Theory and Application of Spatiotemporal Framing Effects: An Exploration

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Abstract

"Understanding and improving decision-making" is considered a fundamental issue that behavioral decision researchers should prioritize. Investigating framing effects can simultaneously achieve the goals of understanding and improving decision-making. Currently, research and application of framing effects have primarily focused on multi-attribute and risky decision-making domains, while exploration of intertemporal and spatial decision-making domains, which are ubiquitous in real life, remains relatively underexplored. Given the interconvertible relationship between time and space, this study urgently seeks to explore whether a class of spatiotemporal framing effects exists (i.e., describing the same decision problem using temporal or spatial frames leads to changes in choice preferences) that can serve a practical function in understanding and improving spatiotemporal decision-making. This study proposes to employ multiple methods, including cognitive-behavioral experiments, eye-tracking experiments, and field experiments, to sequentially examine the phenomenon of spatiotemporal framing effects (Study 1), psychological mechanisms (Studies 2 and 3), and nudging effects (Study 4), thereby providing convergent evidence to answer the proposed questions. The research findings will offer a novel research perspective and paradigm for understanding intertemporal and spatial decision-making, and provide psychological recommendations for nudging individuals and organizations to make superior decisions.

Full Text

Theoretical and Practical Exploration of the Time–Space Framing Effect

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Abstract

"Understanding and improving decision-making" is considered a major priority for researchers in behavioral decision-making. Investigating framing effects can simultaneously achieve both goals. Currently, framing effects are mainly studied and applied in multi-attribute and risky decision-making domains, with relatively less attention directed toward intertemporal and spatial decision-making despite their ubiquity in real life. Given the interchangeable relationship between time and space, this project urgently seeks to explore whether a time–space framing effect exists—specifically, whether describing the same decision problem using temporal versus spatial frames leads to shifts in choice preferences—and whether such an effect can play a practical role in understanding and improving spatiotemporal decisions. Through cognitive-behavioral experiments, eye-tracking studies, and field experiments, this research will sequentially examine the phenomenon of the time–space framing effect (Study 1), its psychological mechanisms (Studies 2 and 3), and its nudging effectiveness (Study 4), thereby providing convergent evidence to answer these questions. The findings will offer a novel research perspective and paradigm for understanding intertemporal and spatial decision-making, while providing psychological recommendations to help individuals and organizations make better decisions.

Keywords: intertemporal choice, spatial choice, framing effect, psychological mechanism, nudge

1. Problem Statement

Humans are constantly making decisions. In 2012, Eric Wargo, Editorial Director of the Association for Psychological Science (APS), noted in a cover article titled "The Mechanics of Choice" in *Observer* that "understanding and improving decision-making will undoubtedly become an increasingly high priority for psychologists of all stripes" (Wargo, 2012). Previous decision-making research has largely focused on "understanding" while neglecting the practically significant goal of "improving." Behavioral scientists have proposed using "nudge" methods to improve and guide people's decisions—methods that do not prohibit any options, restrict freedom of choice, employ economic levers, or resort to commands and instructions, but merely alter the choice architecture people face to encourage behavioral changes in desired directions (He et al., 2018; Thaler & Sunstein, 2008). Among various nudging techniques, the framing effect—where describing the same problem with different frames changes people's preferences (Framing Effect; Tversky & Kahneman, 1981)—is considered a relatively effective and low-cost means of nudging decision-making behavior.

Studying framing effects can simultaneously achieve the dual goals of understanding and improving decisions. For instance, in the risk domain, Tversky and Kahneman (1981) discovered that for the same risky decision problem, people exhibit risk aversion when outcomes are described using a "gain" (positive) frame, but risk-seeking when described using a "loss" (negative) frame, producing the classic gain–loss framing effect. Based on this finding, Tversky and Kahneman further refined Prospect Theory to better explain this effect (Tversky & Kahneman, 1992). In real-world medical contexts, doctors can leverage framing effects to nudge decision-making—for example, describing disease or medication risks using a loss frame (versus a gain frame) can increase people's willingness to engage in preventive behaviors such as using male hormonal contraceptives or adopting sun protection measures (O'Connor et al., 2005; Thomas et al., 2011). In multi-attribute decision-making, Levin et al. (1985) identified the "attribute framing effect," where consumers show higher purchase intention when the same piece of beef is described as "75% lean" (positive frame) rather than "25% fat" (negative frame) (Levin & Gaeth, 1988)—a finding widely applied in consumer contexts to promote or discourage consumption. Larrick and Soll (2008) discovered the "MPG illusion," where using GPM (gallons per 100 miles) instead of MPG (miles per gallon) to measure fuel efficiency makes the benefits of improved fuel economy more transparent, encouraging people to choose more energy-efficient vehicles. This finding can help governments and organizations develop better industry guidelines to promote pro-environmental behavior. Thus, various framing effects discovered in risk and multi-attribute decision domains not only enhance our understanding of decision-making mechanisms but also demonstrate effective nudging potential in real-world contexts such as healthcare, consumption, and environmental protection.

