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Does similarity trigger cooperation? Dyadic effect of similarity in social value orientation and cognitive resources on cooperation

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Abstract

Although a considerable amount of research has demonstrated a robust relationship between social value orientation and cooperation, these studies may be limited by focusing solely on the individual. Building on the growing literature documenting the effect of group formation on cooperation and personality similarity on negotiation, the present study explored whether similarity in social value orientation (both being pro-social or pro-self) leads to more cooperation in social dilemmas among dyad members. Drawing from expectancy theory and the concept of cognitive resources, we further predicted that the relationship between similarity in social value orientation and cooperation uniquely depends on whether the individual is cognitively busy. To test our hypothesis, we grouped our participants according to their social value orientation into three different dyads (similar-pro-self, similar-pro-social, and pro-self-pro-social) to complete a repeated prisoner's dilemma task, and controlled their cognitive resources using a simultaneous digit memory task. The results suggested that (1) heterogeneous dyads' (pro-self-pro-social) cooperation possibility experience a steeper decay as the number of rounds increases compared with the two homogeneous dyads (similar-pro-self, similar-pro-social). In addition, (2) similarity in social value orientation, interacting with participants' cognitive resources, significantly influenced individual-level cooperation. Specifically, both pro-selfs and pro-socials, paired with unlike-minded counterparts, were more cooperative when they had abundant cognitive resources. However, cognitive resources had no significant influence on dyads with similar social value orientation. Overall, these findings demonstrate the importance of considering personality configuration when attempting to understand cooperation in social dilemmas among dyads.

Keywords Cooperation · Social value orientation · Cognitive resources · Social dilemma · Expectancy theory

Introduction

Cooperation within groups is crucial for sustaining and stabilizing human society (Fehr & Fischbacher, 2003; Titlestad et al., 2019). The breakdown of cooperative behavior threatens the long-term development of social and economic stability. Therefore, cooperation has received extensive attention, in both theoretical and empirical work (De Oliveira et al., 2015; Declerck et al., 2013; Jagau & van Veelen, 2017).

There are various drivers for cooperation. Researchers have consistently demonstrated that an individual's social value orientation (SVO) is a strong predictor of cooperation in social dilemmas (Moon et al., 2018; Thomas & Thornock, 2021). However, studies on the influence of SVO on cooperation may be limited by their focus on one individual. Because cooperation is inherently an interpersonal activity, considering only one member of a dyad when

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studying cooperative behavior is theoretically deficient (Wilson et al., 2016). This is especially true in an iterated social dilemma, in which feedback is provided and evaluated by both members. A growing number of studies highlight that an individual's level of cooperation in a repeated social dilemma shows a significant difference when he or she is matched with a like-minded counterpart as opposed to an unlike-minded counterpart (Burlando & Guala, 2005; Guido et al., 2019). However, these studies share a common shortcoming in that they categorized participants and formed the dyads according to the behavioral patterns of their participants instead of their inherent traits, and studies focusing on the match of inherent traits have been limited to gender matching (Colman et al., 2018; Davis et al., 2016). Rather, similarities in personality, specifically agreeableness and extraversion, have been tested in the prediction of positive outcomes of negotiation, which has also been studied in social dilemma paradigms (Wilson et al., 2016). In line with this, the current study examined whether similarity in SVO could predict cooperation in social dilemmas, which would provide insights into whether (i) at the individual level, a participant's personality (SVO) helps predict his or her cooperative behavior in a repeated social dilemma task, and (ii) at the dyad level, whether the match of personality could predict the extent to which cooperation would emerge if these participants are matched to perform a repeated social dilemma task.

Moreover, although "Does SVO similarity work?" is an important question to address, an equally important question is "Why does SVO similarity work?" Scholars often use expectancy theory to explain the effects of individual-level SVO on cooperation. More specifically, pro-socials are inclined to assume that others cooperate, while pro-selfs tend to believe the opposite, which induces behavioral heterogeneity between them (Pletzer et al., 2018). Moreover, because expectation-forming requires cognitive effort (Axelrod & Hamilton, 1981; Capraro, 2013; Evans & Van De Calseyde, 2017), cognitive resources (CR) and SVO would jointly influence cooperation. In line with this, the current study argues that CR may also function in SVO similarity in cooperation. More specifically, because pro-socials have the initial assumption that others will cooperate and are more flexible in adjusting this assumption, they need less CR to detect cooperative signals and to achieve cooperation even when they encounter uncooperative partners (Declerck & Bogaert, 2008). In contrast, pro-selfs hold non-cooperative assumptions and are less likely to change their original opinions (Gunnthorsdottir et al., 2007; Qi et al., 2018); therefore, they are more likely to adhere to their strategy of not cooperating, even when facing a cooperative counterpart.

In sum, we proposed that an individual's choice of whether or not to cooperate is affected by whether he or she encounters a similar-SVO or different-SVO partner. Moreover, there is an interaction effect of SVO similarity and CR on cooperation.

