

## A Two-Dimensional Dynamic Model of Interpersonal Coopetition: The Driving Role of Social Comparison

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**Date:** 2026-03-18T15:47:17+00:00

### Abstract

In human society, competition and cooperation are not mutually exclusive; rather, they exist in a relationship of interdependence and dynamic coexistence. As global resource pressures intensify, social comparison among individuals plays a pivotal role in shaping tendencies toward competition and cooperation, influencing the emergence and transformation of coopetitive behaviors across multiple dimensions. Although coopetition was originally proposed as an intergroup social phenomenon, interpersonal coopetitive behavior and its dynamic evolutionary process remain unclear. This paper first clarifies the relationship between competition and cooperation in interpersonal interactions and innovatively proposes a two-dimensional dynamic model of interpersonal coopetition. This model transcends the traditional view that treats competition and cooperation as two poles of a single dimension, instead constructing them as two independent dimensions driven bidirectionally by “social comparison” and “goal alignment.” Next, after examining common paradigms for studying coopetition, this paper proposes the Share Game paradigm; subsequently, it discusses the neural mechanisms underlying how social comparison influences coopetitive behavior. Finally, the paper identifies current challenges and future directions in integrating the social comparison dimension, unifying coopetition paradigms, and constructing theoretical models. This paper systematically reviews how social comparison influences the individual’s trade-off process between competition and cooperation in game contexts. By integrating evidence from behavioral experiments, computational modeling, and brain imaging research, it provides empirical support for the two-dimensional dynamic model of interpersonal coopetition, as well as theoretical support and methodological guidance for subsequent coopetition research.

Full Text

Preamble

## A Two-Dimensional Dynamic Model of Interpersonal Competition: The Driving Role of Social Comparison

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**Abstract:** In human society, competition and cooperation are not mutually exclusive opposites but rather interdependent and dynamically coexisting relations. As global resource pressures intensify, social comparison among individuals plays a critical role in shaping tendencies toward competition and cooperation, influencing the emergence and transformation of co-opetitive behavior across multiple dimensions. Although co-opetition was originally proposed as an intergroup social phenomenon, interpersonal co-opetition and its dynamic evolutionary processes remain poorly understood. This paper first clarifies the relationship between competition and cooperation in interpersonal interactions and innovatively proposes a two-dimensional dynamic model of interpersonal co-opetition. This model transcends the traditional view of competition and cooperation as two poles of a single dimension, instead constructing them as two independent dimensions driven bidirectionally by “social comparison” and “goal alignment.” Subsequently, after examining common paradigms for studying co-opetition, this paper introduces the “Share Game” paradigm. It then discusses the neural mechanisms underlying the influence of social comparison on co-opetitive behavior. Finally, the paper identifies current challenges and future directions regarding the integration of social comparison dimensions, the unification of co-opetition paradigms, and the construction of theoretical models. By systematically reviewing how social comparison influences the trade-off between competition and cooperation in game-theoretic contexts—and integrating evidence from behavioral experiments, computational modeling, and brain imaging—this paper provides empirical support for the two-dimensional dynamic model of interpersonal co-opetition, offering theoretical foundations and methodological guidance for future research.

**Keywords:** social cognition, cooperation, competition, social comparison **Classification Code:** B845 **Received:** 2025-11-06 \*Supported by the National Natural Science Foundation of China (32371084).

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In modern human civilization, competition and cooperation serve as both the foundation of social functioning and the engine of development. Competition can stimulate individual potential, enhance efficiency, and facilitate the effec-

tive allocation of resources. Conversely, cooperation enables resource sharing, strengthens solidarity, and facilitates the achievement of collective goals. The interaction between these two forces constitutes social interaction, shaping the diverse behaviors of individuals and groups. However, both possess negative aspects: in competition, one person's success is often built upon another's failure, or at least requires demonstrating superiority through comparison, which can easily lead to resource dissipation, interpersonal conflict, and negative emotions. In cooperation, the free-rider effect may lead a minority to betray or exploit others, ultimately damaging or collapsing collective benefits and potentially inducing unethical behaviors such as corruption and cheating [?, ?]. Therefore, finding the balance between competition and cooperation to maximize their positive effects while minimizing negative impacts is a critical issue for improving social interactions.

As global challenges such as population growth, energy crises, and climate change emerge, resources worldwide are becoming increasingly scarce, making resource allocation issues particularly prominent [?, ?, ?]. In this context, if resource allocation is viewed as a zero-sum game, one party's gain must come from another's loss, and one party's investment may be offset by another's. Ultimately, cyclical social comparison pushes groups toward competition, resulting in over-competition or even "vicious" competition. However, whether at the group or individual level, humans are neither absolute competitors nor absolute cooperators; a tension and contradiction between competition and cooperation always exists within human social interaction. Thus, finding a balance between the two—leveraging their positive roles to alleviate resource pressure through shared resources and collaborative innovation to achieve win-win outcomes and avoid lose-lose scenarios—is a key problem in understanding and improving social interaction.

As early as 1992, Ray Noorda, the former CEO of Novell, noted the widespread phenomenon of cooperation among competitors in the computer industry. Subsequently, [?] further elaborated on this in their eponymous book, formally conceptualizing the phenomenon of cooperating with competitors as "co-opetition." Co-opetition describes a special interaction mode that transcends traditional adversarial relationships, reflecting the complex interplay between competition and cooperation and emphasizing their potential complementarity and coexistence. At the organizational level, co-opetition research primarily focuses on how firms acquire external resources to enhance performance and emphasizes how they achieve strategic goals by maintaining a dynamic balance between competition and cooperation [?, ?]. In the following two decades, inter-organizational co-opetitive relationships have attracted increasing attention across various fields [?, ?], exerting a profound influence on business production [?, ?], energy conservation [?, ?], and technological innovation [?, ?].

Although the concept of "co-opetition" was originally used to describe inter-organizational strategic behavior—centered on creating value with competitors and achieving non-zero-sum games—inter-organizational strategies are insepara-

ble from the individuals who serve as decision-making agents. [?] provided the first conceptual definition of interpersonal co-opetition: a situation where two people or parties must invest effort into a common task (cooperation), while the success of one party ultimately undermines the success of the other (competition). The fundamental characteristic of interpersonal co-opetition lies in the dynamic balance between the dimensions of competition and cooperation. Inter-organizational co-opetitive relationships are essentially shaped and driven by interactions between key individuals; thus, co-opetition at the individual level is more dynamic and psychologically complex. A deep analysis of interpersonal co-opetitive dynamics helps in understanding inter-organizational relationships. Furthermore, while co-opetition has been extensively studied in organizational contexts, the academic understanding of interpersonal co-opetition and its underlying mechanisms remains insufficient. In interpersonal co-opetition, individual decision-making is often more complex, involving not only actual payoffs but also the influence of social comparison.

