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People overshoot when choosing resource pools☆,☆☆

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ABSTRACT

This paper studies a pool-choice dilemma, in which two or more resource-seekers decide independently whether to seek resources from a larger pool or a smaller pool. This dilemma mimics many real-life problems, such as firms or vendors deciding whether to enter a market with more potential buyers or one with fewer potential buyers. Across ten studies (five are incentive-compatible), we document a systematic *overshooting bias*, whereby the resource-seekers in the pool-choice dilemma are more likely to choose the large pool than normatively warranted, thereby sacrificing their own earnings. This research is a major extension of the prior work by Hsee et al. (2021) who found an opposite, undershooting effect in a similar dilemma. The current work offers a new look at the dilemma, with a more comprehensive theory that not only explains the overshooting effect found in this research, but also identifies its moderators and reconciles the opposite findings between this and the prior work. Contrary to what the prior work found, we predict and find that people in the dilemma generally overshoot rather than undershoot, unless they are explicitly prompted to predict the choice of their counterparts or the dilemma is framed in such a way that naturally prompts the players to consider the choice of their counterparts. This research carries theoretical implications for strategic thinking, and practical implications for resource competition.

One of the most common and important types of social interactions is resource competition (Erev et al., 1993; McCallum et al., 1985; Sassenberg et al., 2007), and competitors often need to choose whether to seek recources from a larger pool or a smaller pool. For example, sellers need to decide whether to enter markets with more or fewer potential buyers; buyers need to decide whether to seek scarce products at stores with larger or smaller inventories; graduate students need to decide whether to seek mentorship from professors with more or less available time; and political candidates need to decide whether to focus last-minute campaign efforts on regions with more or fewer potential voters. In such competitions, one's outcome depends both on their own choice, and their competitor's choice. Thus, such choices are game-theoretic decisions rather than individual decisions.

Investigating how and why people make choices in such resource competition scenarios has both theoretical and practical implications. From a theoretical perspective, this research makes three contributions. First, it enriches the experimental game-theory literature that examines how *ordinary* people with bounded rationality *actually* behave in strategic interactions and their underlying psychology. This approach goes beyond traditional normative game theory, which primarily analyzes how *rational* people *should* behave. Because game-theoretic paradigms are minimalistic and well-controlled, they have been widely adopted in social and experimental psychology to study complex social interactions, such as competition, cooperation, reciprocity and altruism (Camerer, 2011; Horita & Hamada, 2024; Messick & McClintock, 1968; Mitsuishi & Kawamura, 2025; Nockur et al., 2021; Rand et al., 2012; Sun et al., 2024; Wang et al., 2024; Yang et al., 2022). Second, our study advances understanding of whether and how people make predictions about others in strategic interactions, where outcomes depend on both one's own choice and the choice of their counterparts (Croson, 1999; Hsee et al., 2023; Tesař, 2020). Third, we contribute to the framing literature by examining how seemingly equivalent descriptions

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influence people's behavior in strategic decisions (Columbus et al., 2020; Hsee et al., 2025; Liberman et al., 2004; Zeng et al., 2025). From a practical standpoint, this research provides valuable insights into how people behave in resource competitions, illuminates how different descriptions can influence their choices, and suggests ways to help resource seekers overcome potential biases and make better predictions and decisions. Our findings also carry implications for designing and implementing effective cooperation frameworks in competitive contexts.

1. The dilemma and prior research

The basic version of the dilemma we study in this research involves two players (we will discuss the multi-player version later). In the two-player version, two resource seekers decide independently whether to acquire resources from a large pool (L) containing l units of resources or a small pool (S) containing s units of resources, where $s < l < 2s$.[1] The resources in a given pool will be shared equally by the two players if both players choose that pool, or belong to one player if only that player chooses that pool. We refer to this dilemma as the *Pool-Choice Dilemma*, or simply PCD.

At first glance, it looks as if the PCD were similar to various existing games, but a closer look suggests otherwise: PCD is unique in its set-up, payoff structure, and underlying psychology, which together produce a distinct overshooting effect. We summarize how the PCD relates to but theoretically and empirically differs from various existing paradigms, including the market entry game, the hawk-dove game, the battle of the sexes, the stag-hunt game, the route-choice problem, and foraging in Supplementary Materials A and B.

Among the existing paradigms, our paradigm is most similar to a pool-choice dilemma introduced and studied by Hsee et al. (2021). In their paradigm, many players (not two players) choose between a large pool containing l units of resources and a small pool containing s units of resources (where $l > s$), knowing that the resources in each pool will be divided equally among its choosers. Despite the apparent similarity between the two-player PCD and the multi-player PCD, they are distinct. First, they have different structures and equilibria. In the multi-player PCD, there are many players so that it is unlikely that either pool will be unchosen and wasted. Thus, the mixed-strategy equilibrium probability for choosing the larger pool is $l/(l+s)$. By contrast, in the two-player PCD, there are only two players, and there is a good chance that one of the pools will be unchosen and wasted. Thus, the mixed strategy equilibrium for choosing the larger pool is $(2l\text{-}s)/(l+s)$ (see Supplementary Materials C for detailed calculations). Second, the two paradigms require different framing. While a natural way to frame the multi-player PCD is a more/fewer frame ("the more people choose a certain pool, the less each person would get"; Hsee et al., 2021), this frame is not applicable to the two-player PCD; instead, an obvious way to describe the two-player PCD is to spell out the outcomes of all possible choice combinations, as is the standard frame used in the game-theory literature.

More importantly, the present research yields the opposite conclusion to what Hsee et al. claimed. Hsee et al. (2021) found an undershooting bias and suggested that it is general. We, on the other hand, find a systematic overshooting bias, and show that undershooting occurs only in specific conditions. The current paper is a major qualification (not a minor derivative) of Hsee et al. We offer a new look at the PCD, with a more comprehensive theory that not only explains the overshooting effect, but also identifies its moderators and thereby reconciles the apparently opposite findings between this and the prior work.

[1] We specify $l < n \times s$, because, otherwise, pool L would dominate pool S, and the PCD would no longer be a dilemma.