Theoretical Background and Hypotheses

SVO and Cooperation

SVO is a personal trait that refers to an individual's preference for distributing income between oneself and others (Van Lange et al., 1997). Specifically, it can be divided into four types: (1) cooperative orientation: individuals who tend to cooperate with others and maximize their overall income; (2) individualistic orientation: individuals who tend to maximize their income while ignoring that of others; (3) competitive orientation: individuals who care about their relative benefits and try to maximize it; and (4) altruistic orientation: individuals who tend to sacrifice their benefit for others (Liebrand & McClintock, 1988). In general, individualistic and competitive orientations are classified as pro-self orientation, while pro-social orientation refers to cooperative and altruistic orientations.

In a one-shot social dilemma, individuals predict their opponents' behavior and make decisions based on their values because there is no feedback provided and no their opponents' information is referenced. Previous studies have found that pro-socials exhibit more cooperative behavior than pro-selfs (Kanagaretnam et al., 2009; Van den Bos et al., 2009). Scholars have used expectancy theory to explain the influence of SVO. The theory proposes that specific expectations somehow determine individual behavior, such as cooperation (Pruitt & Kimmel, 1977). In a social dilemma, pro-socials are inclined to consider the positive results of social exchange, while pro-selfs focus more on their relative benefits and thus, become more competitive. This goal difference triggers heterogeneity in cooperation (Bogaert et al., 2008). The role of SVO in social dilemmas has also been demonstrated in repeated social dilemmas. Hong and Sheng (2013) conducted a 15-rounds repeated public goods game in which participants were divided into four groups. The results of that study indicated a consistent and significant main effect of SVO on cooperation at different task stages. In addition, in a dynamic network, pro-socials maintain their ties longer because they cooperate more often. This greater durability of relations in turn leads to increased earnings (Melamed et al., 2017). However, meta-analysis studies demonstrated only a small positive relationship between SVO and cooperation (Balliet et al., 2009; Pletzer et al., 2018). Given that cooperation is an interpersonal activity that involves multiple parties, dyads with different SVO compositions may lead to different outcomes, and considering only individual-level in such a context could show deficits.

SVO Similarity and Cooperation

Similarity has been recognized as a contributing factor of cooperation in various situations. In an organizational context, perceived leader-employee similarities lead to more cooperation and organizational citizenship behaviors among employees (Coyle & Foti, 2015). At a broader group level, similarity promotes group cohesion (Turner et al., 1992), and information about the similarities between ingroups and outgroups results in more positive attitudes toward the outgroups (Hanel et al., 2019). Similarly, the success of a sorting method in matching like-minded individuals has proven to be interlinked with cooperation (Guido et al., 2019). Burlando and Guala (2005) categorized participants according to their investment in social dilemmas as cooperators, reciprocators, free riders, and noisy, and grouped same-categorized participants to complete repeated public goods tasks. The results indicate that the overall cooperation level improves after grouping and that the number of free-riders decreases rapidly as the number of rounds increases. Similar studies have also been conducted in heterogeneous groups. For example, De Oliveira et al. (2015) divided the subjects into selfish (S) and conditional cooperators (C) and developed three-person groups, including C, C, C; C, C, S; C, S, S; and S, S, S. The cooperation level of the C, C, S groups was slightly lower than that of the C, C, C group, but the difference was not significant. However, the difference between the C, C, C and C, S, S groups was pronounced, and the cooperation level of the S, S, S group was significantly lower than that of the other groups. In other words, a match of cooperative individuals can maintain both group-level and individual-level cooperation at a high level (Guido et al., 2019). However, classifications in these studies are based on participants' behavioral patterns rather than inherent traits and values, which raises the question of whether the coherence of inherent qualities, including SVO similarity, can affect cooperation.

Instead, personality coherence has been shown to influence other forms of interpersonal relationships. Moreover, research concerning negotiation, which is also mainly studied in social dilemmas like cooperation (Steinel & Harinck, 2020), has also tested the effect of similarity. For example, evidence from a twin study proved that the interaction of two negotiators' characteristics could explain more variation in negotiation outcomes than individual-level differences (Elfenbein et al., 2018); negotiating dyads with similar levels of agreeableness promotes more positive emotional displays, less time to reach a consensus, and positive perceptions of one's partner (Wilson et al., 2016). Because the high agreeableness in that study, indicating trust, sympathy, and cooperativeness, is similar to the pro-social dimension in SVO, the coherence of SVO may be a possible determinant of cooperation. However, the results of Wilson et al. (2016) hold regardless of whether negotiating dyads are similar in agreeableness or disagreeableness. This differs from the findings of the aforementioned sorting method studies, which suggest that only the matching of cooperative individuals can promote cooperation. These controversies may result from different independent and dependent variables. Specifically, cooperation in social dilemmas differs from a general negotiation situation and inherent personalities are not necessarily related to overt behaviors. To clarify these controversial results, we tested the influence of SVO coherent in the context of prisoner's dilemma. Based on the findings of Zhang et al. (2019), which suggest that four-pro-social-member groups are more cooperative than four-pro-self groups in the 15-rounds public-goods dilemma, we proposed the first hypothesis:

> Hypothesis 1: Dyadic SVO composition significantly influences dyad-level cooperation. Specifically, similar-pro-social dyads are most likely to achieve mutual cooperation, less so in different-SVO dyads, and least so in similar-pro-self dyads.

