right]}{\Theta^2}, \tag{S.6}$$

$$\frac{dg_F^V}{d\lambda} = \frac{\alpha\gamma\phi_F'\left[\Theta\left(4c + \alpha\beta\gamma(\phi_L - \phi_F)\right) + \alpha^2\beta^2\gamma^2\eta\xi_L(1+\phi_F)\right]}{\Theta^2}, \tag{S.7}$$

where $\eta \equiv 1 + \phi_F^2 - 2\phi_L\phi_F \in [0,1]$ for all $\phi_L \in [0,1]$ and $\phi_F \in [0,1]$.

From (S.7), we immediately find that the effect of social interaction on the follower's effort is determined by the sign of ϕ_F', irrespective of the task type. Social interaction induces more effort from the follower if the leader is initially more prosocial ($a_L > a_F$, implying $\phi_F' > 0$), and less effort if the follower is initially more prosocial ($a_L < a_F$, implying $\phi_F' < 0$). In the case of substitutable tasks ($\beta < 0$), the sign of (S.6) is also determined by the sign of ϕ_L', implying that social interaction reduces effort from the leader if $a_L > a_f$, and increases it if $a_L < a_F$.

However, in the case of complementary tasks ($\beta > 0$), the sign depends on $\Theta - \alpha\beta\gamma\mu\xi_L$. If

$$\Theta - \alpha\beta\gamma\mu\xi_L < 0, \tag{S.8}$$

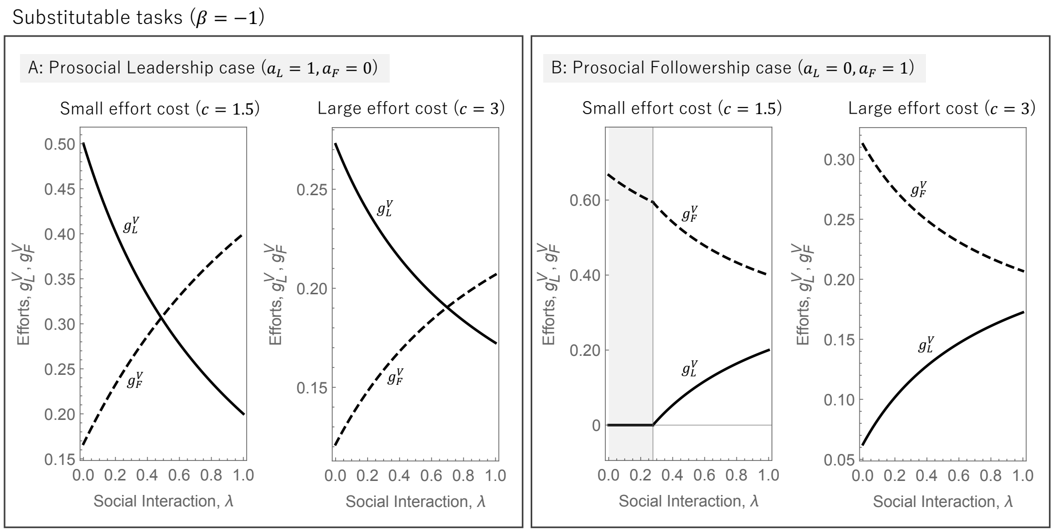
then the sign of (S.6) is positive for $a_L > a_F$, and is negative for $a_L < a_F$. Therefore, if the condition (S.8) is satisfied, then social interaction increases both g_L^V and g_F^V for $a_L > a_F$ and decreases both g_L^F and g_F^V for $a_L < a_F$. Otherwise, social interaction increases reduces effort of the initially more prosocial member and increases effort of the initially less prosocial member. The condition (S.8) is more likely to hold when c is smaller and α and γ are larger. For example, when $\alpha = .5$, $\beta = 1$, $\gamma = 4$, then the condition is satisfied if $c \leq 1.40$ for $\{a_L, a_F\} = \{1, 0\}$ and if $c \leq 1.82$ for $\{a_L, a_F\} = \{0, 1\}$.

S4. Equilibrium Efforts and Payoffs in Vertical Teams Performing Substitutable Tasks

We here provide the numerical examples and explanations for the effects of social interaction on each member's effort and payoff in vertical teams performing substitutable tasks.