2. Normative versus behavioral theories

Normative theory. Assume that you and another player named Zay are playing the basic two-player version of the PCD, in which the large pool (L) contains l units of resources, and the small pool (S) contains s units of resources, where $l >$ s. According to normative game theory, the PCD has two pure strategy equilibria (you choosing L and Zay choosing S, and you choosing S and Zay choosing L), and a mixed-strategy equilibrium whereby both players choose L with a probability of $(2l\text{-}s)/(l+s)$. In our studies, we mainly use the mixed-strategy probability as the normative benchmark, because, at the aggregate level, it is the best way to analyze whether the players are systematically biased in controlled experimental settings (O'Neill, 1987; Rapoport & Amaldoss, 2000; Rapoport & Boebel, 1992; Rapoport & Budescu, 1992; see also Chapter 2 in Camerer, 2011).

Behavioral theory. Despite its normative status, the mixed strategy is rarely adopted by people without game theory training (Camerer, 2011). Moreover, because the players cannot communicate with each other, they cannot easily coordinate to reach the pure-strategy equilibrium either. Then, what would the typical player in the PCD do? We theorize that the typical player will simply choose whichever option appears superior. We define an option as apparently superior if this option on average yields better outcomes than the other option, and the two options are similar on other dimensions (e.g., riskiness). In the PCD, the large pool is the apparently superior option, because the large pool on average yields better outcomes than the small pool, and the two pools seem similar on other dimensions such as riskiness. Therefore, we predict that the player would choose the large pool.

Our theory builds on the well-established thinking level and cognitive hierarchy framework (Camerer et al., 2004; Nagel, 1995; for a review, see Crawford, 2013), which describes how individuals make decisions in strategic situations where outcomes depend on the other players' actions, and we apply it to categorize different types of decision-makers in our context. We refer to people who choose the larger pool because it is apparently superior, rather than because of their predictions of the other player, as K0 thinkers. Note that K0 thinkers are *non-strategic* in that their choices are not based on their prediction of their counterpart's thoughts or behavior. More specifically, a non-strategic thinker can be someone unaware of their counterpart's thought/behavior, someone who is unable to predict their counterpart's thought/behavior, or someone who intentionally ignores their counterpart's thought/behavior. Regardless of the underlying reason why one does not base their choice on their prediction about their counterparts, as long as the player chooses the larger account because it is apparently superior, we refer to them as a K0 thinker. This definition is consistent with extant research on level-0 meta-models (Wright & Leyton-Brown, 2014) (However, prior researchers have used different numerical labels to describe different thinking levels; see[2] for a discussion.) In the context of the PCD, we define K0 thinkers as those who choose the large pool because it is apparently superior. Accordingly, we define K1 thinkers as those who choose the small pool because they predict that the other player is a K0 thinker and will choose the large

[2] Different researchers have used different numbers/labels to describe thinking levels. For example, Costa-Gomes and Crawford (2006), Ho et al. (1998), Nagel (1995), and Crawford et al. (2008) define K0 as non-strategic, while Hsee et al. (2021) define Level 1 as non-strategic. Moreover, different authors have different definitions of "non-strategic". For example, Costa-Gomes and Crawford (2006) define non-strategic as making random choices, and Crawford et al. (2008) define non-strategic as choosing what is salient. In this article, we define K0 as non-strategic, and define non-strategic as choosing the apparently superior option without thinking about which option the other player would choose. This numbering is consistent with Crawford et al. (2008), but different from Hsee et al. (2021). What we call K0 is what Hsee et al. (2021) call Level 1, what we call K1 is what Hsee et al. (2021) call Level 2, and so on.

pool, K2 thinkers as those who choose the large pool because they predict that the other player is a K1 thinker and will choose the small pool, and so on. Among these thinking levels, K0 is non-strategic (i.e., not based on predictions of the counterpart's behavior), and the other thinking levels are strategic. Using these terms, we propose that the typical player in the PCD is a K0 thinker.

3. Overshooting

Based on our proposition that the typical player in the PCD is a K0 thinker, we predict that they will choose the apparently superior option, namely, the large pool, and thereby exhibit an overshooting effect. Specifically, they will be more likely to choose the large pool than the probability prescribed by the mixed-strategy equilibrium. This is our first hypothesis:

H1. Players in the PCD are more likely to choose the large pool than the probability of choosing the large pool as prescribed by the mixed-strategy equilibrium.

4. Moderators

Prediction prompting. According to our theory, the reason people overshoot is that they fail to think strategically, namely, fail to predict what their counterpart would do. Based on this proposition, we predict that prompting participants to predict what their counterpart would do before they make their own choices will make them think more strategically. Specifically, we propose that those who are prompted to predict what their counterpart would do will predict that their counterpart thinks at K0 and will choose the large pool, and so conclude that they themselves should respond by choosing the small pool instead. Consequently, compared with people who do not receive the prompt, those who receive the prompt will be less likely to show the overshooting effect. This is our next hypothesis:

H2. The overshooting effect will mitigate or reverse if the players are prompted to predict what their counterpart would do before making their own choice.

Framing. In this section, we introduce a more subtle moderator—-framing. We propose that the thinking level—and hence the overshooting effect—can also be manipulated merely by the way in which the PCD is framed (described). Extant behavioral research finds that superficially different but substantively equivalent ways to describe a problem can influence people's decisions; such framing effects exist not only in individual decisions (e.g., Hsee & Li, 2022; Larrick & Soll, 2008; Levin et al., 1998; Lieberman et al., 2019; Tversky & Kahneman, 1981; Zeng et al., 2025), but also in interactive decisions (e.g., Dufwenberg et al., 2011; Goerg & Walkowitz, 2010; Hsee et al., 2025; Larrick & Blount, 1997).

In the context of the PCD, we can frame the game in two ways. One is to spell out the outcomes of all choice combination scenarios, like the following:

	If Zay chooses L	If Zay chooses S
If you choose L	you will get half the resources in L	you will get all the resources in L
If you choose S	you will get all the resources in S	you will get half the resources in S

We refer to this frame as the standard frame, because it is the standard method to describe games in the game-theory literature, especially when there are only two players (e.g., the prisoner's dilemma); it is also the default frame in our studies. Note that the hallmark of this frame is that it spells out the outcomes of all four choice combinations; it does not matter whether the four scenarios are presented in a 2 × 2 matrix, or in four sentences. For example, this four-sentence format is still the standard frame: "If you choose L and Zay chooses L…; if you choose L and Zay chooses S…; if you choose S and Zay chooses L; if you choose S and Zay chooses S…".