However, we observe that in intertemporal and spatial decision domains—which are intimately connected to daily life, travel, and other activities—there is almost no direct research examining framing effects. Only a few studies focused on "understanding decisions" have identified anomalies that might be considered framing effects, such as the date/delay effect in intertemporal choice and unit effects for time, distance, and money. The date/delay effect refers to the phenomenon in intertemporal decisions (sooner-but-smaller option, SS, vs. later-but-larger option, LL) where describing delay times using dates (e.g., October 1) rather than delays (e.g., in 3 months) increases preference for the LL option (Read et al., 2005). Time/distance/money unit effects involve manipulating numerical units on temporal (e.g., converting between years, months, days), spatial (e.g., converting between miles, yards), or outcome (e.g., converting between dollars, euros, yen) dimensions to alter preferences (Cai, 2018; Jiang, 2013; Burson et al., 2009; Pandelaere et al., 2011; Shen et al., 2019). These manipulations can be categorized as "quantitative changes"—altering the magnitude of values within a dimension.

Based on different manipulation approaches to descriptive frames, we have summarized representative framing effects across decision domains in Table 1 . Currently, well-studied and effectively applied framing effects primarily concentrate in multi-attribute and risk decision domains, where manipulations involve changing the descriptive nature of information on certain dimensions—using different valences (e.g., gain vs. loss; lean vs. fat) or units of measurement (GPM vs. MPG). These can be categorized as "qualitative changes"—altering the quality of values within a dimension. However, in intertemporal and spatial decision domains, we know little about whether framing effects based on "qualitative" manipulations exist and can contribute to understanding and improving decisions. Therefore, starting from the current research landscape, this project focuses on exploring "qualitative" framing effects in intertemporal and spatial decision domains.

From a practical perspective, we live in an era of rapid urbanization and fast-paced lifestyles where daily activities and travel are intimately tied to spatiotemporal contexts (Chai et al., 2016). People frequently need to make judgments or choices by trading off spatial distance/time costs against outcome benefits—the former constituting spatial decision problems, the latter intertemporal decision problems (Li, 2016). Indeed, research on these two types of decisions is often inseparable because time is typically embedded in space: greater spatial distances require longer travel times (Mühlhoff et al., 2011). Real-world decision contexts involving spatiotemporal information are countless. At the individual level, commuters may choose between jobs with "short commutes but low pay" versus "long commutes but high pay," or their preferences for current employment may be influenced by commute distance or duration. At the organizational level, developers must decide whether to develop locations that are nearby with limited growth prospects or distant with greater potential, and location decisions may be influenced by distance or travel time. Such issues have become common challenges for urban residents and organizations alike, making it crucial to explore how framing effects can scientifically guide or influence people's judgments and decisions.

Both empirical and experimental evidence demonstrate that intertemporal and spatial decisions are closely related, with time and space being mutually convertible (Huang et al., 2023; Casasanto & Boroditsky, 2008; Mühlhoff et al., 2011). When describing the same distance, people can use either spatial units (e.g., 3 kilometers) or equivalent temporal units (e.g., 15 minutes). This suggests that a "qualitative" framing manipulation may exist across intertemporal and spatial domains: the same decision problem can be described using either a spatial frame (as a spatial decision) or a temporal frame (as an intertemporal decision). Consequently, this project investigates: (1) whether a "time–space framing effect" exists in spatiotemporal decision contexts—specifically, whether describing the same decision problem using temporal versus spatial frames changes decision preferences; (2) if such an effect exists, what mechanisms produce it; and (3) whether the time–space framing effect can be leveraged to nudge real-world decision-making. Answering these questions carries theoretical and practical significance: extending classic framing effect research to intertemporal and spatial domains will not only deepen our understanding of these decisions but also help individuals and organizations make choices that change in expected directions.