Particularly when objective standards for measuring performance are lacking, individuals use others as their primary reference point. This can lead to “over-competition” —excessive investment in pursuit of relative advantage, resulting in the irrational consumption of resources. In contemporary social discourse, this phenomenon is often described as “involution” (*neijuan*). Faced with imbalanced competition, individual behavioral decisions may diverge. Driven by the instinct to seek benefit and avoid harm, individuals may shift toward avoidance strategies, often described in current social contexts as “lying flat” (*tangping*).

Therefore, from the perspective of social comparison, this paper clarifies the dynamic relationship between competition and cooperation in interpersonal interactions and innovatively proposes a two-dimensional dynamic theoretical model of interpersonal co-opetition. After reviewing the classic experimental paradigms currently used to study co-opetitive behavior, we propose the “Share Game” paradigm and further explore the neural mechanisms driving interpersonal co-opetition. On this basis, we...

### **总结了现有研究在整合社会比较、统一竞合范式与构建跨层次理论模型方面所面临的主要**

Challenges and future research directions are discussed. By integrating recent evidence from behavioral experiments, computational modeling, and neuroimaging studies, this paper reveals how social comparison influences the dynamic trade-off between competition and cooperation in game-theoretic contexts. Furthermore, we outline the neural processing mechanisms underlying interpersonal competition and cooperation, providing significant support for theoretical refinement and methodological innovation in this field.

## 2.1 人际竞合的相关理论

Lewin's (1935) field theory posits that sociality is the essence of human life. The core of this sociality lies not in the similarity of group members, but in the mutual influence of individuals' thoughts, emotions, behaviors, and outcomes within the group. Building upon this foundation, Deutsch (1949a, 1949b) and Festinger (1954) proposed social interdependence theory and social comparison theory, respectively. These two frameworks analyze the relationship between competition and cooperation in interpersonal interactions from the perspectives of goal structures and self-evaluation.

### 2.1.1 社会相互依赖理论

Social Interdependence Theory was the first to conceptually distinguish the relationship between competition and cooperation. It posits that two types of interdependence exist between individuals: positive and negative. Positive interdependence occurs when an individual's goals promote the goals of others, defined as cooperation; negative interdependence occurs when an individual's goals obstruct those of others, defined as competition. Furthermore, when an individual's goals are unrelated to those of others, no interdependence exists. Within this theoretical framework, competition and cooperation are viewed as mutually exclusive opposites based on three fundamental premises: 1) cooperation and competition exist only when individuals take action to achieve their goals; 2) the actions individuals take to achieve goals depend on their perception of goal interdependence within a specific context, and this perception changes dynamically as individual behavior influences the situation; and 3) causal influence is bidirectional, meaning the consequences generated by a specific social interdependence will, in turn, reinforce that specific interdependence—for example, cooperation fosters mutual trust, while trust further facilitates cooperation.

This theory was the first to utilize goal structures to predict types of social interdependence and interaction patterns among individuals. By clearly defining the boundaries between cooperation and competition, it provided a theoretical foundation for researchers to deeply explore social interdependence and its underlying mechanisms at the individual, group, and organizational levels (Tjosvold et al., 2014). The extensive application of this theory across various disciplines and fields demonstrates its significant value, laying the theoretical groundwork for concepts such as trust (Deutsch, 1962), conflict (Deutsch, 1973), distributive justice (Deutsch, 1985), and social identity (Tyler & Blader, 2003).

Building upon this, researchers have further deepened the understanding of competition and cooperation from the perspective of individual traits. The concept of Social Value Orientation (SVO) is rooted in Interdependence Theory (Kelley & Thibaut, 1978). When individuals face a given situation and adopt a specific strategy, they may transform it into a subjective utility context, which then serves as the basis for decision-making (Zhang et al., 2014). As a stable personality disposition that measures how individuals weigh their own interests

against those of others in interdependent situations, SVO explains individual differences in behavioral and decision-making tendencies within the same context (van Lange, 1999). Based on different allocations of weights to self and other outcomes, researchers have systematically classified SVO. Messick and McClintock (1968) identified four types: cooperative, individualistic, competitive, and altruistic orientations. Cooperative individuals seek to maximize collective outcomes; individualistic individuals seek to maximize absolute self-interest; competitive individuals seek to maximize their own outcomes relative to others; and altruistic individuals seek to maximize the outcomes of others. These motivational differences, driven by stable traits, influence whether an individual tends to reach consensus through cooperation or gain an advantage through competition during interactions.

While Social Interdependence Theory established the binary opposition between competition and cooperation, Social Value Orientation further deepened this understanding at the trait level, suggesting that individuals possess a stable personality disposition in weighing self-interest against the interests of others. In this view, competitive and cooperative tendencies are simply two ends of the same continuum. This theoretical framework, which treats competition and cooperation as two opposing poles on a single continuous spectrum, constitutes the traditional one-dimensional perspective in interpersonal competition research [Figure 1: see original paper].

### 2.1.2 社会比较理论

Social comparison theory focuses on how individuals compare themselves with others during social interactions, elucidating the critical role of social comparison in interpersonal competition and cooperation [?, ?]. On one hand, individuals feel a need to evaluate themselves through social comparison and seek relative superior status, which leads to competition [?, ?]. On the other hand, individuals exhibit an aversion to disparities between their own payoffs and those of others, leading them to consider the interests and feelings of others, which in turn promotes cooperation [?, ?].

Classic social comparison theory posits that humans possess an innate motivation to accurately evaluate their own abilities and opinions. Generally, individuals prefer to assess their standing on a specific attribute using objective information; however, when such information is unavailable, they seek social information from others. Particularly in the absence of objective standards, individuals select others in similar situations as reference points, evaluating their own abilities and opinions by comparing themselves to these targets. When individuals realize through social comparison that their performance is inferior to that of others, they are propelled by a fundamental “unidirectional drive upward.” This drive aims to improve their own performance while simultaneously minimizing the discrepancy between their performance level and that of the comparison target [?, ?].