An alternative frame to describe the PCD is to describe what will happen if you and the other player choose the same pool versus different pools, namely:

If you and Zay choose the same pool	you will get half the resources in that pool
If you and Zay choose different pools	you will get all the resources in the pool you choose

We refer to this alternative frame as the same/different frame. Objectively, the same/different frame and the standard frame are equivalent because they describe the same game. Despite this, we predict that the two frames lead to different thinking processes, and hence different choices. The standard frame separates the choices of the two players in independent dimensions, masks their interconnectedness, and leads each player to think at K0 and choose the large pool. By contrast, the same/different frame makes each player realize that they will get only half the resources in a pool if they choose the same pool as the other player would choose, but can get all the resources in a pool if they avoid choosing the same pool as the other player would choose. This will lead them to predict what the other player would choose, and then choose differently than the other player. In other words, describing the PCD using the alternative same/different frame instead of the standard frame will serve a similar function as the prediction-prompting manipulation described in H2, namely, leading more people to think strategically. This is our next hypothesis:

H3. The overshooting effect will be mitigated or reversed if the problem is presented in the same/different frame rather than in the standard frame.

Note that if the PCD involves multiple players (e.g., 20), it would be confusing to use the same/different frame, because it would involve too many possible scenarios for ordinary people to comprehend. A clearer way to describe the payoff structure for a multi-player PCD is simply to say "the more people choose a certain pool, the fewer resources each player will receive." We call this frame the more/fewer frame. Like the same/different frame, the more/fewer frame also highlights how one's payoff depends on other players' decisions. Therefore, we predict that the more/fewer frame will also mitigate or reverse overshooting, just as we predict the same/different frame will.

5. Overview of studies

We conducted ten studies that tested our hypotheses and their extensions; five of the ten studies were incentive-compatible in the way that participants' monetary compensation was directly linked to their actual choices in the study, incentivizing them to make decisions that align with their actual preferences (Cummings et al., 1997). Table 1 offers an overview.

All studies, measures, manipulations, and data/participant exclusions are reported in the manuscript or its Supplementary Material. All data can be accessed at the Open Science Framework (link). For the studies testing the existence of overshooting in one-shot decisions (Studies 1 and 4), we aimed to recruit 100 to 150 participants per condition. For studies involving moderators (Studies 2, 3, 5, and 6), we aimed to recruit 200 participants per condition. Our sample size was determined following recent research on strategic decisions in similar settings (Hsee et al., 2021, 2023). This sample size would ensure 80 % power to detect an effect size of w = 0.14 or greater in a chi-square test with a 5 % false-positive rate.

Table 1
Study overview.

Study	Manipulated conditions	Normative mixed-strategy benchmark of choosing the large pool	Proportion of participants choosing the large pool	Main finding(s)
1*		51.5 %	83.3 %†	Demonstrates the overshooting effect (H1) with real financial consequences
2	control (without prediction-prompting)	53.7 %	60.7 %†	Demonstrates the moderating effect prediction prompting (H2) and explores its underlying psychology
	treatment (with prediction-prompting)		41.5 %§	
3*	control (standard frame)	51.5 %	70.9 %†	Demonstrates the moderating effect of framing and explores its underlying psychology
	treatment (same/different frame)		43.8 %§	
4*	two players	51.5 %	64.7 %†	Manipulates the number of players (two vs. multiple), and replicates the overshooting effect in both the two-player PCD and the multi-player PCD
	multiple players	54.5 %	62.0 %†	
5	control (without prediction prompting)	50.6 %	69.5 %†	Demonstrates the moderating effect of framing in the multi-player PCD
	treatment (with prediction-prompting)		43.0 %§	
6*	control (standard frame)	52.9 %	66.8 %†	Demonstrates the moderating effect of framing in the multi-player PCD, and reconciles this research and the prior research by Hsee et al. (2021)
	treatment (more/fewer frame)		42.3 %§	
Extra 1	PCD	53.0 %	76.5 %†	Compares the PCD with a comparable market entry game, and finds an overshooting effect in the PCD but not in the market entry game
	market entry	53.0 %	14.0 %§	
Extra 2A		53.0 %	63.6 %†	Replicates the overshooting effect in a business context
Extra 2B	low asymmetry	53.0 %	78.8 %†	Manipulates the asymmetry between the large and the small pools, replicates the overshooting bias with low or moderate asymmetry, and finds a ceiling effect with high asymmetry
	medium asymmetry	74.0 %	86.7 %†	
	high asymmetry	95.0 %	97.8 %	
Extra 2C*		53.0 %	75.8 %-68.1 %†	Replicates the overshooting effect over multiple rounds

* Incentive-compatible, † Overshooting, § Undershooting.
Note: The standard frame spells out the outcomes of all choice combination scenarios. The same/different frame describes what will happen if one chooses the same pool as the other player and what will happen if one chooses a different pool from the other player. The more/fewer frame describes the negative relation between the number of people choosing a given pool and the amount of resources each chooser will have.

6. STUDY 1: demonstrating the overshooting effect with financial consequences

Study 1 tested the overshooting effect (H1) in a fully incentive-compatible setting. The study was pre-registered at https://aspredicted.org/S6F_5DW.

6.1. Method

Participants were 150 workers (92 females, $M_{age} = 31.7$) recruited from Credamo, one of the largest online study platforms in the world and the largest in China. The participants were given the following instructions[3]:

> In this study, you will play a monetary game with an anonymous participant. You and the other player get the same information, but cannot communicate. Each of you can get some bonus money from either a small account or a large account. The small account contains ￥4.90, and the large account contains ￥5.00. Each of you can choose only one account, and must choose independently. Exactly how much bonus money each of you can get is described in the following table:

	If the other player chooses the small account	If the other player chooses the large account
If you choose the small account	you will get ￥2.45; the other player will get ￥2.45	you will get ￥4.90; the other player will get ￥5.00
If you choose the large account	you will get ￥5.00; the other player will get ￥4.90	you will get ￥2.50; the other player will get ￥2.50

After reading the above table,[4] the participants were asked to make a choice between the small account and the large account. Finally, they reported their gender and age. At the end of the study, the participants received the promised bonus money.