2.1 Framing Effects in Intertemporal and Spatial Decision Domains and Their Theoretical Explanations

Theoretical models in intertemporal decision-making can be broadly divided into two categories: utility (discounting) comparison models and dimensional comparison models. Although spatial decision-making has not developed specific mature theoretical models, researchers typically adapt utility/discounting comparison and/or dimensional comparison models from intertemporal choice to understand spatial decisions (Kuang et al., 2023; Luckman et al., 2020). As previously noted, researchers have discovered several framing effects while developing these models (see Table 1). However, because the two types of models make different logical assumptions about decision processes and strategies, their explanations for framing effects also differ.

2.1.1 Explanations from Utility (Discounting) Comparison Models

Utility (discounting) comparison models—such as the discounted utility model (Samuelson, 1937), hyperbolic discounting model (Mazur, 1987), and quasi-hyperbolic discounting model (Laibson, 1997)—assume that decision-makers employ option-based strategies. They multiply each outcome by its corresponding discount rate based on delay time (or spatial distance), independently calculate the discounted utility (total discounted value) for each option, and then select the option with greater utility. According to this logic, framing effects arise because the relative magnitude of utility values (discounted values) for the two options changes across framing conditions (i.e., Option A has greater utility under one frame, while Option B has greater utility under another), leading to preference shifts. For example, some researchers argue that the date/delay effect occurs because using dates to represent time substantially reduces the discount rate and alters the shape of the original hyperbolic curve, changing people's discounted utility valuations of the two options and thus shifting choices (Read et al., 2005; Zauberman et al., 2009). This explanation logic aligns with Prospect Theory's account of gain–loss framing effects in the risk domain (Kahneman & Tversky, 1982; Tversky & Kahneman, 1992).

2.1.2 Explanations from Dimensional Comparison Models

Dimensional comparison models, such as the equate-to-differentiate model (Li, 1994, 2016) and tradeoff model (Scholten & Read, 2010), assume that decision-makers employ dimension-based strategies. They first compare the differences between two options on the time/spatial dimension (denoted as ΔTimeA,B/ΔSpaceA,B) and the outcome dimension (denoted as ΔOutcomeA,B), then compare the relative magnitudes of these dimensional differences (ΔOutcomeA,B vs. ΔTimeA,B/ΔSpaceA,B), and finally base their decision on the dimension with the larger difference, selecting the option that is superior on that dimension. According to this logic, framing effects arise because different frames change the relative magnitude relationship between ΔOutcomeA,B and ΔTimeA,B/ΔSpaceA,B, causing the decision to be based on a different dimension and ultimately shifting preferences (i.e., under one frame, ΔOutcomeA,B is larger, leading to outcome-based decisions and selection of the outcome-superior option; under another frame, ΔTimeA,B/ΔSpaceA,B is larger, leading to time/space-based decisions and selection of the time/space-superior option). For example, Jiang (2013) explained the date/delay effect by arguing that compared to delay descriptions, date descriptions reduce the perceived difference between options on the time dimension (i.e., ΔTimeA,B becomes smaller), altering the relative magnitude relationship between ΔTimeA,B and ΔOutcomeA,B and making people more likely to base decisions on the outcome dimension, thus selecting the superior LL option. This explanation aligns with those for money/distance/time unit effects in studies by Pandelaere et al. (2011), Cai (2018), and Jiang (2013).

Overall, current research on framing effects in intertemporal and spatial decision domains faces several unresolved issues: (1) within each domain, existing studies primarily involve "quantitative" framing manipulations (see upper right of Table 1), while "qualitative" framing manipulations remain unexplored; (2) two different decision models currently explain framing effects, but it remains unclear which provides better explanatory power. Fortunately, the theoretical development trajectories of intertemporal and spatial decisions are similar, and substantial evidence indicates that time and space share an inseparable relationship, providing valuable theoretical references for exploring "qualitative" time–space framing effects.

2.2 Time–Space Interchangeability and Preliminary Exploration of the Time–Space Framing Effect

2.2.1 Mutual Convertibility of Time and Space

Both empirical and experimental evidence demonstrate that time and space are inseparable and mutually convertible. First, they can be objectively and equivalently converted using the formula "spatial distance = time × constant speed"—greater spatial distances require longer travel times. Second, they share conversion relationships in subjective psychological experience, as people frequently use spatial metaphors to represent time (Boroditsky, 2000; Casasanto & Boroditsky, 2008; Ulrich & Maienborn, 2010), such as "I can finish this task in the time it takes to walk one kilometer." Additionally, research has found that damage to the right parietal cortex simultaneously disrupts time and space perception, suggesting shared neural foundations for temporal and spatial perception (Bueti & Walsh, 2009). According to construal level theory and psychological distance theory, attributes such as probability, time, space, and social distance corresponding to decision outcomes can all be represented as psychological distance from the decision-maker, influencing decisions (Liberman et al., 2007; Liberman & Trope, 2008; Trope & Liberman, 2010). Numerous empirical studies show that different distance dimensions are psychologically homogeneous, can influence and substitute for one another in mental space, and ultimately affect decisions through the common single dimension of psychological distance (Chen & He, 2014; Jiang & He, 2017; Huang et al., 2016).