Subsequently, researchers introduced the concept of social comparison orientation to describe individual differences in the personality disposition toward these two aspects of social comparison [?, ?]. [?, ?] proposed that individuals generally seek to achieve superior status relative to others across various situations. Consequently, social comparison serves as a significant source of competitive behavior. Building on this, they developed the social comparison model of competition, which aims to distinguish the effects of individual and situational factors on social comparison and competition.

Furthermore, social comparison may prompt individuals to focus on collective interests and the feelings of others, generating concerns for fairness and inequality aversion that sustain cooperation. According to inequality aversion theory, individuals care not only about their own payoffs but also about the difference between their payoffs and those of others, manifesting as an aversion to such disparities. People tend to dislike both receiving more than others (advantageous inequality) and receiving less than others (disadvantageous inequality), thereby pursuing equitable outcomes [?, ?]. However, research has identified several distinctions between these two types of aversion. First, they differ in terms of evolution and early development. Disadvantageous inequality aversion emerges early in both evolution and human development, whereas advantageous inequality aversion has only been observed in chimpanzees with relatively mature social and cognitive control [?, ?] and in humans over the age of eight [?, ?]. Second, they differ in intensity; although individuals find both types of inequality aversive, the intensity of aversion toward advantageous inequality is typically weaker than that toward disadvantageous inequality. Third, there are differences in their underlying neural mechanisms. Advantageous inequality primarily involves processing related to social cognition, including the left anterior insula, the right dorsolateral prefrontal cortex, and the dorsomedial prefrontal cortex. In contrast, disadvantageous inequality primarily involves processing related to emotion and conflict, including the left posterior insula, the right amygdala, and the dorsal anterior cingulate cortex [?, ?]. Furthermore, evolutionary dynamics models have revealed a dynamic link between the two: when the benefit-to-cost ratio of cooperation exceeds a critical threshold, the dominant motivation of a group can evolve from disadvantageous inequality aversion to advantageous inequality aversion—shifting from a “need-driven” system to a “generosity-driven” system [?, ?]. According to inequality aversion theory, most individuals possess both altruistic and fairness motivations. When encountering non-cooperators who contribute less, this preference for fairness prompts individuals to suppress their own altruistic behavior, leading to a corresponding decrease in their expectations of others’ contributions [?, ?]. Consequently, disadvantageous inequality aversion drives individuals toward competition, while advantageous inequality aversion may drive individuals toward cooperation.

## 2.2 人际竞争的实证研究

Current psychological research still tends to view competition and cooperation as a binary opposition, exploring psychological and neural differences under these distinct contexts (Decety et al., 2004; Lee & Seo, 2022; Lei & Rau, 2023; Liu et al., 2024). For instance, Decety et al. (2004) utilized a “pattern game” paradigm to measure competitive and cooperative behaviors, finding that cooperation specifically activated the orbitofrontal cortex, while competition specifically activated the inferior parietal lobe and the medial prefrontal cortex. Lee and Seo (2022) employed a latent cross-lagged model to measure adolescents’ attitudes toward cooperation and competition; their results revealed a negative correlation between these attitudes among students in grades 7 to 10, whereas no significant correlation was found between grades 10 and 11. Lei and Rau (2023) measured players’ emotional responses to performance feedback in cooperative and competitive settings, finding that in low-demand tasks, cooperative structures increased activation in the left rostral medial prefrontal cortex (rmPFC) compared to competitive structures. Liu et al. (2024) found through competitive and cooperative tasks that the intra-group cooperation index was superior to that of the out-group, while the out-group competition index was stronger than that of the intra-group.

However, as research paradigms have evolved, increasing evidence suggests that competition and cooperation are non-exclusive dimensions of a two-dimensional structure, manifesting in different forms across traits, states, and processes.

First, at the level of static traits, interpersonal competition manifests as mutually independent personality dimensions. Chinese psychologists Xie et al. (2006) first introduced the concept of cooperation into the field of psychology and developed the Cooperation and Competition Personality Tendency Scale. Subsequently, Lu et al. (2013) further validated the two-dimensional structure of this scale through three social dilemma experiments, finding no significant correlation between the two dimensions—thereby challenging the traditional view that treats them as opposite ends of a single continuum. Recent studies have also found a moderate positive correlation between adolescents’ competitive and cooperative attitudes (Lee & Seo, 2022). These stable trait differences are related to individual predispositions in social cognitive processing, where social comparison plays a key role. The ability dimension of social comparison orientation positively predicts trait competition (Liu et al., 2021). Meng et al. (2023) further integrated various dimensions of social comparison, competitive tendencies, and cooperative tendencies into a single network analysis. Their results showed that the “surpassing others” dimension of competitive tendency was positively correlated with the “willingness to cooperate” dimension of cooperative tendency. Social comparison in the ability dimension was closely related to “surpassing others” and “hyper-competitiveness,” reflecting an individual’s tendency to enhance their status through competition during social comparison. Conversely, social comparison in the opinion dimension was positively correlated with all sub-dimensions of cooperative orientation and the “self-development” dimen-

sion of competitive orientation. This suggests that individuals may possess a stronger willingness to cooperate when considering the opinions of others.

Second, at the state and process levels, interpersonal competition is characterized by instantaneous psychological states formed by each decision round, as well as the trade-offs and transitions occurring within sequential decision-making contexts. Landkammer and Sassenberg (2016) conducted the first empirical study on the concept of interpersonal competition by creating a situation where individuals simultaneously cooperated and competed with the same target, thereby operationalizing the “conflicting demands” inherent in competition. Their research found that, unlike pure competition, interpersonal competition does not lead to the spillover of negative behaviors; moreover, managing the conflicting demands within competition can significantly enhance an individual’s cognitive flexibility. An increasing number of studies recognize that competition and cooperation can coexist. For example, research has shown that fishermen in ecological reserves cooperate with others to create richer common resources and increase total yields, while simultaneously competing to enhance their own individual gains (Basurto et al., 2016). Behavioral economics research has also identified a class of individuals who invest more to increase public resources while simultaneously tending to reduce others’ income to achieve competitive victory (Prediger et al., 2014). Computational modeling based on multilayer networks has found that cooperation and competition can co-evolve through cross-network feedback mechanisms, where the success of cooperation increases shared resources, which in turn may intensify competition to acquire those resources (Zhu et al., 2025).