6.2. Results and discussion

In this study, $l = 5.00$ and $s = 4.90$, so the mixed-strategy equilibrium benchmark for choosing the large account was $(2 \times 5–4.9)/(5 + 4.9) =$

[3] The instructions of the studies conducted on Credamo were originally in Chinese.
[4] Unlike the tables in Study 1A and Study 1B, the table in this study described the small pool before the large pool; we implemented this variation to ensure the robustness of our findings.

51.5 %. However, the actual proportion of participants choosing the large account was 83.3 %, significantly higher than the normative benchmark, χ^2 (1, N = 150) = 60.86, $p < .001$, $\phi = 0.64$. This overshooting finding is notable for three reasons. First, it differs from the prediction of normative game theory. Second, it differs from the prediction of regression toward the mean. Third, overshooting is costly—worse than random choice. If the participants had chosen randomly, their average earnings would have been ￥3.71, but due to overshooting, their actual average earnings were only ￥3.18.

To explore the robustness and generalizability of the overshooting effect, we conducted three additional studies (see Supplementary Materials D for details). Extra Study 2A replicated the overshooting effect in a business setting with experienced business professionals. Extra Study 2B manipulated the asymmetry between the large and small pools, replicating the overshooting bias when the asymmetry was low or moderate, but showing a ceiling effect when the asymmetry was high. Finally, Extra Study 2C included multiple rounds and replicated the overshooting bias across the multiple rounds.

7. STUDY 2: the moderator effect of prediction-prompting

Study 2 tested H2 regarding the moderating effect of prediction-prompting, and also tested the underlying psychology by exploring the reasons behind the participants' choices.

7.1. Method

Participants were 401 workers recruited from Prolific (229 females, $M_{\text{age}} = 32.5$). They were randomly assigned to either a control condition (without prediction-prompting) or a prediction-prompting condition. In the beginning, all participants read the following camping case:

> Your family is going camping this weekend. There are two campsites to choose from, one large and one small. The large campsite is slightly (i.e., only 5 %) larger than the small campsite. Besides your family, another family is also going camping at one of the two campsites this weekend. Your family and the other family are not related. Each family wants to have as much camping area as possible, and does not want to share with the other family. Each family has the same information as the other family, and each family has to independently decide which campsite to go to. The following table tells you how much camping area your family will have in different situations; please carefully compare the information:

If your family goes to the small campsite, and the other family also goes to the small campsite	then your family will have half the area in the small campsite
If your family goes to the small campsite, and the other family goes to the large campsite	then your family will have all the area in the small campsite
If your family goes to the large campsite, and the other family also goes to the large campsite	then your family will have half the area in the large campsite
If your family goes to the large campsite, and the other family goes to the small campsite	then your family will have all the area in the large campsite

After receiving the above information, participants in the control condition were directly asked to decide which campsite their family would go to. On the other hand, participants in the prediction-prompting condition were asked first to predict what the other family would do. Specifically, they were asked, "Before deciding which campsite your family will go to, please first make a prediction about the other family: Which campsite do you predict the other family will go to?" After making their prediction, the participants in the prediction-prompting condition were asked to decide which campsite their family would go to.

After making their choices, all participants were directed to a new page, and asked to explain the reason behind their decision. They were reminded, "You said on the last page that your family would go to the XX campsite," and asked, "Why would your family go to the XX campsite?" They were given four answers to choose from:

- Because my family will have more campsite area on average by going to the XX campsite.
- Because I predicted that the other family would go to the large campsite.
- Because I predicted that the other family would go to the small campsite.
- Other reason; please specify _______.

In the original stimuli, "the XX campsite" was either "the large campsite" or the "small campsite," depending on the participant's actual choice on the previous page. Finally, participants reported their gender and age.

7.2. Results and discussion

Pool choice. According to the instructions, the large pool was 5 % larger than the small pool. In other words, $l = 1.05\,s$. Thus, the mixed-strategy equilibrium probability for choosing the large pool is $(2 \times 1.05\,s - s)/(1.05\,s + s) = 53.7$ %. In the control condition, the proportion of participants choosing the large pool was 60.7 %, significantly greater than the equilibrium benchmark, χ^2 (1, N = 201) = 3.96, $p = .047$, $\phi = 0.14$. In the prediction-prompting condition, the proportion of participants choosing the large pool dropped to 41.5 %, significantly lower than the corresponding proportion in the control condition, χ^2 (1, N = 401) = 14.78, $p < .001$, $\phi = 0.19$, and also significantly lower than the equilibrium probability, χ^2 (1, N = 200) = 11.97, $p < .001$, $\phi = 0.24$. This result lent strong support to H2 regarding the moderating role of prediction prompting, showing that the prompt not only eradicated the overshooting effect, but turned it to the opposite, undershooting effect. We also analyzed their prediction data and found (a) that the majority of the participants (85.5 %) predicted that their counterpart would choose the large pool, and (b) that those who predicted that their counterpart would choose the large pool were more likely to choose the small pool themselves than those who predicted that their counterpart would choose the small pool, $r_s = -0.287$, $p < .001$.

Thinking level. We infer a participant's thinking level from a combination of the campsite they chose to go to and the reason they identified. If a participant chose to go to the large campsite, and her reason was "Because my family will have more campsite area on average by going to the large campsite," it indicates that her thinking level was K0. If a participant chose to go to the small campsite, and her reason was "Because I predicted that the other family will go to the large campsite," it suggests that her thinking level was K1.[5] If a participant chose to go to the large campsite, and her reason was "Because I predicted that the other family will go to the small campsite," it indicates that her thinking level was a K2. If a participant chose any other combination of campsite and reason, it suggests that she did not fit any of the thinking levels. Fig. 1 shows the relationship between prompting and thinking level. In the control condition, the predominant thinking level is K0. By contrast, in the prediction-prompting condition, the predominant thinking level is K1. A comparison between the two conditions shows (a) that more participants in the control condition than in the prediction-prompting condition thought at K0, χ^2 (1, N = 401) = 7.08, $p = .008$, $\phi = 0.13$,

[5] Our analysis could not distinguish K1 from any higher odd-numbered levels (e.g., K3, 5, etc.), nor could our analysis distinguish K2 from any higher even-numbered levels (e.g., level 4, 6, etc.). However, prior research indicates that people rarely think beyond K2 (Costa-Gomes & Crawford, 2006; Nagel, 1995). Therefore, it is reasonable to assume that if a participant chose the small pool and picked the second reason, their most likely thinking level was K1 (not 3, 5, or higher), and that if a participant chose the large pool and picked the third reason, their most likely thinking level was K2 (not 4, 6, or higher).

