Positive Framing Enhances Sense of Agency: The Roles of Outcome Characteristics and Audiovisual Channels*

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Abstract

This study adopted the "losses disguised as wins" paradigm in a simulated slot-machine gambling task to examine whether positive framing can enhance sense of agency and to test the roles of outcome valence, reward magnitude, and audiovisual modalities. The study included four experiments, and sense of agency was measured using the temporal compression paradigm. Experiments 1 and 2 presented outcomes through unimodal visual and auditory channels, respectively; Experiment 3 used congruent audiovisual presentation; and Experiment 4 used incongruent audiovisual framing. Action-outcome time estimates were used to reflect implicit sense of agency. The results showed that the positive framing effect was jointly moderated by outcome valence and reward magnitude, appearing most stably in low-reward loss outcomes. This effect was observed under unimodal visual, unimodal auditory, and congruent audiovisual conditions, whereas no stable evidence was obtained under audiovisual incongruence. Audiovisual congruence may help the effect emerge more stably, but there is as yet no evidence that it is significantly stronger than unimodal presentation, nor can it be confirmed that any one modality has a dominant advantage. The findings indicate that, when objective outcomes remain unchanged, positive framing can enhance sense of agency under specific conditions by altering outcome representation; its effect has outcome-related boundaries and does not depend on a specific sensory modality.

Full Text

Positive Framing Enhances Sense of Agency: The Roles of Outcome Characteristics and Audiovisual Channels*

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Abstract This study adopted a "framing a loss as a gain" paradigm in a simulated slot-machine gambling task to examine whether positive framing can enhance the sense of agency, and to test the roles of outcome valence, degree of reward, and audiovisual channels. The study included four experiments, and sense of agency was measured using a time-compression paradigm. Experiments 1 and 2 presented outcomes through a single visual or auditory channel, respectively; Experiment 3 used audiovisually congruent presentation; and Experiment 4 used audiovisually frame-incongruent presentation. Implicit sense of agency was reflected by estimates of the action–outcome interval. The results showed that the positive-framing effect was jointly moderated by outcome valence and degree of reward, appearing most stably for low-reward loss outcomes; this effect was observed in the single visual channel, the single auditory channel, and under

audiovisually congruent conditions, whereas stable evidence was not obtained under audiovisually incongruent conditions. Audiovisual congruence may facilitate the stable emergence of the effect, but there is as yet no evidence that it is significantly stronger than single-channel presentation, nor can it be determined that one channel has a dominant advantage. The study indicates that, when the objective outcome remains unchanged, positive framing can enhance sense of agency under specific conditions by altering outcome representations; its effect has outcome boundaries and does not depend on a specific sensory channel.

Keywords sense of agency; positive framing; framing a loss as a gain; audiovisual channels; degree of reward

1 Introduction

Sense of agency (SoA) refers to the subjective feeling that one has performed an action and produced an external outcome, and is an important foundation for behavioral subjectivity and responsibility attribution (Haggard, 2017; Moore, 2016). Research has found that action intention, motor prediction, action–outcome congruence, and emotional valence are prospective cues that influence sense of agency. The Optimal Cue Integration model further proposes that retrospective cues related to outcomes are also weighted and integrated according to their availability and reliability (Moore et al., 2009; Synofzik et al., 2009, 2013). Therefore, even when the objective causal relation remains unchanged, how an outcome is represented may, after the fact, reshape an individual' s experience that "I caused this outcome."

Chance-based gambling tasks provide a typical scenario for examining how outcome representation influences sense of agency. Existing studies have found that, although the winning and losing outcomes of slot machines are determined by random procedures, the interface's stop buttons, choice operations, and feedback methods may still induce a sense of control