In such complex situations where competition and cooperation coexist, how individuals navigate trade-offs and make decisions is central to understanding interpersonal interaction. Social comparison plays a critical role in regulating this dynamic balance. Computational modeling techniques have provided supporting evidence. Regarding competition, van den Bos et al. (2013) used an auction paradigm to find that individuals assign extra value to the outcome of “outperforming” others. Martinez-Saito et al. (2022) utilized a common-pool resource task to demonstrate that reinforcement learning of option values is based not only on actual rewards but also on social comparisons resulting from the difference between self and other gains. Regarding cooperation, Hutcheron et al. (2015) found that individuals possess altruistic motives during social decision-making, linearly processing both their own and their opponent’s gains. Park et al. (2019) used a public goods game task to show that individuals simultaneously incorporate both personal and collective interests into option utility. A recent large-scale meta-analysis involving over 1.35 million participants further revealed this dynamism. The study found that the effectiveness of social comparison as a behavioral intervention technique is significantly moderated by information framing: when information is used to emphasize desired behaviors, its effect is superior to interventions focusing on reducing undesired behaviors (Hoppen et al., 2025). Therefore, social comparison does not simply lead to competition or cooperation; rather, it drives individuals to engage in sequential

decision-making and achieve transitions between different cooperative states.

Finally, although traits are stable, their power to shape final behavior is significantly moderated by situational factors. Stapel and Koomen (2005) treated cooperation-competition tendencies as individual difference variables and found that social comparison makes individuals with high competitive tendencies more likely to produce contrast effects with others, while making those with high cooperative tendencies more likely to assimilate with others' perspectives. Furthermore, empirical research supports the influence of specific spatio-temporal contexts on behavior: Waddell and Peng (2014) found that by altering the goal structure of a game, cooperative behavior could be significantly induced even after controlling for individual competitive traits.

Individual behavioral decisions are the result of the interaction between stable traits and specific spatio-temporal contexts. The empirical evidence mentioned above suggests that competition and cooperation are not a one-dimensional opposition where one increases as the other decreases (Figure 1a); instead, they form a two-dimensional structure that is non-exclusive in space and dynamically evolving in time. To clearly define the connotation of cooperation at different levels of analysis, this paper proposes a hierarchical analytical framework (Table 1), clarifying the essential differences between traits, states, and processes in terms of timescales and measurement indicators. The two-dimensional static model (Figure 1b) defines initial behavioral tendencies, while the two-dimensional dynamic model (Figure 1c) characterizes the instantaneous psychological states and their transition sequences formed by each decision round within a specific context.

Table 1: Hierarchical analytical framework of interpersonal cooperation: Comparison of traits, states, and processes. Stable personality tendencies. Mixed state: Instantaneous behavioral representation. Transition sequence:

Observable Indicators: Long-term, cross-situational stability. Cooperative and competitive personality tendencies (Xie et al., 2006); Social Value Orientation (Murphy et al., 2011). Single decision round (Trial). Share game investment: Relative position to Nash equilibrium and the median of the strategy space. Continuous interaction sequence (Trial by Trial / Block / Session). Strategy transition probability: The amount of investment change in subsequent trials relative to previous trials. Dynamic evolutionary path. This paper first introduces a two-dimensional static model of interpersonal cooperation (Figure 1b). This model is adapted from the research on cooperative and competitive personality tendencies by Xie et al. (2006), which posits that cooperation and competition can be viewed as stable personality tendencies that potentially influence individual behavior, validating that they are two independent personality dimensions rather than poles of a single dimension. This model is no longer limited to capturing instantaneous states in specific tasks but shifts toward relatively stable individual traits. It constructs four quadrants of interpersonal cooperation traits: high competition-high cooperation, high competition-low cooperation, low competition-high cooperation, and low competition-low cooperation. For

example, research has found that the “high competition–high cooperation” profile is often exhibited by highly educated, experienced senior managers (Xie et al., 2006). Such individuals possess both the competitive motivation to pursue relative advantage and the cooperative quality to coordinate goals and facilitate win-win outcomes. Thus, cooperation and competition, as stable personality tendencies, influence behavioral performance and state selection across different contexts.

In specific spatio-temporal contexts, interpersonal cooperation is characterized by an individual’s instantaneous psychological state in each decision round and the dynamic transition process of strategy adjustment based on feedback (Figure 1c). Each decision round corresponds to an instantaneous state, reflecting the individual’s weighting of the “social comparison” and “goal alignment” dimensions at that moment. “Social comparison” originates from social comparison theory (Festinger, 1954); this model adopts the definition by Garcia et al. (2013), defining it as the evaluation process where people assess themselves against others and seek relative advantage, leading to competition. “Goal alignment” originates from social interdependence theory (Deutsch, 1949a), referring to the cognitive process where individuals perceive their own goals and others’ goals as mutually promoting and harmonious, thereby driving cooperation. This process depends on the objective resource structure. In a zero-sum structure, goals cannot be aligned because the interests of both parties are in complete opposition. Only in non-zero-sum contexts, where there is room for mutual gain or loss reduction, can individuals develop a subjective perception of maintaining overall value. Therefore, goal alignment is essentially an individual’s cognitive alignment with a non-zero-sum reward structure, manifested as the perceived coordination between both parties toward the goal of “reducing resource dissipation and maintaining collective gains.” To further clarify the core concepts involved in this model, the definitions and connotations of relevant terms are provided in Table 2.

Table 2: Glossary of Terms. Definitions and connotations within the context of this paper. Zero-sum game: A game where one party’s gain is necessarily another’s loss, and the sum of gains is zero (“I win, you lose”). Non-zero-sum game: A game where one party’s gain is not necessarily another’s loss; participants can even obtain incremental gains, and the sum of gains is no longer zero.

Mutual promotion / Goal alignment: Derived from social interdependence theory. Describes the direction in which the realization of one party’s goal affects the attainment of the other’s goal. The cognitive process where individuals perceive coordination between both parties in “reducing resource dissipation and maintaining collective gains.”

Social comparison: The evaluation process where individuals assess their own status by comparing their gains with those of an opponent and pursue a position of relative advantage. Nash Equilibrium: A specific strategy combination where no player can increase their own gain by unilaterally changing their strategy,

reflecting a state of rational investment.