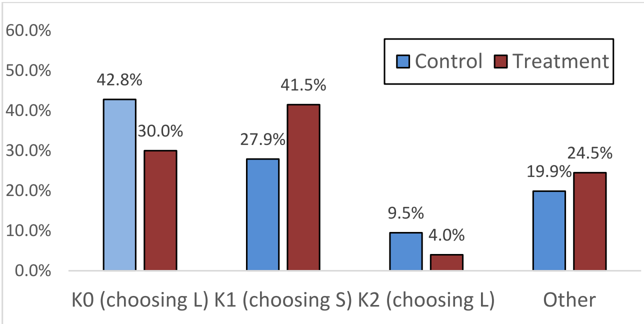

Fig. 1. Relationship between Prediction Prompting and Thinking Level in Study 2.

and (b) that more people in the prediction-prompting condition than in the control condition thought at K1, χ^2 (1, $N = 401$) = 8.24, $p = .004$, $\phi = 0.14$. Because K0 corresponded to choosing the large pool, and K1 corresponded to choosing the small pool, these thinking-level results elucidated why people in the control condition would overshoot, while people in the prediction-prompting condition would undershoot. For more details, see Supplementary Materials E.

8. STUDY 3: the moderating effect of framing

Study 3 tested H3 that the overshooting is less likely to occur if the PCD is presented in the same/different frame than in the standard frame. Like Study 2, Study 3 also explored the participants' underlying psychology. The study was incentive-compatible.

8.1. Method

Participants were 402 workers (188 females, $M_{age} = 40.4$) recruited via CloudResearch Approved Participants. The participants were randomly assigned to either a control condition or a treatment condition. The control condition used the standard frame and the treatment condition used the same/different frame. At the beginning, all participants read the following instructions:

> In this study, you will work on a vendor-decision-making case with another online worker. You two are anonymous to each other. The goal of each of you is to have as many buyers as possible for the self. After we complete the project, we will randomly pick two participants, and pay each of them a bonus based on the number of buyers they have in the case, with one buyer worth 10 cents. Therefore, the more buyers you have, the more bonus you will get if you are picked.
>
> You and the other worker are two independent water vendors who plan to sell bottled water at an outdoor event tomorrow. You two are not personal friends; each of you wants to have as many buyers as possible for the self. You two have the same information. There will be two outdoor events tomorrow—event S and event L. Event S will have a total of 198 buyers, and event L will have a total of 202 buyers. Each of you can go to only one event and must decide independently which event to go to.
>
> In the control condition, we described the outcomes as follows:

	If the other vendor goes to event S	If the other vendor goes to event L
If you go to event S	you'll have 99 buyers	you'll have 198 buyers
If you go to event L	you'll have 202 buyers	you'll have 101 buyers

In the treatment condition (using the same/different frame), we described the outcomes as:

> If you go to the same event as the other vendor will go to, you will have half the buyers at that event. If you go to the different event than the other vendor will go to, you will have all the buyers at the event you go to.

All participants were then asked to decide which event to go to. After that, they were directed to a separate page, and asked to explain their decision. They were asked "Why did you go to event XX?" and given five options:

- because I will have more buyers on average by going to event XX.
- because I predicted that the other vendor would go to event L.
- because I predicted that the other vendor would go to event S.
- because I didn't want to end up with fewer buyers than the other vendor.
- other reason; please specify.

In the original stimuli, "event XX" was either "event L" or "event S," depending on the participant's actual choice on the previous page. Finally, participants reported their gender and age. Note that, compared with the options in Study 2, the above list includes an additional option— "because I didn't want to end up with fewer buyers than the other vendor." This option reflects inferiority aversion—the desire to avoid being worse off than one's counterpart (Cox, 2013; Kuziemko et al., 2014; Messick & Thorngate, 1967). Like K0 thinking, inferiority aversion also predicts overshooting, because by choosing the large pool, the chooser will never be worse off than their counterpart regardless of which pool the counterpart chooses, but by choosing the small pool, the chooser will be worse off than their counterpart if the counterpart chooses the large pool.

8.2. Results and discussion

Pool choice. According to the instructions, $l = 202$, and s = 198, so that the mixed-strategy equilibrium probability for choosing the large pool is (2 × 202–198)/(202 + 198) = 51.5 %. In the control condition, the proportion of participants choosing the large pool was 70.9 %, significantly greater than the mixed-strategy equilibrium benchmark, χ^2 (1, $N = 199$) = 29.84, $p < .001$, $\phi = 0.39$. This result replicated the overshooting effect. In the treatment condition, the proportion of participants choosing the large pool dropped to 43.8 %, significantly lower than the corresponding proportion in the control condition, χ^2 (1, $N = 402$) = 29.95, $p < .001$, $\phi = 0.27$, and also significantly lower than the mixed-strategy equilibrium benchmark, $\chi^2(1, N = 203) = 4.77, p = .029$, $\phi = 0.15$. These results demonstrated the moderating effect of framing as predicted in H3. The framing manipulation in this study not only removed the overshooting effect, but also turned it into an undershooting effect.

Thinking level. As in Study 2, we inferred participants' thinking level from the event they chose and the reason they identified. Fig. 2 shows the relationship between framing and thinking style. The predominant thinking style in the control condition is K0, and the predominant thinking style in the treatment condition is K1. Specifically,

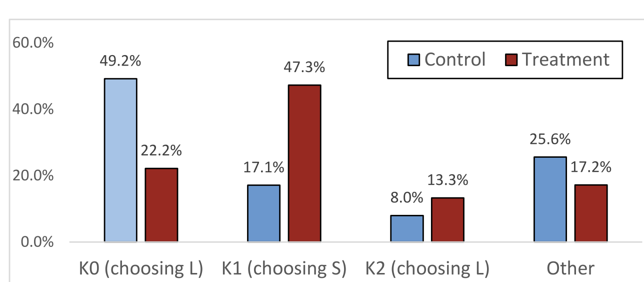

Fig. 2. Relationship between Framing and Thinking Level in Study 3.

more participants in the control condition than in the treatment condition thought at K0, 49.2 % vs. 22.2 %, χ^2 (1, N = 402) = 32.15, $p < .001$, $\phi = 0.28$, and more participants in the treatment condition than in the control condition thought at K1, 47.3 % vs. 17.1 %, χ^2 (1, N = 402) = 41.90, $p < .001$, $\phi = 0.32$. Because K0 corresponded to choosing the large pool, and K1 corresponded to choosing the small pool, these thinking-level results explained why participants in the control condition overshoot, and participants in the treatment condition undershot. For more information on thinking levels, see Supplementary Materials F. Besides differential thinking level, differential inferiority aversion may also have contributed to the framing effect. More participants in the standard frame than in the same/different frame cited inferiority as their main reason for choosing the large pool (11.1 % versus 4.9 %, $p = .023$). Despite the difference, the absolute proportion of participants citing the inferiority aversion was low in both conditions. Therefore, we doubt inferiority aversion was the main reason for overshooting in the control condition, or the main reason for the difference in choice between the control condition and the treatment condition.