Notably, although temporal and spatial distances share similar connections in language, conceptual structure, and mental representation, different distance dimensions hold varying importance for individual perception and understanding (Hua & Lü, 2012). Spatial distance is more fundamental, learned earlier, communicates information more clearly, creates less ambiguity, and is easier to communicate, whereas time is considered more abstract than space, and the relationship between time and space is asymmetric (Casasanto et al., 2010; Casasanto & Boroditsky, 2008). People's perception of time is more susceptible to contextual factors, such as physical effort required during travel (Block et al., 2016; Roxani, 2021; Schwarz et al., 2013). Consequently, we hypothesize that when temporal and spatial distances are objectively and equivalently converted, the asymmetric relationship between time and space may cause differences in people's subjective perception of these two types of psychological distance, thereby affecting their decisions or judgments.

2.2.2 Preliminary Exploration of the Time–Space Framing Effect and Its Mechanisms

Recent research has begun exploring whether "qualitative" time–space framing effects exist in intertemporal and spatial decision domains. Kuang et al. (2023) used the conversion formula "spatial distance = time × constant speed" to equivalently transform "spatial distance" information in spatial decision problems into "temporal distance" information in intertemporal decision problems (e.g., setting speed at "30 km/hour," making "30 km" equivalent to "1 hour"), constructing logically equivalent pairs of "spatial frame" and "temporal frame" decision problems to examine whether choice preferences differ across descriptive frames. Below is an example from a "job selection" decision scenario, where participants were asked to choose their preferred option (A or B) based on the cover story:

[**Cover Story**]
Assume you are job hunting and have received offers from two companies. You can only commute to these companies by subway. Note: The average subway speed is approximately 0.60 km/minute (36 km/hour). Which would you choose?

[**Spatial Frame**]
Company A: Approximately 3 km from your home by subway, salary ¥19,000/month
Company B: Approximately 10 km from your home by subway, salary ¥21,000/month

[**Temporal Frame**]
Company A: Approximately 5 minutes from your home by subway, salary ¥19,000/month

Company B: Approximately 16 minutes from your home by subway, salary ¥21,000/month

Across a series of decision scenarios with varying parameters, Kuang et al. (2023) consistently found that choice preferences changed when the same decision problem was described using spatial versus temporal frames. They named this novel finding the "time–space framing effect." Additionally, the study explored the underlying mechanism by measuring changes in dimensional differences between options and differences in discounted utility values across temporal and spatial frames, comparing the explanatory power of the dimension-comparison-based equate-to-differentiate model versus the utility-comparison-based discounting model. Results showed that the equate-to-differentiate model could effectively explain the effect, while the discounting model could not. Specifically, the time–space framing effect occurs because temporal and spatial frame descriptions alter decision-makers' judgments about the relative magnitude of differences between options on the "virtual" (time/space) dimension versus the "real" (outcome) dimension, causing the decision to be based on a different dimension and ultimately changing the choice outcome—not because the frames alter judgments about the relative magnitude of discounted values.

2.2.3 Unresolved Issues

Despite Kuang et al.'s (2023) initial discovery of the time–space framing effect and preliminary exploration of its mechanism, several issues remain unresolved:

1. **Generalizability to single-option contexts.** Prior research has only examined two-option binary choice scenarios, yet in real life, people more frequently face single-option or single-plan decisions. For example, food delivery and e-commerce apps typically present only one delivery option, and consumers decide whether to order based on the presented delivery distance or duration; renters may select apartments based on travel information (e.g., walking distance/time to subway stations) provided on rental platforms; citizens may decide whether to participate in fitness programs based on given exercise plans (e.g., mileage/time). Therefore, it is necessary to investigate whether the time–space framing effect can be detected in single-option decision contexts. Answering this question will not only provide richer evidence for the effect's replicability but also carry important practical significance. For these examples, relevant enterprises or app developers could use "personalized" descriptive frames to increase consumer ordering intentions; rental platform publishers could enhance property attractiveness and facilitate transactions; fitness program designers could boost public participation in exercise.