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misperception and a relatively high sense of agency (Dixon et al., 2018). In the feedback mode of slot machines, "losses disguised as wins" (LDWs) refers to situations in which the player' s wager exceeds the amount returned, objectively resulting in a net loss, but the system treats the returned amount as a winning outcome and accompanies it with winning text, lights, or sound stimuli (Dixon et al., 2010). For example, in slot-machine gambling, after a player wagers 100 credits, when the outcome is "loss of 90 credits" or "win of 10 credits," a positive frame provides feedback such as "gain 10 credits" or "gain 110 credits." Although the two descriptions correspond to the same net outcome, the positive frame may lead individuals to encode and evaluate the outcome more positively (Kahneman & Tversky, 1979; Levin & Gaeth, 1988; Levin et al., 1998). LDWs

increase players'estimates of the number of wins and increase persistent gambling behavior (Barton et al., 2017; Graydon et al., 2021). These studies indicate that players misread outcomes, but they have not answered whether this misreading further enters into the action–outcome attribution process, making a random outcome seem more like one "caused by me."

LDWs are, in essence, a typical feature of attribute framing. Attribute framing refers to describing a certain attribute of an object or event positively or negatively without changing the objective content of the information (Levin et al., 1998). Because it changes only the valenced description of an attribute, attribute framing helps reveal the basic mechanism by which wording affects information processing (Levin et al., 1998). Outcome valence is also an important retrospective cue for the sense of agency. A recent meta-analysis showed that although positive outcomes generally produce stronger implicit sense of agency, reversals may also occur in highly salient or aversive contexts, indicating that the valence effect depends on the influence of the context and other outcome characteristics (Mariano et al., 2025). For example, with regard to the magnitude information of outcomes, Moretto et al. (2011) found that in moral decision-making, severely negative outcomes produce stronger intentional binding than moderately negative outcomes, suggesting that the sense of agency depends not only on whether the outcome is positive or negative, but may also depend on the degree of the outcome. Framing effects are likewise modulated by magnitude and proportion information (Gamliel & Kreiner, 2017, 2020; Holford et al., 2022). Therefore, whether a positive frame can change the sense of agency may be influenced simultaneously by the loss-or-win nature of the outcome and by the magnitude of the outcome.

In addition to outcome characteristics, LDWs usually contain both visual and auditory feedback. Research on multisensory integration holds that different channels are not simply added together, but are weighted according to their reliability in the task (Alais & Burr, 2004; Ernst & Banks, 2002). Existing evidence on the influence of visual and auditory channels, as carriers of outcome feedback, on the sense of agency is inconsistent: auditory feedback can sometimes enhance the sense of agency in human–machine collaboration tasks (Morita et al., 2022), and emotional sounds can also significantly influence implicit sense of agency more than visual pictures (Pan et al., 2024); however, when a task relies on outcome location or numerical information, visual cues may dominate intentional binding (Dai & Hsieh, 2025). This suggests that the relative influence of visual and auditory channels on the sense of agency may depend on the function and reliability of the cues in a specific task.

In slot-machine tasks, LDWs are usually presented jointly through visual and auditory channels. Most studies consider sound to be an important cue for distinguishing wins from losses (Dixon et al., 2014, 2015; Scarfe et al., 2021); however, even when LDWs are presented only through visual text, participants still judge objective losses as wins (Myles et al., 2023). Therefore, the relative weights of visual and auditory channels in the processing of LDWs remain

unclear. Existing research has found that when the uncertainty of visual information increases,

the influence of auditory cues on visual judgment increases accordingly (Heron et al., 2004). Based on this, in slot-machine feedback outcomes, the positive or negative valence conveyed by sound may provide supplementary cues for visual text, especially when the visual representation cannot directly reflect net gains or losses; auditory information may therefore receive greater integrative weight. At the same time, visual text can continuously present specific information about the amount and net gain, and thus may also have an advantage in precise quantitative processing. Hence, whether slot-machine feedback outcome processing is ultimately visually dominated or auditorily dominated still needs to be tested in light of the specific manner in which the outcomes are represented.

In addition, Ernst and Bülthoff (2004) found that different sensory information will be integrated to the greatest extent possible, suggesting that consistency between sensory channels may also influence the integration of framing information. When visual and auditory channels convey consistent outcome frames, the two cues jointly point to the same outcome representation, which may promote cross-channel integration; when one channel presents the outcome as a "gain" while the other presents it as a "loss," audiovisual conflict increases the burden of information integration and conflict control (Fong et al., 2018; Kang Guanlan, Luo Xuexiao, 2020; Wang Aijun et al., 2026). Therefore, positive framing may be more stable when audiovisual information is consistent and may be weakened when audiovisual information is inconsistent.