9. STUDY 4: replicating the overshooting effect in the multi-player PCD

While the studies reported so far focused on the two-player PCD, Study 4 (incentive-compatible) manipulated the number of players in the PCD (two or multiple), and tested whether the overshooting effect would replicate in the multi-player PCD.

9.1. Method

Participants were 300 workers (210 females, $M_{age} = 30.9$) recruited via Credamo. The participants were randomly assigned to either a two-player or a multi-player condition. Those in the two-player condition received the following instructions:

> Suppose that you and another participant are playing a money-acquisition game. You do not know each other and cannot communicate, but you two have the same information. In order for you to be involved in this game, we will randomly pick two players upon the completion of this project (which may take some time), and will give each player a real monetary bonus based on the money they acquire during the game. The rules of the game are as follows: We have two accounts, one large and one small. The large account contains ¥102, and the small account contains ¥96. Each of you can acquire money from only one account, and must choose independently from account to acquire money from. How much money each of you can acquire depends your choices; see below for details (please read the entire table):

	If you choose the large account	If you choose the small account
If the other player chooses the large account	you will get ¥51	you will get ¥96
If the other player chooses the small account	you will get ¥102	you will get ¥48

The participants were then asked to make their choice between the two accounts.[6]

The multi-player condition was the same as the two-player condition except that there were five players instead of two. Specifically, the participants read the following:

> Suppose that you and four other participants are playing a money-acquisition game. You do not know each other and cannot communicate with each other, but you have the same information. In order for you to be involved in this game, we will randomly pick five players upon the completion of this project (which may take some time), and will give each player a real monetary bonus based on the money they acquire during the game.
>
> The rules of the game are as follows: We have two accounts, one large and one small. The large account contains ¥102, and the small account contains ¥96. Each of you can acquire money from only one account, and must choose independently from account to acquire money from. How much money each of you can acquire depends your choices; see below for details (please read the entire table):

	If you choose the large account	If you choose the small account
If all of the other four players choose the large account	you will get ¥20.4	you will get ¥96
If three of the other four players choose the large account and one chooses the small account	you will get ¥25.5	you will get ¥48
If two of the other four players choose the large account and two choose the small account	you will get ¥34	you will get ¥32
If three of the other four players chooses the small account and one chooses the large account	you will get ¥51	you will get ¥24
If all of the other four players choose the small account	you will get ¥102	you will get ¥19.2

Finally, participants reported their gender and age. As promised, upon the completion of the project, we randomly picked two participants in the two-player condition and five participants in the multi-player condition, and paid each of them a bonus according to the instructions.

9.2. Results and discussion

In the two-player condition, the mixed-strategy equilibrium probability for choosing the large pool is (2 × 102–96)/(102 + 96) = 54.5 %. In the multi-player condition, the mixed-strategy equilibrium probability for choosing the large pool is 102/(102 + 96) = 51.5 %. In both conditions, the players overshot. In the two-player condition, 64.7 % of the players chose the large account, significantly higher than the corresponding mixed-strategy benchmark, χ^2 (1, $N = 150$) = 6.25, $p = .012$, $\phi = 0.20$. In the multi-player condition, 62.0 % of the players chose the large account, also significantly higher than the corresponding mixed-strategy benchmark, χ^2 (1, $N = 150$) = 6.62, $p = .010$, $\phi = 0.21$.

The result in the multi-player condition is particularly noteworthy. It did not replicate the undershooting bias found in Hsee et al. (2021). Instead, it replicated the overshooting bias found in the two-player version of the PCD. This finding supported our thinking-level theory, suggesting that, like the players in the two-player PCD, the players in the multi-player PCD also think at K0. If this theory is correct, then the overshooting effect in the multi-player PCD should also be moderated by prediction-prompting and framing, just as in the two-player PCD. Study 5 and Study 6 tested these moderators in the multi-player PCD.

10. STUDY 5: the moderating effect of prediction-prompting in the multi-player PCD

Just as Study 2 and Study 3 tested moderators of the overshooting effect in the two-player PCD, Study 5 and Study 6 did so for the multi-player PCD. Like Study 2, Study 5 manipulated the presence or absence of a prediction prompt.

[6] The orientation of the tables in this study was different from the orientation of the tables in most other studies. Here, the columns of the tables described one's own options, and the rows described the options of the other player(s). We adopted this orientation in order to test the robustness of our findings and also in order to prevent the table in the multi-player condition from being horizontally too congested.

10.1. Method

Participants were 400 workers (298 females, $M_{age} = 30.9$) recruited via Credamo. The participants were randomly assigned to either a control condition or a prediction-prompting condition. All participants read the following vignette:

> There are four mutually competing private companies in your region. You are the owner of one of the companies. The owners of the four companies do not communicate with each other, but have the same information. Each of you wants to enter a new market to sell your products, and each of you wants as many buyers as possible. There are two new markets to choose from: one relatively small and one relatively large. The small market has a total of 4.92 million buyers, and the larger market has a total of 5.04 million buyers. Each of you can enter only one market and must decide independently which market to enter. The following table describes how many buyers you will have in the different scenarios:

	If all the other three persons enter the small market	If two of them enter the small market and one of them enters the large market	If two of them enter the large market and one of them enters the small market	If all the other three persons enter the large market
If you enter the small market	you will have 1.23 million buyers	you will have 1.64 million buyers	you will have 2.46 million buyers	you will have 4.92 million buyers
If you enter the large market	you will have 5.04 million buyers	you will have 2.52 million buyers	you will have 1.68 million buyers	you will have 1.26 million buyers

In the control condition, the participants were then asked to decide which market to enter. In the prediction-prompting condition, the participants first received the following prompt “Before you make your choice, please first think about what the other three persons will choose: which market do you think most of them will enter?” They answered by choosing one of two answers: “I guess most of them will enter the small market” and “I guess most of them will enter the large market.” After that, the participants were asked to make their own choice. Finally, participants reported their gender and age.