2. **Mechanism applicability to single-option scenarios.** The decision models used to explain the time–space framing effect in prior research (utility comparison vs. dimensional comparison) only apply to two-option scenarios and cannot readily explain single-option decisions because no

alternative option exists for comparison. Moreover, Levin et al. (1998) noted that framing manipulations in single-option contexts (e.g., manipulating the positive/negative valence of an attribute) represent the most straightforward approach for directly and effectively understanding how descriptive frames influence information processing at a fundamental level. Therefore, this study focuses on investigating the mechanism underlying the time–space framing effect in single-option scenarios, aiming to develop a theoretical model that can simultaneously explain and predict the effect in both single-option and two-option contexts.

3. **Limited methodological approaches in prior mechanism testing.** Previous research used indirect, static methods by measuring mediating variables to test mechanisms, finding that the equate-to-differentiate model provided effective explanations. However, more intuitive, dynamic process evidence is lacking regarding whether individuals truly employ dimension-comparison strategies when processing spatiotemporal decisions. Prior research shows that behavioral outcome data alone cannot accurately reveal people's true decision processes (Wei & Li, 2015; Green et al., 1994; Scholten & Read, 2010). Eye-tracking technology, which focuses on cognitive processes, can more directly reflect individuals' decision processes and compensate for limitations of purely behavioral methods based on outcome fitting (Wei & Li, 2015; Ashby et al., 2016; Glaholt & Reingold, 2011). Therefore, this study will enhance methodological diversity in subsequent research to obtain more convergent evidence.

4. **Unknown practical nudging effectiveness.** While framing effect research has demonstrated promising potential applications, prior studies have only detected the time–space framing effect in virtual laboratory settings. Its nudging effectiveness in real-world contexts—especially the more applicable single-option scenarios—awaits examination. This study will therefore focus on testing the practical nudging effects of time–space framing in single-option contexts.

2.3 Summary

Based on the above literature review and analysis, this project proposes three research objectives: (1) to detect the existence of the time–space framing effect in single-option decision contexts, which have broader real-world applicability; (2) to develop a theoretical model that can simultaneously explain and predict the time–space framing effect in both single-option and two-option contexts; and (3) to examine the real-world application value of time–space framing effects for nudging decision-making behavior. This study aims to provide multiple convergent evidence sources for better understanding and improving spatiotemporal decisions, while offering psychological recommendations to help individuals and organizations make superior decisions.

3. Research Design

This project plans to achieve these objectives through four studies. Study 1 will use questionnaire surveys to explore whether people's decision preferences for a single option change significantly when described using temporal versus spatial frames. Studies 2 and 3 will respectively employ static behavioral outcome testing and dynamic eye-tracking technology to reveal the psychological process mechanisms underlying the time–space framing effect in both single-option and two-option contexts. Study 4 will use a field quasi-experimental design to explore the nudging effectiveness of time–space framing in real-life contexts. The project framework is illustrated in Figure 1 [Figure 1: see original paper].

3.1 Study 1: Testing the Existence of the Time–Space Framing Effect in Single-Option Contexts

Study 1 will adapt the experimental paradigm from Kuang et al. (2023), manipulating temporal and spatial frames to equivalently describe distance information for a single option based on the formula "spatial distance = time × constant speed," to examine whether the time–space framing effect exists in single-option contexts. Previous research (including meta-analyses) has identified numerous factors influencing the emergence and magnitude of framing effects, such as decision context specificity, task response mode, option configuration, experimental design, and individual differences (e.g., mathematical ability, need for cognition) (Kuang et al., 2023; Kühberger, 1998; Levin et al., 1987, 2002; Peters et al., 2006; Simon et al., 2004; Stanovich & West, 1998). Accordingly, this study will design multiple sub-studies to test the robustness and boundary conditions of the time–space framing effect in single-option contexts by varying experimental materials (different decision scenarios, option parameters), employing different experimental designs (within-subjects, between-subjects), and recruiting different participant samples (e.g., participants with scenario-relevant characteristics, varying mathematical ability or need for cognition levels).

Specifically, Study 1 will primarily examine whether people's preferences for a single option/plan change significantly when its distance information is equivalently described using temporal and spatial frames. If preferences change significantly, the time–space framing effect exists in single-option contexts; if not, it does not. For example, in a "job willingness evaluation" scenario, participants will assess their willingness to accept a job (using a 6-point Likert scale: 1 = very unwilling, 6 = very willing) based on commute descriptions in different frames:

[**Spatial Frame**]
Assume you are job hunting and have received an offer from a company. You can only commute by subway, which requires 15 km of subway travel. How willing are you to accept this job? (Note: Average subway speed is approximately 0.60 km/minute [36 km/hour]).