A commonly used method for measuring sense of agency is the intentional binding (IB) paradigm, also known as the temporal binding paradigm. It primarily refers to the phenomenon whereby a person' s action and the outcome of that action are perceived as closer together in subjective awareness (Haggard et al., 2002). The interval-estimation method in the IB paradigm requires participants to estimate the temporal interval between an action and its outcome in order to calculate the amount of temporal compression. A shorter subjective time estimate indicates stronger temporal compression and a higher sense of agency (Humphreys & Buehner, 2009). This method has also been widely used because of its simplicity and reliability (Bu Yubo et al., 2022).

In summary, the present study will examine the following questions. First, can positive framing in losses disguised as gains enhance individuals' sense of agency over loss and gain outcomes? Second, is the enhancing effect of positive framing on sense of agency jointly moderated by outcome valence and return magnitude? Third, are there differences between auditory and visual channels in the enhancing effect of positive framing on sense of agency, and does its influence differ between single-channel and dual-channel conditions?

This study tests the above questions through two substudies comprising four experiments; the research logic is shown in Figure 1. Study 1 examines, under

Figure 1. Research logic diagram

Figure 1: Figure 1. Research logic diagram

single-channel conditions, the effects of framing condition, outcome valence, and return magnitude. According to the sensory channel through which outcome feedback is presented, two experiments are conducted: Experiment 1 uses a visual single channel, and Experiment 2 uses an auditory single channel. On the basis of the conclusions obtained in Study 1, Study 2 further examines, under audiovisual dual-channel conditions, the effects of framing condition, outcome valence, and return magnitude on sense of agency. The first aim of the study is to explore whether an audiovisual dual channel, compared with single-channel conditions, can strengthen the effect of positive framing; the second aim is to examine whether one modality has a processing advantage in audiovisual integration. Because previous studies (Dixon et al., 2014, 2015; Scarfe et al., 2021) found that when the auditory channel was examined, there may be a confounding effect of audiovisual inconsistency—that is, the weakening effect produced by replacing sound with silence may originate from audiovisual conflict rather than from the influence of the auditory channel—to further examine the weight of influence of the audiovisual channels, the present study sets audiovisual consistency in audiovisual integration, including Experiment 3, which repeats this manipulation under audiovisual-consistent conditions;

Experiment 4 presented a positive frame in one channel and a baseline frame in the other channel to examine audiovisual conflict and channel weight. The following hypotheses were proposed:

(1) The effect of positive framing on sense of agency is jointly moderated by outcome valence and degree of return;

(2) The effect can occur in both visual and auditory single-channel conditions;

(3) The effect pattern under audiovisual congruent conditions is more stable, whereas audiovisual conflict weakens the effect of positive framing. Given that previous studies have reached inconsistent conclusions regarding visual or auditory dominance, the specific channel weight in the present study was treated as an exploratory question.

Figure 1. Research logic diagram

2 Study 1: Effects of Positive Framing, Outcome Valence, and Degree of Return on Sense of Agency Under Single-Channel Conditions

Study 1 presented slot-machine feedback outcomes through visual and auditory channels separately, examining whether positive framing can influence individuals' sense of agency, and whether this effect is jointly moderated by outcome valence and degree of return.

2.1 Experiment 1: Effects of Positive Framing, Outcome Valence, and Degree of Return on Sense of Agency in the Visual Channel

2.1.1 Research Objective To examine the effects of positive framing, outcome valence, and degree of return on sense of agency when outcomes are presented through the visual channel. The experiment used a slot-machine game task, aiming to investigate whether positive framing in a gambling context leads to enhanced sense of agency and the conditions under which this enhancement effect occurs.