10.2. Results and discussion

In the control condition, the proportion of participants choosing the large market was 69.5 %, significantly higher than the mixed-strategy benchmark in the study (50.6 %), χ^2 (1, N = 200) = 28.58, $p < .001$, $\phi = 0.38$. This result replicated the overshooting effect in the multi-player PCD initially found in Study 4. In the prediction-prompting condition, the proportion of participants choosing the large market fell to 43.0 %, significantly lower than that in the control condition, χ^2 (1, N = 400) = 28.54, $p < .001$, $\phi = 0.27$, and also significantly lower than the mixed-strategy benchmark, χ^2 (1, N = 200) = 4.62, $p = .032$, $\phi = 0.15$. These results corroborated the findings of Study 2 by showing that prediction-prompting can moderate the overshooting bias in both the two-player and the multi-player PCDs. In the prediction-prompting condition, most participants (85.0 %) predicted most of their competitors would choose the large market, χ^2 (1, N = 200) = 98.00, $p < .001$, ϕ = 0.70, compared with 50 %, and their own choice was negatively correlated with their prediction, $r_s = -0.23$, $p = .001$. These results supported our theory that the prediction prompt changed people's thinking level.

11. STUDY 6: the moderating effect of framing in the multi-player PCD

In this study (for the multi-player PCD), we included two framing conditions: a control condition and a treatment condition. In the control condition, we used the standard frame. In the treatment condition, we used the frame that Hsee et al. (2021) used in their studies for the multi-player PCD: it described the negative relation between the number of people choosing a given pool and the amount of resources each chooser will have. We refer to this frame as the more/fewer frame. Unlike the standard frame but like the same/different frame, the more/fewer frame highlights the need to think strategically.

11.1. Method

Participants were 403 workers recruited from Prolific (225 females, $M_{age} = 28.0$). They were randomly assigned to either a control condition which used the standard frame or a treatment condition which used the more/fewer frame. This was an incentive-compatible study. At the beginning, all participants read the following:

> In this study, you will work on a vendor-decision-making case with four other online workers. The five of you are anonymous to each other. The goal of each of you is to have as many buyers as possible for the self. After we complete the project, we will randomly pick five participants, and pay each of them a bonus based on the number of buyers they have in the case, with one buyer worth 1 cent. Therefore, the more buyers you have, the more bonus you will get if you are picked.
>
> You and the other workers are five independent water vendors who plan to sell bottled water at an outdoor event tomorrow. These vendors are not personal friends; each vendor wants to have as many buyers as possible for the self. All vendors have the same information. There will be two outdoor events tomorrow—event S and event L. Event S will have a total of 480 buyers, and event L will have a total of 540 buyers. Each vendor can go to only one event and must decide independently which event to go to.

In the control condition, we described the payoff structure as follows:

	If you go to event S	If you go to event L
If all other vendors go to event S	you'll have 96 buyers	you'll have 540 buyers
If three other vendors go to event S and one goes to event L	you'll have 120 buyers	you'll have 270 buyers
If two other vendors go to event S and two go event L	you'll have 160 buyers	you'll have 180 buyers
If one other vendor goes to event S, and three go to event L	you'll have 240 buyers	you'll have 135 buyers
If all other vendors go to event L	you'll have 480 buyers	you'll have 108 buyers

In the treatment condition (using the more/fewer framing), we described the payoff structure as:

> The buyers at each event will be “shared” equally by the vendors who go there. Therefore, the more vendors go to a certain event, the fewer buyers each vendor who goes there will have. Conversely, the fewer vendors go to a certain event, the more buyers each vendor who goes there will have.

After reading the case, participants in both conditions were asked to decide which event they would go to. After making their decision, all participants were directed to a separate page, and asked to explain the reason behind their decision. They were asked, “Why did you go to event X?” and given four possible reasons to choose from:

- because I will have more buyers on average by going to event X.

- because I predicted that most other vendors would go to event L.
- because I predicted that most other vendors would go to event S.
- other reason; please specify.

In the original stimuli, "event X" was either "event L" or "event S," depending on the participant's choice on the previous page. Finally, participants reported their gender and age.

11.2. Results and discussion

Pool choice. In this study, $l = 540$, and $s = 480$; hence, the mixed-strategy equilibrium for choosing the large pool was 540 / (540 + 480) = 52.9 %. In the control condition, the proportion of participants choosing the large pool was 66.8 %, significantly higher than the equilibrium benchmark, χ^2 (1, $N = 202$) = 15.74, $p < .001$, $\phi = 0.28$. This result replicated the overshooting effect found in our other studies. By contrast, in the treatment condition (using the more/fewer frame), the proportion of participants choosing the large pool was only 42.3 %, significantly lower than the proportion of participants choosing the large pool in the control condition, χ^2 (1, $N = 403$) = 24.48, $p < .001$, $\phi = 0.25$, and also significantly lower than the mixed-strategy equilibrium benchmark, χ^2 (1, $N = 201$) = 9.08, $p = .003$, $\phi = 0.21$. This result replicated the undershooting bias reported by Hsee et al. (2021). Together, these results reconciled the apparent contradiction between the overshooting effect found in the standard frame in the current research, and the undershooting bias found in the more/fewer frame in Hsee et al. (2021)'s original work. These effects occurred even though the responses were incentive-compatible.

Thinking level. We infer participants' thinking levels in the same way as described in Study 2, and present the results in Fig. 3. As the figure illustrates, the predominant thinking level in the control condition (the tallest light-colored column) is K0, and the predominant thinking level in the treatment condition (the tallest dark-colored column) is K1. More participants in the control condition than in the treatment condition thought at K0, 52.5 % vs. 18.9 %, χ^2 (1, $N = 403$) = 49.44, $p < .001$, $\phi = 0.35$, and more participants in the more/fewer-frame condition than in the control condition thought at K1, 45.3 % vs. 25.7 %, χ^2 (1, $N = 403$) = 16.79, $p < .001$, $\phi = 0.20$. These thinking-level results were consistent with the thinking-level results in both the current research and the prior research by Hsee et al. (2021), and further reconciled the seeming conflict between the two lines of work.