[**Temporal Frame**]

Assume you are job hunting and have received an offer from a company. You can only commute by subway, which requires 25 minutes of subway travel. How willing are you to accept this job? (Note: Average subway speed is approximately 0.60 km/minute [36 km/hour]).

3.2 Study 2: Testing the Psychological Mechanism of the Time–Space Framing Effect—Evidence from Static Behavioral Outcomes

Study 2 will use cognitive-behavioral experiments to further reveal the psychological mechanism underlying the time–space framing effect. According to psychological distance and construal level theory, spatial and temporal distances are important dimensions of psychological distance that are automatically evaluated and associated with mental construal levels, thereby influencing judgments and decisions (Trope & Liberman, 2010). What determines construal level is not objective spatial distance in meters or objective temporal distance in seconds, but subjective perception of distance magnitude at the psychological level (i.e., psychological distance). In fact, people's subjective perceptions of temporal and spatial distances often do not perfectly correlate with objective distances (Han & Gershoff, 2018). Some research suggests that a key difference in how people understand spatial versus temporal information lies in perceived control. People feel greater control over spatial distance, believing it "can be controlled by moving closer to or farther from things," whereas they cannot actively approach or move away from time points, making temporal distance "uncontrollable" (Han & Gershoff, 2018; Trope & Liberman, 2010). Han and Gershoff (2018) demonstrated that this difference leads to inconsistent responses when people subjectively evaluate the "nearness" or "farness" of spatial versus temporal distances for the same object. According to Liberman et al. (2007), when temporal and spatial frames equivalently describe objective distances, they may appear different due to "cognitive" or "motivational" psychological factors (Liberman et al., 2007). Furthermore, as previously mentioned, people perceive spatial and temporal information at different levels of abstraction, with time being more abstract than space (Casasanto et al., 2010; Casasanto & Boroditsky, 2008). When converting temporal and spatial distances using constant speed, the two may not exhibit a one-to-one mirrored relationship in subjective psychological experience but rather an asymmetric relationship.

In summary, we hypothesize that differences in perceived control and abstraction levels for time and space may lead to different subjective perceptions of temporal and spatial unit distances (i.e., different psychological distances), thereby influencing judgments and decisions. Specifically, in single-option contexts, time–space framing manipulations may alter people's judgments about the psychological "nearness" or "farness" of temporal/spatial distances in the option, consequently changing their preferences for that option (see path X→M1→Y1 in Figure 2 [Figure 2: see original paper]). In two-option contexts, the fundamental reason why time–space framing changes the relative magnitude judgment of virtual versus real dimensional differences is that the manipulation alters individuals' distance perception (i.e., psychological distance changes) (see path X→M1→M2→Y2 in Figure 2). Thus, we propose a theoretical model that can simultaneously explain the time–space framing effect in both single-option and two-option contexts, as illustrated in Figure 2.

When examining psychological mechanisms, two general approaches exist: First, following Baron and Kenny (1986), mediation analysis can effectively explain internal influence mechanisms when causal relationships between variables exist theoretically or empirically. Second, Spencer et al. (2005) proposed that simultaneously manipulating independent and mediating variables allows for stronger causal chain inferences than measuring mediators alone, better revealing the proposed psychological process. Therefore, this study will use both direct measurement and indirect manipulation of the core mediating variable (psychological distance) in single-option and two-option contexts to provide multiple sources of evidence testing whether the time–space framing effect's mechanism follows our proposed theoretical model. For two-option contexts, measurement of "dimensional difference comparison outcomes" will follow Kuang et al.'s (2023) paradigm using a six-point intuitive analog scale to assess subjective judgments of relative differences between options across dimensions (for detailed task description, see Kuang et al., 2023). Measurement of "psychological distance" will adapt previous research methods (Han & Gershoff, 2018), asking participants to subjectively evaluate the temporal/spatial distance in each option. Using the "job willingness evaluation" scenario from Section 3.1 as an example, participants in different framing conditions would evaluate:
[**Spatial Frame**]**:** "How far do you subjectively perceive the distance of '15 km of subway travel'?"
[**Temporal Frame**]**:** "How far do you subjectively perceive the distance of '25 minutes of subway travel'?"
(Using a 9-point Likert scale: 1 = very near, 9 = very far).