Cognitive Resources, SVO Similarity, and Individual-Level Cooperation

The concept of CR is closely related to the dual-process model, which divides mental processes into intuitive and deliberate systems (De Neys, 2021; Weber & Johnson, 2009). Intuitive systems process faster and occupy less CR, while deliberate systems have a slower processing speed and cost more CR (Gilovich et al., 2002; Kahneman & Frederick, 2002). Many researchers claim that cooperation may be rooted in human nature since it appears at a very young age (Warneken & Tomasello, 2006), and therefore individuals would intuitively cooperate. Other researchers view cooperation as a calculated decision, as it is often optimal from a long-run strategic perspective (Santos et al., 2017). The mixed results in the literature make the relationship between cooperation and cognitive resources more controversial. As exploration deepens, researchers have found that there may be no general intuitive cooperation in humans. Instead, the inference of what is more or less intuitive may be based on subjects' personal preferences. Pro-socials intuitively tend to cooperate with others, while pro-selfs must think carefully before making suitable choices (Bogaert et al., 2008). Therefore, the cognitive mechanisms behind the cooperative decisions of pro-socials and pro-selfs are different, and individual-level SVO and CR could jointly influence cooperation. This has been demonstrated in several empirical studies that exert time pressure to manipulate participants' mental states (Alós-Ferrer & Garagnani, 2020; Andrighetto et al., 2020).

Researchers have employed expectancy theory to explain this interactive effect of individual-level SVO and CR, suggesting that pro-socials are inclined to assume that others cooperate, while pro-selfs believe the opposite, which induces behavioral heterogeneity between the two types (Pletzer et al., 2018). This SVO-induced expectation is identical to that of stereotypes. Studies on interpersonal relationships suggest that individuals are more likely to analyze current attribute information rather than rely on predigested category-based information when they invest more cognitive effort in the impression formation process, increasing the likelihood of individuation over stereotyping. Conversely, a lack of cognitive effort increases reliance on available cues for categorization and produces stereotyping (Brown & Gaertner, 2002, p.12). Furthermore, another consequence of SVO that should be considered is how perceivers analyze current information. Pro-socials, who have better empathic ability to detect opponents' characteristics, can quickly adjust their original expectations when opposite (non-cooperative) signals appear, losing less CRs compared with pro-selfs who hold non-cooperative assumptions and are stubborn with their original opinions (Gunnthorsdottir et al., 2007; Qi et al., 2018). This is closely related to the "categorical blinders" effect proposed by Wilder (1986), which proposes that individuals' perceptions of new information produce confirmation of pre-existing category-based expectations rather than disconfirmation. Hence, to achieve ultimate cooperation, pro-selfs need more CR to adjust their original expectations than pro-socials (Declerck & Bogaert, 2008), consistent with the study result from Kuss et al. (2015) which found that pro-selfs displayed the longest decision times in the non-costly situation in which the participant's payoff was constant in the two alternatives, and only the receiver's outcome could be varied (e.g., \$6 for themselves and choose to give \$4 or \$10 for the receiver), and participants' neural activity during the game indicated that pro-selfs require more explicit and deliberative processing to make pro-social decisions. Therefore, an individual's CR, interacting with SVO, determines the expectation formation process, which has also been supported in studies concerning cooperative behaviors (Axelrod & Hamilton, 1981; Capraro, 2013; Evans & Van De Calseyde, 2017; Lin et al., 2016). In line with this, we propose that the mechanism of SVO similarity on individual-level cooperation also depends on participants' CR. Specifically, decision makers develop their original preferences depending on their individual-level SVO in a social dilemma. However, as the number of game rounds increases, they gradually learn their opponents' characteristics from the feedback of past rounds, and accordingly form expectations that impact their decision of whether to cooperate (Brown & Gaertner, 2002; Fischbacher & Gächter, 2010). It should be noted that, CR only functions when individuals confront opponents with different SVO. Processing expectation-incongruent information and adjust original expectation may trigger more effortful elaborative encoding than processing expectation-congruent information, which depends on the mobilization of additional CR. This was supported by Zürn and Topolinski' (2017) research, which demonstrated that the increased ease or fluency with which people can interpret others' behaviour may leads to greater trust in economic games, especially when the situation is complicated and others' behavior pattern is contrary to decision makers' intuitions. Thus, we propose the following hypothesis:

> Hypothesis 2: Dyadic SVO composition and CR significantly influence individual-level cooperation. Specifically, in a 12-round prisoner's dilemma task, the interaction between dyad composition and CR significantly predicts an individual's cooperation in 12 rounds. CR functions only when the individual's opponent has a different SVO.

Methods

Data collection included an online questionnaire and an offline experiment. The online questionnaire was used to collect respondents' demographic information and measure their SVO to recruit potential participants for the offline experiment. Two participants were matched according to their SVO and asked to participate in the offline experiment simultaneously. In the offline experiment, two dyad members completed a 12-round repeated prisoner's dilemma and had to remember the digits while playing. Overall, a 3 (heterogeneous dyad vs. similar-pro-self dyad vs. similar-pro-social dyad) × 2 (high CR vs. low CR) between-subjects design was used. Generalized linear mixed models (GLMM) were employed to analyze the data.