This state is continuously adjusted upon receiving outcome feedback, presenting a dynamic transition process. Individuals modify their strategies in real-time based on the influence of previous reward outcomes and opponent strategies (Hunter et al., 2021; Zhu et al., 2012). When an individual is in the “competition” quadrant driven by “high social comparison–low goal alignment,” if they focus excessively on surpassing others—driven by social comparison to pursue status while ignoring the collective benefits brought by goal alignment—it may lead to an imbalanced state of damaged collective interests and ineffective resource dissipation, known as “hyper-competition.” At this point, the individual will transition from the hyper-competitive state toward a more sustainable equilibrium. The path of this dynamic transition is determined by changes in the two dimensions: high social comparison and high goal alignment lead to the “cooperation” quadrant; low social comparison and high goal alignment lead to the “withdrawal” quadrant; and low social comparison and low goal alignment lead to the “withdrawal” quadrant. From the perspective of approach-avoidance motivation, withdrawal is a defensive transition taken by individuals to avoid loss after perceiving the risks associated with hyper-competition. It differs from low-level competition or cooperation by minimizing investment to achieve a “departure” or strategic “lying flat” (tang ping) in decision-making. This strategic shift from an imbalanced state to the withdrawal quadrant is widespread in social contexts. In education, irrational competition for school admissions often triggers “track-switching” or “lying flat”; in the workplace, extreme “bottom-out” elimination systems often induce “quiet quitting.” These behaviors are essentially active defensive strategies taken to avoid loss after perceiving an imbalance between gains and losses. This model is applicable to non-zero-sum game contexts. Under this premise, resource sufficiency acts as a key external constraint, regulating the relative weights of goal alignment and social comparison. Specifically, when the total resource pool is abundant relative to the initial endowment, the players’ total gains are at least no lower than their initial endowment; here, social comparison dominates, driving individuals to pursue relative advantage. When resources are relatively limited, hyper-competition directly leads to loss of individual income; in this case, resource scarcity constitutes a rigid constraint, forcing individuals to find a dynamic balance between “increasing investment to expand share” and “decreasing investment to reduce dissipation,” thereby potentially strengthening the motivation for goal alignment.

Note: This figure aims to explain the dynamic relationship between competition and cooperation in interpersonal interaction. Figure 1: Dynamic evolutionary model of interpersonal cooperation. (a) One-dimensional model: Views competition and cooperation as opposite ends of a single continuum. (b) Two-dimensional static model, adapted from Xie et al. (2006): Views competition and cooperation as two independent personality trait dimensions, constructing a quadrant space of four trait types. (c) Two-dimensional dynamic model: Explains how individuals, driven by “social comparison” and “goal alignment” in sequential decision-making, may evolve from an imbalanced “hyper-competition”

state toward “coopetition” (high comparison, high alignment), “cooperation” (low comparison, high alignment), or even “withdrawal” (low comparison, low alignment) to stop losses.

### 实验室中一般采用博弈任务来考察互动情境下的人际或群际行为，这为探究竞争与合

Cognitive mechanisms of cooperation provide a powerful tool for understanding human interaction (van Dijk & De Dreu, 2021). These types of tasks primarily possess three characteristics: 1) each individual must make one or more decisions that affect the interests of themselves and others; 2) the outcomes of these decisions are presented numerically; and 3) these numbers are pre-set before the decision is made. Among these, games where players make decisions sequentially, such as the Dictator Game, Ultimatum Game, and Trust Game, are classified as asymmetric games. In contrast, games where players make decisions simultaneously, such as Contest Games, the Prisoner’s Dilemma, and Public Goods Games, are classified as symmetric games. Because asymmetric games reflect specific prosocial preferences of individuals, symmetric games are more commonly used to study interpersonal cooperation or competitive behavior.

Regarding competition, researchers currently generally employ contest games such as all-pay auctions or lottery games (Dechenaux et al., 2015; Kasumovic et al., 2017). In a contest game, participants must first place a bid; the highest bidder wins the reward either directly or with a higher probability. This process inevitably involves social comparison (Delgado et al., 2008). Research has found that participants generally engage in overbidding, investing beyond the rational Nash equilibrium (Savikhin & Sheremeta, 2013); nearly half of participants even bid for items with a value of zero (Sheremeta & Zhang, 2010). Although overbidding increases the chance of winning an auction, it also leads to monetary loss. Furthermore, evidence suggests that reinforcement learning models can effectively fit individuals’ investment behaviors and their changes in competitive games (Martinez-Saito et al., 2019; van den Bos et al., 2013). Additionally, individuals show a willingness to avoid wasteful competition in contest games: when communication is permitted, participants usually participate in the contest at a cost close to zero (Cason et al., 2012); when random methods such as coin flips can be used to determine distribution, participants also prefer to avoid competition (Kimbrough et al., 2014). In recent years, emerging paradigms represented by patent races have provided a new platform for studying strategic competitive behavior (Hunter et al., 2021; Zhu et al., 2012, 2019). Specifically, in a patent race, a “strong” player with more resources competes against a “weak” player with fewer resources. They are randomly matched at the start of each round and compete for a prize by choosing investments in integer units from their respective endowments; these investment amounts are non-refundable. The player who invests more wins the prize; in the event of a tie, neither party receives the prize.

In terms of cooperation, early research mostly adopted paradigms such as the

Prisoner's Dilemma, the Hawk-Dove game, and the Snowdrift game (Huang et al., 2019; Kollock, 1998; Rilling et al., 2002; van Lange et al., 2013; Wang et al., 2016). In recent years, researchers have primarily used the Public Goods Game and the Common Pool Resource Game to simulate multi-person cooperation (van Dijk & De Dreu, 2021). Specifically, participants contribute or extract an amount  $c$  to/from a public good; the total or remaining amount of the public good is multiplied by a coefficient  $r$  ( $1 < r < N$ ) and then distributed equally among all participants. Ideally, when all participants invest or refrain from extraction, they can maximize collective interests. However, individuals are easily tempted by free-riding or over-extraction, which harms collective interests and ultimately leads the system into the "tragedy of the commons" (Shi et al., 2020). Recently, by analyzing 237 public datasets, researchers found that individual investments and changes in Public Goods Games are not driven by altruistic motives but rather stem from payoff-based learning. This suggests that dynamic decision-making in cooperative games may also be influenced by social comparison (Burton-Chellew & West, 2021). Furthermore, Li et al. (2022) pointed out that oxytocin can maintain cooperation in social networks by promoting the punishment of non-cooperative behavior. Other researchers have found through computational models that individuals can adopt a "friendly competition" strategy—cooperating as much as possible as long as others are not allowed to achieve greater gains—which can effectively maintain cooperation (Murase & Baek, 2021).