3.3 Study 3: Testing the Process Mechanism of the Time–Space Framing Effect—Evidence from Dynamic Eye-Movement Processes

Study 2 used indirect, static measurement or manipulation of mediating variables to test the psychological mechanism, lacking direct, dynamic process evidence. Therefore, Study 3 aims to employ dynamic eye-tracking technology to reveal the process mechanism of the time–space framing effect, identifying objective and effective eye-movement indicators to explain and predict decision-making behavior and processing. Specifically, this study will adopt a research approach coupling decision-makers' eye-movement patterns with their behaviors to explore the eye-movement patterns exhibited when decision-makers perform spatiotemporal decision tasks in single-option and two-option contexts, seeking objective eye-movement indicators that effectively reflect decision strategies and processing.

At the behavioral level, this study will examine whether collected data support the theoretical model proposed in Study 2—that is, whether time–space framing manipulations influence individual choice preferences or behaviors by affecting psychological distance changes (which in two-option contexts further affect dimensional difference judgments or discounted value differences).

At the eye-movement process level, this study will analyze eye-tracking data collected during single-option preference evaluations or two-option binary choices. The focus will be on eye-movement indicators revealing decision strategies, such as the SM (Strategy Measure) value reflecting the degree of option-based versus dimension-based information search (Böckenholt & Hynan, 1994) and the similarity of scan paths (Zhou et al., 2016). More importantly, the study will examine relationships between actual choice behaviors, subjectively reported core variables (psychological distance, dimensional differences, discounted value differences), and eye-movement indicators reflecting processing depth and complexity (e.g., reaction time, fixation count, fixation duration, saccade frequency) to identify objective eye-movement indicators that can substitute for or predict decision-making behaviors and internal psychological processes.

3.4 Study 4: Testing the Real-World Nudging Effectiveness of Time–Space Framing

The first three studies examine the time–space framing effect and its psychological mechanisms in hypothetical or laboratory contexts. Study 4 focuses on investigating whether time–space framing can serve as an effective nudging tool in real-life contexts (e.g., presentation of outdoor exercise routes, food delivery plans, navigation schemes) to shift decision preferences in desired directions. For example, a field experiment could involve a labor union organizing outdoor exercise activities, where activity notices use three framing approaches: "time information only," "spatial information only," and "both time and spatial information." By analyzing differences in employees' preferences for participation and actual participation numbers across these three framing conditions, we can evaluate which descriptive frame most effectively nudges exercise behavior.

Notably, for practically significant nudging research, the ideal outcome would be providing practitioners with a clear guide (e.g., when spatial framing is more effective than temporal framing for nudging a particular decision, and vice versa). However, based on previous framing effect research, we anticipate that a "one size fits all" guide may not satisfy all decision problems. For instance, the classic Asian disease problem initially provided clear guidance: use a "loss" frame to encourage risk-seeking and a "gain" frame to encourage risk-aversion. Unfortunately, this rule was overturned by subsequent research revealing a "fourfold pattern" of risk preferences across outcome probabilities (Tversky & Kahneman, 1992) and outcome magnitudes (Li, 1998; Li & Xie, 2006; Markowitz, 1952; Scholten & Read, 2014). This means that when using gain–loss framing to nudge decisions, specific decision contexts and applicability must be considered. Similar patterns have emerged in preliminary time–space framing research.

Kuang et al. (2023) found that across different two-option decision contexts, the direction/pattern of preference changes caused by time–space framing manipulations varied: in contexts involving subway, car, and high-speed rail travel (requiring minimal physical effort; Roxani, 2021), spatial frames increased the proportion choosing the "closer distance" option compared to temporal frames; conversely, in walking contexts (requiring physical effort), temporal frames increased the proportion choosing the "closer distance" option compared to spatial frames. This suggests that physical effort requirements may be an important factor influencing the direction of time–space framing effects. Previous research indicates that physical effort (and associated arousal) may increase attention to temporal information (Schwarz et al., 2013), and high physical effort correlates positively with longer time perception (Block et al., 2016; Roxani, 2021). We therefore hypothesize that physical effort levels primarily affect people's perception of temporal distance but have less impact on spatial distance perception. Consequently, spatial framing may be more effective for increasing travel willingness when physical effort is required, whereas temporal framing may be more effective when little or no physical effort is required. Furthermore, based on previous research on factors influencing framing effect magnitude, we hypothesize that time–space framing nudging effects may vary across individuals—for example, the manipulation may be more effective for those with lower need for cognition or poorer mathematical ability, as they are more susceptible to descriptive frames (Kuang et al., 2023; Peters et al., 2006; Simon et al., 2004).

In summary, as mentioned in Section 3.1, Study 1 will examine factors such as decision context specificity, option configuration (e.g., applicable range of objective physical distances), and individual differences (e.g., sensitivity/familiarity with temporal/spatial information, need for cognition, mathematical ability) as potential moderators. Building on Study 1's findings, this nudging study will further validate how these factors affect real-world nudging effectiveness, aiming to provide practitioners with more precise, personalized nudging recommendations.