Participants

The latest review of GLMM report quality in the psychology field suggested that most previous studies were based on a sample size of approximately 100 (Bono et al., 2021). In addition, following De Oliveira et al. (2015), whose experiment design was similar to that of the present study, the sample size of the present study should be approximately 100.

Two hundred forty-eight online questionnaires were collected, of which 142 respondents agreed to participate in the offline experiment and left their contact information (phone numbers, WeChat number, e-mail), by which we contacted them one by one. Simultaneously, all 142 respondents' SVOs were calculated. Because of the lockdown of the university campus during COVID-19, only students and people who had access to the in-campus laboratory were invited to

participate in the offline experience. Finally, a total of 116 college students from a university in Beijing, China participated in the offline experiment. The sample was 66.27% women and the average age was 21 years.

Online Questionnaire and SVO Measurement

The participants were recruited through an online questionnaire called the 'Decision-making Research Questionnaire, which contains basic demographic information and an SVO slider measuring respondents' SVO. At the end of the questionnaire, respondents were asked if they were willing to participate in the follow-up offline experiment in which they would be paid 15–30 RMB for participation. Those who agreed to participate voluntarily provided their contact information (the questionnaire available in Online Resource 1). The questionnaire was released at bulletin board systems (BBS) of several universities in Beijing, China.

Participants' SVOs were measured using an SVO slider. It consists of six items, each containing nine money allocation schemes. The subjects chose their preferred allocation over a well-defined continuum of joint payoffs for each item. The mean allocation for self and that for others were computed, and then 50 was subtracted from each mean. Finally, the inverse tangent of the ratio between the subtracted means was computed as a person's SVO (Murphy et al., 2011). Following previous studies, we classified subjects with SVO greater than 22.45° as pro-social and subjects with SVO less than 22.45° as pro-self (Liu & Hao, 2011; Hong & Sheng, 2013); Zhang et al., 2020).

Offline Experiment: Repeated Social Dilemma and Digit Memory Tasks

Based on SVO data obtained from the questionnaire, pro-social (C) and pro-self (S) participants were placed in three types of dyads: pro-social-pro-social (CC), pro-social-pro-self (SC), pro-self-pro-self (SS), with SC as heterogeneous dyads. The two participants in a dyad were informed that they would participate in the offline experiment simultaneously, and they were told that the matching was based on the time order of answering the questionnaire. Each dyad was randomly divided into high-and low-CR groups. The dyad composition and the number of digits remained unchanged throughout the experiment.

The experiment included a repeated prisoner's dilemma (PD) task and a digit memory task, which were completed simultaneously. The PD is a classic task in research on cooperation (Capraro et al., 2014; Rand, 2016). In the PD, the two members of the dyad decide whether to cooperate with their partner. If both cooperate, their total income is maximized. If both parties refuse to cooperate, they receive the lowest income. However, if one party cooperates while the other party betrays the other, the betraying side will win the highest individual income, but the cooperative side will suffer great losses. We developed our income matrix based on that of Embrey et al. (2018); both sides receive 51 RMB if they cooperate and 39 RMB if both sides refuse to cooperate. In heterogeneous situation in which one side cooperates but the other refuses to cooperate, the refuser receives 87 RMB, while the cooperator receives only 5 RMB (see Table 1).

An audio-based digit memory task manipulated the participants' CR. While playing the two-paired prisoner's dilemma task, two participants listened to a record including two or seven randomly generated digits. Dyads in the high CR group memorized two digits, whereas those in the low CR group memorized seven digits (the audios available in Online Resource 2). The experiments were conducted in a sound-insulated laboratory. Two participants sat opposite each other, and there was a baffle between them to prevent eye contact or facial expressions. The two participants first read and signed the informed consent form and were provided with game instructions (the game introduction available in Online Resource 3), a pen, and a paper form on which they recorded whether they cooperated (yes$\surd$ no $\times$) in each game round and the numbers they heard during the experiment. The experimenter explained the rules to the two participants, made sure that both understood the instructions, and then played the first record. At the end of the recording, participants wrote down whether they cooperated, followed by the number they had just heard. After both parties made their decisions and wrote down the digits, the experimenter informed them of the incomes of the current game round. Then, the next recording is performed. This process continued until the 12th round.

To avoid the ending effect, in which cooperation rates decline steeply in the last round (Nowak & Sigmund, 1994), participants were informed that the rounds were random. There were actually a total of 12 rounds. To successfully manipulate the CR and ensure that the participants' CR was still occupied while making the decision whether to cooperate, we emphasized that the written numbers must be the same as those playing. Participants had to obey the following orders strictly: writing down the current number of rounds, listening to the radio, writing down their decision whether to cooperate, and writing down the numbers they heard. The writing was not allowed while the recording was playing, and the decision whether to cooperate had to be made before writing the digits. To ensure that participants were motivated to play the game, every participant was informed before the start of the

Table 1 Income Matrix of the Prisoner's Dilemma Task

	Cooperation	Non-cooperation
Cooperation	51, 51	5, 87
Non- cooperation	87, 5	39, 39

game that they would receive the average income of the 12 rounds/10×4 at the end of the experiment.