Recently, some researchers have proposed using the spatial dilemma paradigm to explore the dynamic changes in interpersonal competition and cooperation (Pisauro et al., 2022).

In this paradigm, participants are matched in pairs to forage in a linear space, where the location of the target "food" is randomly drawn from a uniform distribution. In each trial, participants need to pre-set their positions to wait for the target; the person closer to the target wins and receives a reward, and the smaller the distance, the higher the reward. However, this paradigm still manipulates the social environment by controlling reward distribution to distinguish between competition and cooperation. In the cooperative scenario, both parties split the reward equally; in the neutral scenario, the winner receives the reward; and in the competitive scenario, the winner receives twice the reward while an amount corresponding to the loser's reward is deducted.

In summary, previous classic paradigms have mainly relied on symmetric laboratory games and adopted "all-or-nothing" principles (e.g., all-pay auctions, patent races) or equal distribution principles (e.g., Public Goods Games) to investigate interpersonal competitive or cooperative behavior. In a patent race, the individual with the highest investment obtains all the resources, while the individual with the lower investment obtains nothing, simulating scenarios such as R&D innovation and bidding. In the Public Goods Game, members of a group can choose whether to contribute their own property to increase public resources, simulating scenarios such as the construction of social public welfare.

However, these do not align with the “joint-stock” or “distribution according to work” principles most common in modern society. To this end, we propose the “share game” paradigm. In this paradigm, total resources are distributed according to the proportion of investments made by both parties: the more one invests, the higher the share of resources one receives, thereby better simulating resource allocation in real-world contexts. This paradigm is applicable to real-life scenarios where total resources are fixed and distributed according to effort, such as scholarship allocation and performance-based pay assessments, helping to understand phenomena like hyper-competition ( “involution” ) and cooperation in these settings. Compared with traditional paradigms, the distribution mechanism of the share game is more flexible, breaking the limitations of “all-or-nothing” or “absolute equality.” This allows “increasing investment to expand share” and “decreasing investment to reduce dissipation” to coexist, forcing individuals to make dynamic trade-offs between competition and cooperation. This makes it more sensitive than traditional paradigms in capturing the dynamic process from hyper-competition to win-win cooperation.

In the share game paradigm, two players allocate total resources through investment. Resources are distributed in proportion to the investments, and the invested amounts are not returned. In the payoff matrix of the share game, individuals have a competitive motivation to increase investment to allocate more resources on one hand, and an internal constraint to suppress excessive competition with the other party to reduce resource dissipation on the other. Therefore, individuals must dynamically weigh competition against the avoidance of hyper-competition. The specific experimental procedure is shown in [Figure 2: see original paper]. At the beginning of each stage, a random letter is used to prompt the interacting player for that stage. At the start of each round, the total resource amount for the round is presented, followed by investment options displayed on a horizontal axis. Participants need to select an investment amount by clicking within 10 seconds; the decision time of the interacting player fluctuates randomly between 2 and 10 seconds. After both parties have submitted their investment amounts, the feedback page presents the number of investment tokens, allocated tokens, and the final payoff (i.e., the sum of uninvested tokens and allocated tokens) for both parties.

Note: In the share game, both parties decide on an investment amount, and the invested tokens are consumed. The total market profit is distributed according to the proportion of investments made by both parties. [Figure 2: see original paper] Flowchart of the Share Game Paradigm.

In the share game, each player receives a fixed initial endowment  $E_i$  at the start of each round as capital for investment. Assuming a share game with  $n$  players (in this study,  $n$  is always 2, i.e., a two-player share game), each player  $i$  independently decides their investment amount  $I_i$ , where  $I_i \leq E_i$  always holds. The total payoff  $T_i$  for a player consists of two parts: one part is the total resource  $C$  allocated according to the proportion of their investment  $I_i$  relative to the total investment of all players, and the other part comes from the remaining

uninvested endowment  $E_i - I_i$ . Thus, the payoff is  $C \cdot \frac{I_i}{\sum I_j} + E_i - I_i$ . The Nash equilibrium for the mixed strategy is  $NE = \frac{C(n-1)}{n^2}$ . Since the ratio between the total resources and the sum of initial endowments determines the break-even point for the players' investment strategies, we introduce a resource factor  $R$  to operationally define the independent variable.  $R$  describes the linear relationship between the total resources  $C$  and the sum of initial endowments  $\sum E_i$ , namely  $R = \frac{C}{\sum E_i}$ . Specifically, when  $R \geq 1$ , the sum of players' investments is always less than or equal to the total resource amount; therefore, it can be ensured that each player's total payoff is at least no lower than their initial endowment. Since the Nash equilibrium point is at a high level or even exceeds the strategy median at this time, players do not need to make difficult trade-offs between pursuing shares and avoiding dissipation. When  $R < 1$ , the total resources are limited and insufficient to cover the initial costs of all players, forcing individuals to find a dynamic balance between "increasing investment to expand share" and "decreasing investment to reduce dissipation."

At the start of each round of the game, the subject and the opponent both receive an initial endowment  $E$  and allocate the total resource  $C$  through investment. The Nash equilibrium for the share game task is  $NE = \frac{C}{4}$ . This study sets the experimental context under the constraint of limited resources ( $R < 1$ ), which mathematically ensures that the Nash equilibrium point is always lower than the strategy space median  $M = \frac{E}{2}$ . An individual's behavioral state is jointly determined by the relative position of their investment to the Nash equilibrium and the strategy median. Specifically, an investment higher than the strategy space median is defined as a competitive state. An investment higher than the Nash equilibrium but lower than the strategy space median is defined as a co-competitive state; this represents an investment above the rational equilibrium point but below medium intensity, reflecting a dynamic trade-off between pursuing shares and avoiding dissipation. An investment lower than the Nash equilibrium is defined as a cooperative state. For example, if the initial endowment is 15 and the total resource is 20, the strategy space median is 8 and the Nash equilibrium is 5. In this case, an investment in the range  $[8, 15]$  represents a competitive state; an investment in the range  $[5, 8)$  represents a co-competitive state; and an investment in the range  $[1, 5)$  represents a cooperative state. Furthermore, full investment represents hyper-competition (involution), an extreme manifestation of an individual seeking absolute advantage at the cost of resource dissipation. Zero investment is defined as withdrawal ("lying flat"). Since the individual contributes no investment, their resource share is 0, the total resource  $C$  belongs entirely to the opponent, and the subject retains the endowment  $E$ , reflecting a defensive migration taken by the individual to avoid harm and stop losses.