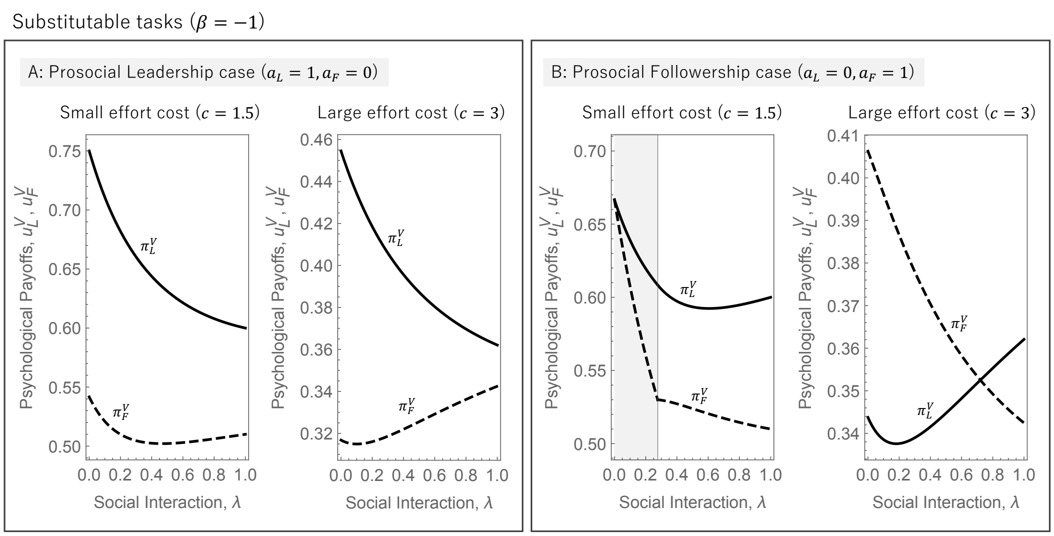
Figure S1 depicts the effect of social interaction on each member's effort. In panel B of the figure, the graph for the case of low effort cost shows the grey area where a less prosocial leader becomes a complete free rider by exerting no effort. In all four plots, it is confirmed that $g_L < g_F$ holds when the prosociality of both members is equal at $\lambda = 1$, and social interaction does not cause changes in the effort levels of both members in the same direction, unlike in the complementary task case.

Figure S2 depicts the effect of social interaction on each member's psychological payoffs. Also in panel B of the figure, the graph for the case of low effort cost shows the grey area where a less prosocial leader becomes a complete free rider by exerting no effort. In all four plots, it is confirmed that $u_L > u_F$ holds when the prosociality of both members is equal at $\lambda = 1$, reflecting the first-mover advantages. The crucial point here is that social interaction never leads to an increase in the payoffs of both members, although it may result in a decrease in payoffs for both members.



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$.

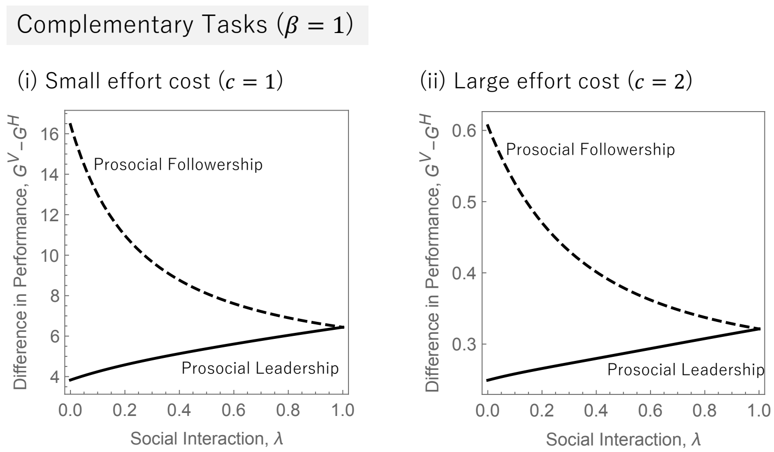
Figure S1: Equilibrium Efforts in Vertical Teams Performing Substitutable Tasks



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$.

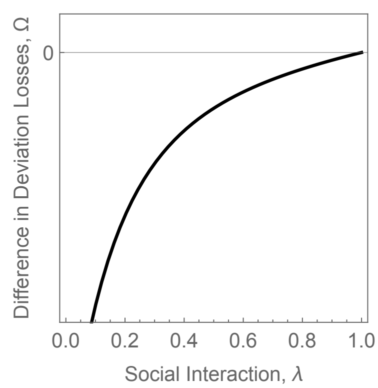
Figure S2: Psychological Payoffs in Vertical Teams with Substitutable Tasks

S5. Other Figures



Note. Parameters: $\alpha = .5$, $\beta = 1$, $\gamma = 4$, $\{a_L, a_F\} = \{1, 0\}$ for Prosocial Leadership case, and $\{a_L, a_F\} = \{0, 1\}$ for Prosocial Followership case..

Figure S3: Comparison of Team Performance for Complementary Tasks



Note. Parameters: $\alpha = .5$, $\beta = 1$, $c = 2$, $\gamma = 4$, and $\{a_1, a_2\} = \{1, 0\}$.

Figure S4: The Difference of Deviation Loss (Ω)