Statistical Analysis

To test Hypothesis 1, which demonstrated that the dyadic SVO composition influences dyad-level cooperation results, we treated the cooperation results as dichotomous outcomes: "cooperate" signified that both participants chose to cooperate, and "not cooperate" signified that either or neither of the dyad members chose to cooperate. Because the result of each dilemma is a dichotomous outcome (cooperate or not), and the 12-round choices are interdependent, we used a generalized linear mixed model (GLMM) with a binomial distribution and logit link function to analyze the data. The GLMM analysis was conducted using R4.1.2, with R studio and the lme4 package (Bates et al., 2014). In the analyses, dyad composition (CC: similar-pro-social dyads, CS: different-SVO dyads, SS: similar-pro-self) was first entered into the first GLMM equation. Round and the dyad composition-round interaction were also specified as fixed effects variables as they reveal the dynamic process of dyad composition on cooperation. CR was entered into the equation as a fixed effect variable only to achieve control, and therefore the interaction between dyad composition and CR was not taken into consideration. For random effect, most previous studies using GLMM specified participants and items (experiment material) as random effects to control the bias brought by the same person or the same item. Because the current study used the same item (only one income matrix) for different participants, only dyads were specified as random effect variables accounting for differences among dyads (analysis code available in Online Resource 4).

For Hypothesis 2 concerning the dyadic SVO composition and CR impact on individual-level cooperation, we also used the GLMM with a binomial distribution and logit link function to analyze the data. A random intercept was included in the model for each participant accounting for individual differences among participants. For fixed effects, dyad composition, CR, and the interaction between them were entered into the GLMM; round and the corresponding interactions were also specified as fix effects variables to reveal the dynamic process of dyad composition and CR on cooperation. Model comparison was conducted to provide a clear rationale for selecting fixed effects. We first specified a zero model that only included a random factor (intercepts for each participant) and then enriched these zero models by gradually adding independent variables and their interactions. Finally, the chi-squared test compared the model fit indices evaluated using the maximum likelihood method. In the selected model, 12 round cooperate results were predicted in GLMM by dyad composition (CC: similar-pro-social dyads, CS: different-SVO dyads, SS: similar-pro-self)), cognitive resource (2 digits "high CR" and 7 digits "low CR"), round and pairwise interactions between these variables (analysis code available in the supplementary material Online Resource 5). The guidelines provided by Meteyard and Davies (2020) were used in the analysis and to report the results.

Results

Missing Data and Attrition

Eight samples were excluded from the analysis because they violated the writing order or wrote digits while the recording was playing during rounds 1–11. Because the behavior of the violators could affect the behavior of their partners, their partner's data were also excluded. Four samples (three pro-self and one pro-social) wrote digits while the recording was playing in the 12th round, and the corresponding data were also excluded. However, their partner's data were retained for individual-level data analysis of Hypothesis 2 because their 1–12-round behaviors were not biased. Therefore, 46 dyads were included in the analysis of Hypothesis 1. These included 12 pro-self homogeneous dyads, 13 pro-social homogeneous dyads, and 21 heterogeneous dyads. Ninety-six individuals remained for the testing of Hypothesis 2. These included 78 women (81.25%) and 18 men (18.75%), with an average age of 20.7 years (SD = 2.44). There were 50 pro-socials and 46 pro-selfs. Forty-seven participants listened to 2 digits (high CR), and 49 listened to 7 digits (low CR) (see Table 2).

Table 2 Numbers of Pro-social and Pro-self Participants in Different Experiment Settings

	Pro-self			Pro-social		
	Low CR	High CR	Total	Low CR	High CR	Total
Matched with pro-self	12	12	24	12	12	24
Matched with pro-social	12	10	22	11	15	26
Total	24	22	46	23	27	50

The numbers indicate how many pro-selfs/pro-socials are included in these experiment settings (e.g., 12 pro-selfs are matched with pro-self opponents and in low CR)

Dyad Composition and Group-Level Cooperation

The first hypothesis proposes that dyad composition has an impact on group-level cooperation. As mentioned before, 58 dyads were included in the offline experiment, but 12 participants violated the writing order or wrote digits while the recording was playing during the 1–12 round, so the corresponding 12 dyad data were excluded from the analysis of Hypothesis 1, leaving 46 dyads. To test this hypothesis, we treated a dyad's cooperation results as dichotomous outcomes: cooperate stands by both participants choose to cooperate, and no cooperate stands by either or neither of the dyad members cooperate.

A generalized linear mixed model (GLMM) with a logit link function was conducted using R4.1.2, with the R studio lme4 package (Bates et al., 2014). Twelve rounds of cooperating results were predicted in GLMM by dyad composition (CC: similar-pro-social dyads, SC: different-SVO dyads, SS: similar-pro-self), round, and their interaction as fixed effects, and the CR was also entered into the equation to achieve control. Random intercepts were specified for each dyad. A simulation method with a package called simr and powersim function were employed to do the analysis (Green & MacLeod, 2016). This package was developed based on Monte Carlo simulation and uses successive iterations of the data to estimate the power of the specified fixed effects (Kumle et al., 2021). As recommended by Brysbaert and Stevens (2018), this simulation method can be run for all possible designs and are robust.