In the share game, social comparison based on payoff feedback drives individuals to increase investment in pursuit of a relative advantage. Social comparison is measured by the payoff difference between the subject and the opponent: if the subject's payoff is higher than the opponent's, it is downward social compar-

ison; if the subject's payoff is lower than the opponent's, it is upward social comparison. For example, if the subject's total payoff is 25 and the opponent's is 28, it is an upward social comparison; if the subject's total payoff is 30 and the opponent's is 25, it is a downward social comparison. Through this setup, we can explore how social comparison affects the co-opetitive process. As shown in the schematic [Figure 3: see original paper], individuals may maintain their strategy when facing downward social comparison but tend to increase investment when facing upward social comparison. After the investment feedback in each round, participants are required to provide real-time subjective ratings of the valence and arousal of their current emotions. By capturing the differences in subjective perception under different social comparison outcomes (such as winning or losing), objective payoff values are transformed into quantifiable emotional experience indicators, decoding the intensity and tendency of individual emotional responses in social comparison contexts. Goal alignment drives individuals to reduce resource dissipation by decreasing investment. In terms of indicators, if the average investment of both parties is lower than the strategy median, it is judged as goal alignment; otherwise, it is non-alignment. Furthermore, the dynamic changes in decision sequences help to decouple the two types of heterogeneous motivations behind this behavior: low investment may reflect consideration for collective interests or may stem from a cautious assessment of resource scarcity. Among these, "consensual regulation" usually manifests as reciprocal state feedback—that is, after observing an opponent reduce investment, an individual produces positive behavioral convergence with a relatively short decision time, reflecting efficient cognitive alignment. In contrast, "individual avoidant restraint" is more influenced by resource sensitivity—that is, the individual's investment level decreases as the resource factor  $R$  shrinks. This migration is often accompanied by longer decision times, reflecting psychological conflict caused by the trade-off between gains and losses. Through the analysis of these dynamic sequences, this model can more accurately characterize the motivations of "consensual regulation" and "individual avoidant restraint." In summary, this paradigm defines different co-opetitive states through investment levels:

The competitive state reflects an individual's tendency to pursue absolute advantage driven by social comparison; the cooperative state reflects an individual's tendency to avoid dissipation driven by goal alignment; and the co-opetitive state reflects the dynamic trade-off an individual makes between "pursuing share" and "avoiding dissipation." Using the share game paradigm, we can examine how environmental factors (e.g., total resource amount, availability of resource information), social factors (e.g., reputation, ingroup/outgroup), and individual factors (e.g., social comparison orientation, trait anxiety) affect the overall co-opetitive tendency in "distribution according to work" scenarios, and whether they modulate the impact of factors such as social comparison on the transition between co-opetitive states.

[Figure 3: see original paper] Schematic diagram of the influence of social comparison on co-opetition.

#### 4 人际竞争与合作的神经基础

The integration of behavioral economics paradigms with neuroimaging methods has significantly advanced research into the neural mechanisms underlying interpersonal competition and cooperation. Regarding electrophysiological components, the Feedback-Related Negativity (FRN) and the P300 are the primary focus in this field. The P300 is sensitive to positive outcomes, with positive feedback eliciting a more positive P300 than negative feedback; furthermore, its amplitude increases as the disparity in social comparison between an individual and others grows [?]. Conversely, the FRN is sensitive to negative outcomes, with negative feedback eliciting a more negative FRN than positive feedback [?]. In social interaction contexts, the FRN amplitude depends on the degree of attention the participant pays to the errors committed [?]. Previous work has found that observing a competitor's outcome induces a smaller P300 compared to observing a partner's outcome, and observing a competitor lose also induces a smaller FRN [?]. Cross-gender studies further indicate that males exhibit a larger FRN than females when observing others lose in competitive contexts [?]. These results suggest that individuals pay less attention to the outcomes of competitors, while males are more attentive to a competitor's failure than females. Notably, recent research has also found that both the competitive behavior of partners and the cooperative behavior of competitors induce a larger P300 [?], suggesting that the P300 may also reflect social interaction expectations.

In neuroimaging, functional Magnetic Resonance Imaging (fMRI) has revealed brain regions that guide competition [Figure 4: see original paper]. The Ventral Striatum (VS) updates the value of competitive decisions by encoding prediction errors \cite{Martinez-Saito2019, van\_{den}Bos2013}, showing significant negative activation when individuals lose to other players [?]. The Anterior Insula (AI) and the Dorsal Anterior Cingulate Cortex (dACC) are responsible for processing negative outcomes \cite{van\_{den}Bos2013} and are significantly activated during upward social comparison [?]. As a core region for Theory of Mind, the Temporoparietal Junction (TPJ) is also involved in competitive interactions [?], showing stronger activation during competitive victories \cite{Martinez-Saito2019, van\_{den}Bos2013}. Transcranial Direct Current Stimulation (tDCS) studies have further found that inhibiting TPJ activity significantly increases overbidding behavior, revealing a causal link between the TPJ and competitive behavior [?]. Computational neuroscience research has further refined the link between psychological processes and neural activity: the VS processes social reward prediction errors—composed of social comparison information and actual payoff information [?—driving individuals to compete excessively to avoid social comparison failure [?].

The Medial Prefrontal Cortex (mPFC) is responsible for comparing the expected utility of competition and cooperation to guide decision-making [?].

[Figure 4: see original paper] Shared Brain Networks for Competition and Cooperation. Note: This figure integrates key brain regions associated with interper-

sonal competitive and cooperative behaviors. Red ovals represent brain regions primarily associated with competition; blue ovals represent regions primarily associated with cooperation; purple ovals represent regions jointly involved in both. AI, anterior insula; Amy, amygdala; dACC, dorsal anterior cingulate cortex; dlPFC, dorsolateral prefrontal cortex; dmPFC, dorsomedial prefrontal cortex; TPJ, temporoparietal junction; VS, ventral striatum; vlPFC, ventrolateral prefrontal cortex; vmPFC, ventromedial prefrontal cortex.