4. Theoretical Contributions and Innovations

Previous research has shown that framing effects in multi-attribute and risky decision domains not only advance theoretical understanding of decision mechanisms but also effectively nudge people toward expected choices in practical applications. However, past studies have paid little attention to spatiotemporal decision problems involving time and space information that are widespread in reality. This project aims to explore whether a time–space framing effect can effectively contribute to understanding and improving spatiotemporal decisions. Although preliminary research has detected the effect in two-option contexts, the limited decision scenarios and methodologies prevent direct generalization to the more prevalent single-option contexts in reality. Therefore, driven by practical needs, this study focuses on examining the existence and boundary conditions of the time–space framing effect in single-option contexts. Grounded in psychological distance theory, construal level theory, and two major decision-making models (dimensional comparison and utility comparison), we aim to construct a theoretical model that can simultaneously explain and predict the time–space framing effect in both single-option and two-option contexts (see Figure 2), while validating its nudging effectiveness in real-world settings. This study's distinctive contributions and innovations are 主要体现在以下三个方面:

First, previous framing manipulations have involved equivalent transformations within the same domain. For example, attribute framing effects in multi-attribute decisions and classic gain–loss framing effects in risky decisions manipulate the positive/negative valence of attributes or outcomes within the real dimension (categorized as "qualitative" manipulations within domains). Money/time/space unit effects in intertemporal and spatial decisions manipulate numerical units within the same real (outcome) or virtual (time/space) dimension (categorized as "quantitative" manipulations within domains). In contrast, the time–space framing manipulation in this study crosses the important domains of intertemporal and spatial decision-making, representing a new exploration of cross-domain "qualitative" framing manipulations (Figure 3 [Figure 3: see original paper]).

Second, investigating the time–space framing effect and its mechanisms provides a new research perspective and paradigm for better understanding intertemporal and spatial decisions. Although researchers have recognized the close relationship between time and space, most have examined them separately within their respective domains or applied intertemporal decision-making approaches to spatial decisions, with few directly exploring the two through mutual conversion. This study integrates evidence regarding the convertibility of time and space, the similarity in theoretical model development across the two decision domains, and psychological distance and construal level theories to propose a theoretical model that can integrate both single-option and two-option contexts. Using multiple methods including static behavioral outcome testing and dynamic eye-tracking technology, we aim to provide convergent evidence for the decision processes people use in spatiotemporal contexts and the internal reasons for decision changes. It should be noted that although we propose the hypothetical path "time–space framing → psychological distance change → (dimensional difference judgment change) → preference change" to explain the effect in both single-option and two-option contexts, this does not preclude other possible explanatory pathways. Therefore, this study will continuously explore and validate alternative mechanisms during empirical investigation.

Third, this study's expected results may apply a "domain-general" rather than "domain-specific" rule to understand the underlying mechanisms of intertemporal and spatial decisions. Specifically, when processing intertemporal and spatial decisions, objective temporal and spatial distance information is mentally represented as "near" or "far" perceptions along the common single dimension of psychological distance, which subsequently influences judgments and preferences. When processing single-option intertemporal and spatial decisions, decision-makers judge the psychological distance of temporal and spatial information in the option to determine their preference level; subjectively nearer psychological distance leads to stronger preference. When processing two-option intertemporal and spatial decisions, decision-makers tend to adopt a "dimensional comparison" strategy—comparing the relative magnitude of perceived psychological distance differences between options on the time/space dimension versus perceived differences on the outcome dimension (ΔTimeA,B/ΔSpaceA,B vs. ΔOutcomeA,B) and selecting the option superior on the dimension with the larger difference—rather than a "utility comparison" strategy of comparing utility values (UtilityA vs. UtilityB) and selecting the option with greater utility.

Finally, while prior research has been limited to laboratory or virtual contexts, this study will implement a series of field quasi-experiments in real-world settings to provide concrete evidence and recommendations for the time–space framing effect's nudging effectiveness. Examining this nudging effect will be crucial for helping individuals, advertising/marketing industries, and government departments improve decision-making. In today's fast-paced society, people increasingly face spatiotemporal decision contexts. For instance, apps developed by food delivery companies or public transportation departments often present distance information using both temporal and spatial frames. Developers of these apps could leverage the time–space framing effect by adopting "personalized" frame descriptions to nudge target customers or citizens toward directions they might not have initially chosen (Thaler & Sunstein, 2008).

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