Table 3 summarizes the results of the GLMM. The possibility of achieving dyad-level cooperation in heterogeneous dyads (CS) ($\beta = 1.19$, 95% CI [−1.70, 4.08], $z = 0.81$, $p = 0.42$) and similar-pro-social dyads (CC) ($\beta = 2.43$, 95% CI [−1.05, 5.91], $z = 1.37$, $p = 0.17$) were larger than in similar-pro-self dyads (SS), but the difference between the three types of dyads was not significant. Thus, Hypothesis 1 was not supported. However, the interaction effect of rounds on SC was significantly different from that of SS dyads ($\beta = -0.25$, 95% CI [−0.45, −0.06], $z = -2.54$, $p = 0.01$). That is, heterogeneous dyad cooperation possibility experiences a steeper reduction as the number of rounds increases compared with similar-pro-self dyads, while there is no significant difference between SS and CC dyads ($\beta = -0.22$, 95% CI [−0.46, 0.02], $z = -1.81$, $p = 0.07$), which replicate the result of De Oliveira et al. (2015) study. The power analysis results revealed a nearly 80% (79.2%) power for the significant interaction effect of rounds and dyad comosition on dyad-level cooperation (the estimated statistical power available in the Supplementary Material Online Resource 6, Supplementary Table 1).

Table 3 Results of Generalized Linear Mixed Models Using the Round and Dyad Type to Predict the Dyad-level Cooperation Choices in the 12-Round Prisoner's Dilemma While CR is Controlled

Predictors	Dyad-Level Cooperation				
	β	S.E.	95% CI	*z*	*p*
Intercept	−0.16	1.32	[−2.74, 2.42]	−0.12	0.90
Round	0.09	0.09	[−0.08, 0.26]	1.02	0.31
CR[a]					
CR(low)	0.06	1.11	[−2.13, 2.25]	0.05	0.96
Dyad composition[b]					
SC	1.19	1.47	[−1.70, 4.08]	0.81	0.42
CC	2.43	1.77	[−1.05, 5.91]	1.37	0.17
Dyad composition×Round[c]					
Round×SC	−0.25	0.10	[−0.45, −0.06]	−2.54	0.01
Round×CC	−0.22	0.12	[−0.46, 0.02]	−1.81	0.07
Random Effects					
σ^2	3.29				
$\tau_{00\ dyadid}$	12.51				
ICC	0.79				
N_{dyadid}	46				
Observations	552				
Marginal R^2 / Conditional R^2	0.04 / 0.80				

The dependent variable was cooperating (1) or not (0) with dyad i in round t. Each dyad had 12 rounds/decisions. Round is treated as a continuous variable. The *p*-values for fixed effects were calculated using Satterthwaites approximations. Confidence intervals were calculated using the Wald method. Model equation: cooperation~round × dyad composition + CR + (1 | dyad)

[a]High CR is the reference

[b]SS group is the reference

[c]Round*SS group is the reference

Dyad Composition, Cognitive Resources, and Individual-Level Cooperation

As mentioned before, four samples (three pro-self and one pro-social) wrote digits while the recording was playing in the 12th round and the corresponding data were also excluded, but the data of their partners were kept for individual-level data analysis of Hypothesis 2 because their 1–12-round behaviors were not biased. Therefore, 96 individual data points were included in the analysis for Hypothesis 2.

We also used the generalized linear mixed model (GLMM) method with a binomial distribution and logit link function to test Hypothesis 2. Model comparison was firstly conducted to provide a rationale for selecting fixed effects. We first specified a null model that only included round as the fixed effect and random factors (intercepts for each participant), and then enriched this null model by gradually adding independent variables and their

interaction. Finally, a chi-square test was performed to compare the new model with the previous model. Table 4 summarizes the fit indices of the models with different fixed effects. The fitting degree of the model was significantly improved by adding the interaction between round, dyad type, and CR significantly improved the fit degree of the model ($\chi^2 = 6.23$, $p = 0.04$). Therefore, we chose model 3 as the analysis model. Also, the power analysis was conducted using the simulation method with simr package and powersim function.

Table 5 summarizes the results of model 3. We failed to find a statistically significant main effect of dyad composition, neither round nor CR. However, there was a significant impact of CR in heterogeneous dyads (SC) ($\beta = -2.75$, 95% CI [−5.31, −0.18], $z = -2.10$, $p = 0.04$), while CR showed no statistically significant influence on homogeneous dyads (CC/SS). However, because the significant interaction effect of rounds and SC dyad may be slightly underpowered (the estimated statistical power available in the Online Resource 6, Supplementary Table 2), this result should be interpreted with caution. We still include interpretation of this effect because it is congruent with previous research demonstrating that the increased ease or fluency with which people can interpret others' behaviour may lead to greater trust in economic games (Zürn & Topolinski, 2017), especially when the situation is complicated and others' behavior pattern is contrary to decision makers' intuitions (SC situation). In addition, the results also indicated a significant interaction between rounds and CR ($\beta = -0.11$, 95% CI [−0.21, −0.01], $z = -2.25$, $p = 0.02$). More specifically, individuals with low CR experienced a greater decline with each additional round than those with adequate CR (high CR), which replicated the previous research demonstrating the limited cognitive resources leads to less cooperation and shorter survival of the common resource (Brozyna et al., 2018). However, it should also be interpreted with caution because the power analysis only reveals 65.1% power of this interaction, lower than 80%.