2.1.2 Participants G*power 3.1 was used for sample-size calculation. Based on prior research settings, with $\alpha = 0.05$, $1 - \beta = 0.8$ (Chen et al., 2024), and effect size $f = 0.25$, the calculated total sample size was 16 participants. To improve the stability of parameter estimation and to allow for possible data exclusion, this study planned to recruit 48 participants. Because abnormal interruption due to noise contamination occurred during the experiment, 2 participants were excluded. The final sample included 46 participants, comprising 34 female participants and 12 male participants, with $M = 21.80$, $SD = 2.64$.

Participants were right-handed, with normal vision (naked or corrected) and normal hearing. All participants took part in the experiment voluntarily; before the experiment they were unaware of its specific purpose and content, and they received corresponding compensation after the experiment.

2.1.3 Experimental Materials and Apparatus

In this study, the outcome levels were set according to the proportion of points wagered relative to 100 points: 10%, 30%, 60%, and 90%. Specifically, in the loss condition, this variable indicated the proportion of wagered points that was returned; for example, 10% corresponded to receiving 10 points back after wagering 100 points, that is, a net loss of 90 points. In the gain condition, this variable indicated the proportion of net gain relative to the wagered points; for example, 10% corresponded to receiving 110 points after wagering 100 points, that is, a net gain of 10 points. To maintain consistency with the terminology for the relevant variable in slot-machine studies, this paper refers to it uniformly as the return level. By manipulating both outcome valence and return level, we could examine whether the effect of a positive frame on sense of agency exists at specific outcome boundaries. The experimental program was written in MATLAB R2020a and Psychtoolbox 3.0.19.16, and was presented on a 15.6-inch monitor with a screen resolution of 2560 × 1440 and a refresh rate of 165 Hz.

2.1.4 Experimental Design and Procedure

The experiment adopted a 2 (frame condition: baseline frame, positive frame) × 2 (outcome valence: loss, gain) × 4 (return level: 10%, 30%, 60%, 90%)

Figure 2. Difference between the representations of points in the positive frame and baseline frame in terms of reference points

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mixed design. Frame condition was a between-participants variable, and outcome valence and return level were within-participants variables. The dependent variable was participants' estimate of the temporal interval between the keypress and outcome presentation. A shorter subjective time estimate indicates stronger action–outcome temporal compression and a higher implicit sense of agency (Haggard et al., 2002; Humphreys & Buehner, 2009).

Outcome valence was related to the valence represented by the net loss or net gain of the outcome itself in the experiment. When the points obtained by the participant in the game were lower than the points wagered, the outcome was a loss outcome. When the points obtained by the participant in the game were higher than the points wagered, the outcome was a gain outcome. In all experimental tasks in this study, the wager was set at 100 points.

Figure 2. Difference between the representations of points in the positive frame and baseline frame in terms of reference points

Frame condition refers to the frame representation used for game outcomes in the experiment. The difference in frame representation lies in the difference in reference points. As shown in Figure 2, the 0 tick mark in the frame is the reference point. In the baseline frame, outcomes were presented directly in terms of the valence of the outcome itself, namely in the form "lose ……points" or "win ……points." In the positive frame, all outcomes except 0 points were presented in the form "obtain ……points," and 0 points was presented as "thank you for your patronage."

The degree of return in this study was defined as the percentage of the stake points returned to participants in loss or gain outcomes. For example, if a participant' s stake in the experiment was fixed at 100 points, a loss outcome with a 10% return was framed positively as "gain 10 points," whereas in the baseline frame it was "lose 90 points." The four representative levels of return used here were established with reference to the boundary conditions under which prior research found the framing of losses as gains to exert an effect (Salaghe et al., 2023). That study found that the influence of LDWs on gambling behavior varied with the proportion returned. Across the whole game phase, the higher the proportion of LDWs below 25% of the stake, the fewer bets players completed; the higher the proportion of LDWs between 25% and 75%, the more bets players completed; and LDWs above 75% produced behavioral effects relatively close to those of genuine wins. Thus, these findings may reflect boundary conditions for the strength of the representational effect of positive framing in slot-machine gambling. Accordingly, the present study set four levels

Figure 3. Flowchart of Experiment 1

Figure 3: Figure 3. Flowchart of Experiment 1

of return: a low return of 10%, which may produce no effect; medium returns of 30% and 60%, which may produce effects; and a high return of 90%, which is equivalent to a win, in order to comprehensively examine the role of information at different magnitudes in the sense of agency.