12. General discussion

This research makes three contributions. First, it studies the pool choice dilemma (PCD), a problem that reflects many real-life resource-competition situations and is new in the literature, except for Hsee et al. (2021). Second, the present research documents a robust overshooting bias in the PCD, an effect that has never been demonstrated before. We show that people overshoot in both the two-player PCD and the multi-player PCD, and people overshoot across multiple rounds with only limited learning. These results differ from the undershooting effect found by Hsee et al. (2021), and the equilibrium effects found in paradigms such as market entry, foraging, and route choice. Third, we attribute the overshooting effect to K0 thinking, and identify two moderators that support this theorizing: one is prediction-prompting and the other is framing. We theoretically propose and empirically demonstrate that people generally overshoot, unless they are explicitly prompted to predict the behavior of their counterpart or if the dilemma is framed in such a way that would naturally prompt the players to consider the behavior of their counterpart.[7] Such framing includes the same/different frame in the two-player PCD, and the more/fewer frame in the multi-player PCD. The above analysis also explains why Hsee et al. (2021) found undershooting instead of overshooting: they found undershooting because they studied only the multi-player PCD and used only the more/fewer frame. In the rest of the article, we discuss open questions and suggest possible answers.

12.1. Which frame to use

We have covered three frames in this work—the standard frame (as used in all our studies, as well as in most two-player games in the game-theory literature), the same/different frame, and the more/fewer frame. Of these three frames, the standard frame is the most precise and least ambiguous method to describe a dilemma; it can be used to describe both the two-player PCD and the multi-player PCD, the only caveat being that if the multi-player PCD involves too many players (e.g., more than 10), this frame may become too complicated for the average person to comprehend. On the other hand, the same/different frame makes more sense in the two-player PCD than in the multi-player PCD, and the more/fewer frame makes more sense in the multi-player PCD than in the two-player PCD.

Objectively, these frames are equivalent, in the sense that the same/different frame conveys the same underlying information as the standard frame in the two-player PCD, and the more/fewer frame conveys the same underlying information as the standard frame in the multi-player PCD. Despite the objective equivalence, our theory predicts and our studies demonstrate that these frames engender different thinking processes and lead to different behaviors: The standard frame engenders K0 thinking and leads the players to overshoot, whereas the same/different frame and the more/fewer frame engender K1 thinking, decrease the players' proclivity to overshoot, and may even lead them to undershoot. Therefore, which frame to use for a PCD depends on a combination of the type of PCD one wants to describe and the effect one wants to have.

12.2. Other thinking styles

While we have focused on K0 thinking and K1 thinking in this research, there are other thinking styles. For example, players may choose randomly, either because they do not know which option to choose, or because they believe it is the best strategy. Players may also adopt thinking styles that cannot be described using the thinking-level framework. For example, people may adopt a "conformity" heuristic—choosing the option that they believe their counterpart would choose, or adopt an "inferiority-aversion" heuristic—choosing the option that they believe will prevent them from being worse off than their counterpart. In the reason-exploration parts of Study 2 and Study 3, we explored some of those possibilities, and we also gave participants the option to report "other reasons." Based on the reason-exploration data, it seemed that most participants adopted K0 or K1 thinking.

As noted earlier, which thinking level people adopt is context-dependent. For example, Arad and Rubinstein (2012) found that the most common thinking level in the 11–20 Game is K1, whereas Crawford et al. (2008) found a mixture of K0 and K1 thinkers in the X-Y Game, and Camerer et al. (2004) found a mixture of K1 and K2 thinkers in the Beauty Contest Game. Our current research contributes to the extant behavioral literature by showing that, even for the same game, different frames can engender different thinking levels. We hope that the present research will stimulate future research to further investigate this topic

[7] Another condition that may counter the overshooting effect is when the large pool is so much larger than the small pool that the overshooting effect is supressed by a ceiling effect or overridden by a regression-toward-the-mean effect. However, these are statistical artifacts, not psychological effects.

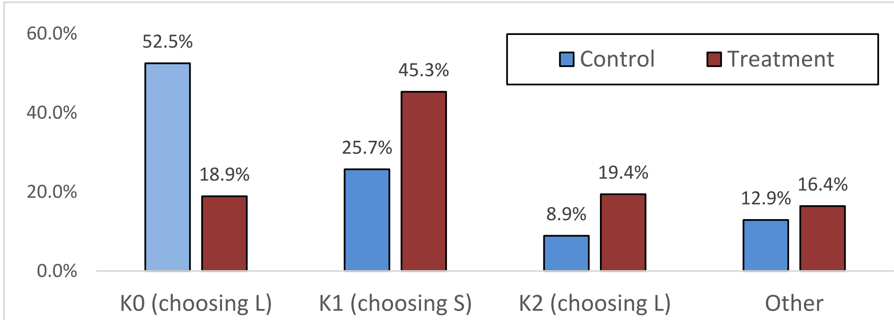

Fig. 3. Relationship between Framing and Thinking Level in Study 6.

and identify factors that influence thinking levels and other thinking styles.

12.3. Limitations and future directions

Our experimental design prioritizes internal validity. As such, a major limitation of our research is its generalizability to real-world settings. Our experimental paradigm omits many elements that are present in real-world contexts. For instance, in our studies, the players were not allowed to communicate, but in real-world interactions, people may have a chance to communicate with each other. Our studies were either hypothetical or provided low incentives, but in real life, the stakes could be high. In our research, we examine only the average pattern of all participants, but in reality, people with different personalities and different backgrounds may behave differently. We hope this research will inspire future work to extend the present research to real-life settings and explore moderators that differ from the experimental settings and the real world.

Open practice

All studies, measures, manipulations, and data/participant exclusions are reported in the manuscript or its Supplementary Material. Data are posted on Open Science Framework: https://osf.io/zfcxr/?view_only=20dbde2ba8994b9aba33280e762633a4. Study 1 preregisteration: https://aspredicted.org/S6F_5DW.

CRediT authorship contribution statement

Christopher K. Hsee: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Xilin Li:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ying Zeng:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesp.2025.104775.

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