Figure 1 summarizes the interaction effect of dyad composition and CR on an individual's cooperation possibility, which clearly illustrates the discrepancy in cooperation possibility between high CR and low CR SC-dyad individuals. More interestingly, individuals' cooperation possibility in heterogeneous dyads (SC) showed an opposite pattern compared with other homogenous dyads (CC/SS); high CR created a higher cooperation possibility for SC-dyad individuals but a relatively lower cooperation possibility for those in CC and SS dyads.

Discussion

Using a 12-round prisoner's dilemma task, this study explored whether being similar in SVO promotes more dyad- and individual-level cooperation decisions. The state of the cognitive resources possessed by an individual was also identified as an essential variable in understanding the heterogeneity in individuals' cooperative behavior. The result indicated that the possibility of a dyad achieving cooperation varies as the number of rounds increases, with the most profound decay being for heterogeneous dyads, while no statistically significant difference appears between SS and CC dyads. Individuals in heterogeneous dyads cooperate less when they do not have an adequate CR (low CR) for individual-level cooperation. Thus, Hypothesis 2 was supported.

However, we failed to find support for Hypothesis 1, which demonstrated that the possibility of dyad-level cooperation differs among the three types of dyads; there was no statistically significant difference, even though the coefficient was large. This result differed from those of previous research on trait similarity and should be interpreted with caution given our relatively limited number of rounds. More specifically, similarity works if individuals learn the behavior of their opponents. However, a 12-round game may not be sufficient for individuals to evaluate their opponents accurately, and therefore the full impact of trait similarity on cooperation would not be exerted. As the 15-round public

Table 4 Model Comparison of Different Fixed Effect Models

Model Specification	Fixed Effects	Model Fit			ANOVA LRT Test	
		AIC	BIC	LL	df	χ^2
RE only (model 0)	round	1099.50	1114.70	−546.76		
FE main effects (model 1)	round + dyad com + CR	1100.80	1131.10	−544.40	3	4.72
FE Two-way interactions (model 2)	round×(dyad com + CR)	1100.40	1145.80	−541.21	3	6.39
FE Two-way interaction (model 3)	model 2 + dyad com × CR	1098.20	1153.70	−538.09	2	6.23*
FE Three-way interaction (model 4)	round×(dyad com × CR)	1101.70	1167.30	−537.84	2	0.49

**$p < 0.01$, *$p < 0.05$. RE = Random effect; FE = Fixed effect; Dyad com = dyad composition, the dependent variable is choosing to cooperate(1) or not(0) by participant i in round t. There were 96 participants, with 12 rounds for each participant. Round is treated as a continuous variable. All models were estimated using the maximum likelihood (ML) method, and the random effect was (1| participant)

Table 5 Results of Generalized Linear Mixed Models Using Round, Dyad Type, and CR to Predict Individual Cooperation Choices in the 12-Round Prisoner's Dilemma Task

Predictors	Individual-Level Cooperation				
	β	S.E.	95% CI	*z*	*p*
Intercept	0.77	0.83	[−0.86, 2.41]	0.93	0.36
Round	−0.04	0.06	[−0.16, 0.08]	−0.69	0.49
Dyad composition[a]					
SC	1.53	1.00	[−0.42, 3.49]	1.54	0.12
CC	1.57	1.19	[−0.76, 3.90]	1.32	0.19
CR[b]					
CR(low)	1.87	1.13	[−0.35, 4.09]	1.65	0.10
Dyad composition×Round[a]					
Round×SC	−0.06	0.07	[−0.18, 0.07]	−0.85	0.39
Round×CC	−0.06	0.08	[−0.21, 0.09]	−0.76	0.45
CR×Round [b]					
Round×CR(low)	−0.11	0.05	[−0.21, −0.01]	−2.25	0.02
Dyad composition× CR[b, c]					
SC×CR(low)	−2.75	1.31	[−5.31, −0.18]	−2.10	0.04
CC×CR(low)	−0.25	1.50	[−3.19, 2.69]	−0.17	0.87
Random effects					
δ^2	3.29				
$\tau_{00\ ID}$	5.19				
ICC	0.61				
N_{ID}	96				
Observations	1152				
Marginal R^2 / Conditional R^2	0.11 / 0.65				

The dependent variable is choosing to cooperate (1) or not(0) by individual i in round t. Each individual had 12 rounds/decisions. The round is treated as a continuous variable and is centralized. The *p*-values for fixed effects were calculated using Satterthwaites approximations. Confidence intervals were calculated using the Wald method. Model equation: cooperation~round×(dyad composition + CR)+dyad composition×CR+ (1 | participant)

[a]SS group is the reference

[b]High CR is the reference

[c]The coefficient of CR*SS is omitted because it is redundant

goods game employed by De Oliveira et al. (2015) found a statistically significant difference in group-level contribution in different three-person groups, it might be that the statistically significant effect of dyad type truly exists when more game rounds are employed.