The experiment consisted of a time-estimation practice phase and the formal experiment. During the practice phase, participants were required to complete time-perception estimation training. A fixation point "+" appeared at the center of the screen; after 800 ms the fixation point disappeared, and the screen remained blank for a period of time. Participants were told in advance that the blank screen would last for an integer number of milliseconds between 0 and 1000 ms. After the blank screen ended, a question appeared asking participants to estimate the duration of the blank screen. Each interval was repeated 3 times, and feedback on the correct duration was provided; participants then completed 5 blocks of procedural practice for the formal experiment so that they could become familiar with the formal experimental content.

Figure 3. Flowchart of Experiment 1

In the formal experiment, participants experienced a simple slot-machine game. First, an 800 ms fixation point "+" appeared at the center of the screen. Participants then pressed the "←" key or the "→" key to choose one slot machine and simultaneously bet 100 points. The points used by participants in the game came from part of their participant payment. The instructions informed participants in advance that their participant payment consisted of a base reward (10 yuan) and a game bonus. The initial game bonus was 20 yuan, which was converted into 10,000 points at the start of the game (at a ratio of 1:500). Total game points = initial points − cumulative bets + cumulative gains. At the end of the experiment, the total points in the participant's account were converted at the same ratio into the game-bonus portion of their participant payment. Meanwhile, the two slot machines were completely identical in winning probability, outcomes, and the relationship between categories and stake points; this choice was only intended to provide participants with an active task environment so that they could generate a sense of agency and maintain points.

After the participant pressed the key, the slot machine disappeared. After a random interval of 200 ms, 500 ms, or 800 ms, the outcome of the current game was presented on the screen in text form. There were 10 possible game outcomes, including 5 loss outcomes and 5 gain outcomes. In the baseline frame, the outcome received by the participant was the net gain/loss result of the current game, with the previously invested 100 points automatically taken into account at presentation. The outcomes included losses of 100/90/70/40/10 points and gains of 10/30/60/90/550 points. In the positive frame, participants were in-

formed only of the points they obtained, without calculating the wager they had invested; therefore, the outcomes included obtaining no points and obtaining 10/30/60/90/110/130/160/190/650 points.

Each frame included 324 trials. Loss outcomes included complete loss (no points or losing 100 points) for 90 trials; partial loss (obtaining 10/30/60/90 points or losing 90/70/40/10 points) for 36 trials each; and gain outcomes (obtaining 110/130/160/190/650 points or winning 10/30/60/90/550 points) for 18 trials each. At each level, the allocation ratio of the three time intervals was 1:1:1. Complete loss and obtaining 650 points (winning 550 points) served as filler trials, totaling 108 trials, and were not analyzed in the experiment. Through this design of the frequency and magnitude of gambling outcomes, the structural characteristics of commercial gambling designs could be reproduced: that is, in gambling-type games of chance, the expected value provided by the frequency and magnitude of payouts is negative, while also matching the optimal house-edge percentage in average casino advantage analyses: 10%, meaning that, on average, players lose 10 points for every 100 points wagered (Woolley et al., 2013).

After the visual outcome was presented for 500 ms, participants were required to estimate the keypress–outcome time interval between 0 and 1000 ms. After every 54 trials, participants received a 2-minute break. They could freely choose how to rest, but they were not allowed to use their mobile phones during the experiment. Figure 3 shows the experimental procedure.

2.1.5 Results

The experiment used IBM SPSS Statistics 26 for data analysis. As shown in Table 1, with frame condition, outcome valence, and reward magnitude as within-subject variables and time estimation as the dependent variable, a three-factor repeated-measures analysis of variance was conducted, with Bonferroni correction applied.

Main analysis

The main effect of reward magnitude was significant, $F(3, 132) = 3.40$, $p = 0.020$, $\eta_p^2 = 0.07$. Post hoc comparisons indicated that time estimates in the 10% reward condition were lower than those in the 60% reward condition, $p = 0.031$.