On the other hand, research on cooperation has revealed similar patterns of brain activation. In public goods games, the degree of damage to an individual's Ventromedial Prefrontal Cortex (vmPFC) is positively correlated with their contribution, while the degree of damage to the Dorsolateral Prefrontal Cortex (dlPFC) and the Amygdala (Amy) is inversely correlated with contribution [?]. The vmPFC encodes individual interests, while the Lateral Frontopolar Cortex (lPFC) encodes collective interests; shifts in cooperative strategies are associated with the dACC and the Ventrolateral Prefrontal Cortex (vlPFC) [?]. Furthermore, an individual's expectations regarding cooperation are linked to the activation of the right TPJ [?].

In common-pool resource games, fMRI combined with computational modeling indicates that the VS is negatively activated when protecting common resources and positively activated when protecting private resources. Social comparison modulates an individual's value representation, subsequently leading to the over-exploitation of public resources [?]. Recently, Pisauro et al. [?] employed a "space dilemma" paradigm to explore competitive-cooperative decision-making across competitive, neutral, and cooperative contexts. They found that inferences about others' intentions modulate cooperation, and computational modeling results revealed that the TPJ, Dorsomedial Prefrontal Cortex (dmPFC), and Anterior Cingulate Cortex (ACC) encode social expectation error signals.

Overall, interpersonal competition and cooperation have received increasing attention in recent years. These studies have widely adopted traditional behavioral economic game paradigms and are increasingly applying brain imaging and computational modeling techniques to the field, enhancing our understanding of human social cognitive mechanisms. However, four main limitations remain, which future research should address:

First, existing research often treats competition and cooperation as opposing ends of a spectrum, lacking a unified theoretical framework. The dynamic evolution model of interpersonal "co-opetition" proposed in this paper addresses this theoretical gap. Its primary contributions are as follows: First, the model integrates and extends classical trait theories, enhancing the explanatory power for dynamic behavior. Traditional Social Value Orientation (SVO) theory, based on the weight distribution of self and other payoffs, views competition and cooperation as two ends of a single continuum. The two-dimensional static model introduced here posits that competitive and cooperative tendencies are two independent psychological dimensions. This orthogonal structure allows individuals to possess high competitive and high cooperative traits simultaneously, pro-

viding an explanatory framework for the complex behavior of “co-opetition” at the trait level. By constructing independent “competition” and “cooperation” dimensions, the two-dimensional dynamic model establishes “co-opetition” as a key behavioral state. Simultaneously, it introduces “social comparison” and “goal alignment” as core driving variables, explaining how traits interact with contexts to drive the dynamic migration of behavior toward states such as “co-opetition,” “cooperation,” or “avoidance,” thereby serving as an important supplement to SVO theory. Second, this model innovatively proposes a testable driving framework: sequential decision-making in a given context is driven bidirectionally by “social comparison” and “goal alignment.” Future research can utilize this framework to further examine the relationship between trait levels (e.g., social comparison orientation) and interpersonal co-opetition tendencies. Additionally, given the potential motivational heterogeneity in goal alignment, future studies could introduce scales for social value orientation, social trust, and risk preference as trait-based supplements to validate instantaneous decision states.

Notably, this framework also resonates with fundamental perspectives in evolutionary psychology and evolutionary game theory regarding the coexistence of competition and cooperation. Evolutionary research has long pointed out that competition and cooperation are not simply opposing strategies but adaptive behaviors that individuals dynamically adjust based on relative payoffs and social comparison cues in resource-constrained, interdependent social environments [?, ?]. The social comparison mechanism emphasized in this paper is functionally consistent with core hypotheses in evolutionary psychology regarding relative status, resource threats, and alliance value assessment [?]. However, unlike evolutionary game theory, which primarily focuses on strategy distribution and long-term stability at the group level, the model in this paper further deconstructs competition and cooperation into individual-level psychological dimensions. It reveals the immediate psychological driving mechanisms behind strategy transformation, thereby providing a complementary explanatory path at the micro-level for the classic question of “how competition and cooperation coexist.”

Second, the investment and distribution methods in traditional competition paradigms (e.g., lottery games, all-pay auctions) and cooperation paradigms (e.g., public goods games, common-pool resource games) differ significantly from those in modern society. They lack ecological validity and fail to comprehensively reflect the dynamic trade-offs in interpersonal co-opetition dilemmas. Future research needs to develop new behavioral economic paradigms to examine the role of social comparison in the dynamic trade-off of interpersonal co-opetition under the influence of various factors (individual, situational, social). This will facilitate the construction of co-opetition computational models that integrate multiple parameters, such as individual investment and return, opponent investment and return, and social comparison.

Third, most previous studies have examined the neural mechanisms of competi-

tion or cooperation in isolation. However, these studies are limited by existing paradigms and lack a unified tool capable of exploring the dynamic trade-off between the two. Furthermore, the interpretation of the underlying computational neural mechanisms remains controversial.

Although evolutionary game theory has developed a series of modeling traditions to describe competition-cooperation dynamics—such as replicator dynamics, payoff-driven learning models, and network evolution models [?, ?]—these models mostly remain at the strategy or group level, making it difficult to map them directly to specific neural and psychological processes. The “Share Game” paradigm proposed in this paper provides a feasible research approach. This paradigm effectively captures the dynamic trade-off process between “social comparison” and “goal alignment.” Researchers can observe the dynamic evolution of co-opetition states in real-time by tracking the shifts in investment amounts across different quadrants. Future research could combine brain imaging with computational modeling, integrating classical reinforcement learning models with social game decision processes and related parameters—such as social comparison (upward/downward) and counterfactual thinking. By linking strategy dynamics in evolutionary games with individual-level neural computation processes, researchers can systematically reveal the neural dynamic characteristics and computational mechanisms of co-opetition decision-making, providing integrated, cross-level evidence for understanding interpersonal co-opetition behavior.

Finally, due to the lack of a unified theoretical framework for understanding and explaining interpersonal competition and cooperation, previous research has yet to propose effective intervention schemes or practical methods. Future research should build on the mechanism of social comparison’s influence on co-opetition behavior to develop and validate interventions for excessive competition. On one hand, behavioral interventions could be applied to individuals with weak competitive tendencies to promote cooperation by altering their environmental perception. On the other hand, for individuals with strong trait-based competitiveness, researchers could explore the use of neuromodulation techniques (such as inhibiting competition-related brain regions or activating cooperation-related regions) to enhance their cooperative tendencies.

(Citations omitted for brevity as per instructions)

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empirical support for the Two-Dimensional Dynamic Model and offering theoretical support and methodological guidance for future research.

Keywords: social cognition, cooperation, competition, social comparison 27 / 27

*Note: Figure translations are in progress. See original paper for figures.*

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