Overall, this study provides insights into the role of personality similarity in cooperation and why the relationship between cooperation and CR remains undefined (Balliet et al., 2009; Liu & Hao, 2011). Additionally, it explored the dynamic cooperation process as the round was entered into equations and showed the interaction with dyad type and CR. More specifically, heterogeneous dyad cooperation possibility decreased sharply as the round increased compared with similar-pro-self dyads, while there was no significant difference between homogeneous dyads; for individual-level cooperation, as the round increased, individuals with low CR showed a greater decline in cooperation possibility compared with those with adequate CR (high CR). The novelty of the present study is its combination of two observations from previous research: the match of cooperative individuals can mitigate the cooperation decline over time (Guido et al., 2019), and the cognitive mechanisms behind the cooperative decisions of pro-socials and pro-selfs are different (Declerck & Bogaert, 2008). Besides, the result is somehow congruent with Fischbacher and Gächter's (2010) study suggesting that the contributions decline in a public good game is caused by the way people form (and change) their beliefs about how others will behave. Fischbacher and Gächter's (2010) study reveals this belief-change process by assessing participants' brief about the average contribution of the other group members, and the current study achieves this by controlling participants' cognitive resources. In addition, the result of the present study can also shed light on how information and memory affect cooperation as the CR is closely related to memory. Previous studies suggest that cooperation crucially depends on pre-play information, especially the surprising,

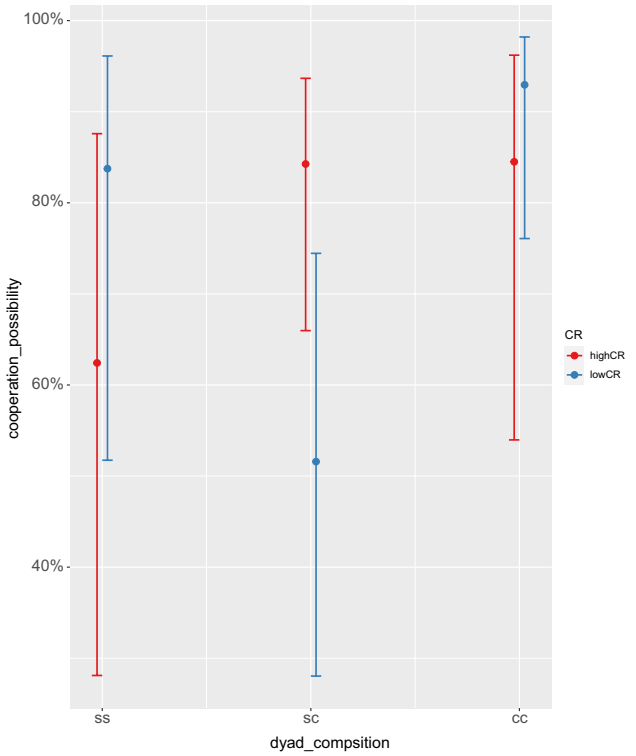

Fig. 1 The interaction of dyad composition and CR on individual cooperation possibility in the 12-round prisoner's dilemma task

unfavorable information which can be remembered without costing too much CR (Engel et al., 2021).

Moreover, this study also guides the promotion of cooperation among group members. Specifically, organizations could encourage group members to cooperate by reducing their cognitive burden, describing the task requirements clearly, reducing interference in team tasks, and using information technology to make member-to-member communication more convenient.

Limitations and Future Directions

Although the results of the current study contribute to a better understanding of cooperative behaviors, we recognize that there are several limitations in the research that should be noted. First, due to the COVID-19 pandemic and the lockdown of Chinese universities, the sample was restricted to students who could enter on-campus laboratories. This resulted in a relatively small sample size. The power analysis results also indicated that the GLMM result for hypothesis 2 was slightly underpowered, which might have decreased the robustness of the conclusion and should be interpreted with caution. Future replication would be valuable for examining the robustness of our results with different group sizes and parameters. Furthermore, online experimental techniques should also be considered for the collection of the data. This approach may aid researchers in collecting the data remotely and solve the problem of limited samples.

Additionally, this study was based on expectancy theory but did not directly measure individual cooperative expectations, and because there may be differences between expectations and actual behavior, the two need to be explored separately. It would also be a fruitful avenue for future research to explore the effects of SVO and CR on cooperative behavior and cooperative expectations separately, providing a complete image of cooperation in cooperative behavior social dilemmas. Furthermore, participants' working memory capacity might cause bias in CR manipulation. Therefore, future studies should consider the impact of working memory capacity when designing the experiment. The neuroimaging technologies such as fMRI and ERP can also be used to assess participants' cognitive activities and help extend our understanding of the cognitive demands-cooperation relationship.

A third potential weakness of our experiments is that we simply investigated cooperation in a binary group using a prisoner's dilemma. However, cooperation in an actual situation is not limited to two individuals. Cooperation within a multi-person group and between groups are also significant issues that need attention. In addition, some realistic factors (such as interaction, etc.) may also affect the impact of feature similarity on cooperation results. It would be fruitful to further investigate the impacts of these factors and provide an integrated understanding of cooperation.

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing Interests The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical Approval This study was carried out in accordance with the recommendations of the ethics committee of The Department of Psychology, Renmin University of China with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by

the ethics committee of The Department of Psychology, Renmin University of China.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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