Simple-simple effects analysis of frame

The three-way interaction among frame, outcome valence, and reward magnitude was significant after Greenhouse–Geisser correction, $F(1.42, 62.61) = 5.77$, $p = 0.011$, $\eta_p^2 = 0.12$, indicating that the effect of positive framing on the sense of agency depended on the integration of outcome valence and reward magnitude.

To explain the three-way interaction, differences between the positive frame and the baseline frame were further compared under each outcome valence and

reward magnitude. The simple-simple effects analysis found that, among loss outcomes, under the 10% ($p = 0.016$) and 30% ($p = 0.014$) reward conditions,

The time estimates under the positive framing were lower than those under the baseline framing. Under the 60% and 90% return conditions, the differences between the two framings were not significant. For gain outcomes, under the 60% ($p = 0.030$) and 90% ($p = 0.012$) return conditions, the time estimates under the positive framing were lower than those under the baseline framing. Under the 10% and 30% return conditions, the differences between the two framings were not significant. The patterns of results are shown in Figure 4 and Figure 5. These results indicate that the positive framing did not generally enhance the sense of agency; rather, its effect depended on outcome valence and return level: the positive framing mainly enhanced the sense of agency for loss outcomes with low returns and for gain outcomes with high returns.

Table 1 Time estimates at each level in Experiment 1 ($N = 46$)

Framing condition	Outcome valence	Return level	Time estimate ($M \pm SD$)
Baseline framing	Loss	10%	489.69 ± 113.75
Baseline framing	Loss	30%	486.86 ± 99.69
Baseline framing	Loss	60%	475.73 ± 87.43
Baseline framing	Loss	90%	433.56 ± 120.34
Baseline framing	Gain	10%	439.03 ± 105.40
Baseline framing	Gain	30%	464.49 ± 104.83
Baseline framing	Gain	60%	488.26 ± 80.82
Baseline framing	Gain	90%	516.52 ± 119.77
Positive framing	Loss	10%	414.22 ± 88.68
Positive framing	Loss	30%	416.95 ± 84.47
Positive framing	Loss	60%	432.36 ± 88.04
Positive framing	Loss	90%	439.90 ± 98.49
Positive framing	Gain	10%	425.07 ± 98.26

Figure 4. Effect of positive framing on the sense of agency for loss outcomes at different return levels

Figure 4: Figure 4. Effect of positive framing on the sense of agency for loss outcomes at different return levels

Figure 5. The effect of positive framing on sense of agency in gain outcomes at different reward magnitudes

Figure 5: Figure 5. The effect of positive framing on sense of agency in gain outcomes at different reward magnitudes

Framing condition	Outcome valence	Return level	Time estimate ($M \pm SD$)
Positive framing	Gain	30%	434.64 ± 91.14
Positive framing	Gain	60%	429.07 ± 97.76
Positive framing	Gain	90%	431.74 ± 97.59

Figure 4 Effect of positive framing on the sense of agency for loss outcomes at different return levels

Note: The error bars in the figure represent standard errors, $p < 0.05$, **p* < 0.01,** $p < 0.001$. For ease of understanding, when different levels of reward magnitude are presented on the x-axis, the corresponding net loss and net gain outcomes under the baseline frame are also indicated. This study focuses on the role of framing; the significant effects shown in the figure refer only to the significance of differences in sense of agency between different frames. The same applies to the following figures.

Figure 5 The effect of positive framing on sense of agency in gain outcomes at different reward magnitudes

Note: The error bars in the figure represent standard errors, $p < 0.05$, **p* < 0.01,** $p < 0.001$.

Effect of Time on Sense of Agency

In addition, to examine whether the above results were influenced by the actual action–outcome time interval, the actual time intervals (200, 500, and 800 ms) were included in the analysis. The main effect of time interval was significant, $F(1.13, 49.56) = 140.06$, $p < 0.001$, $\eta p^2 = 0.76$. The time estimates in the 200 ms condition were lower than those in the 500 ms and 800 ms conditions, and the time estimates in the 500 ms condition were lower than those in the 800 ms

condition, $ps < 0.001$, indicating that participants could effectively distinguish the three time intervals.

The remaining interactions involving time interval were not significant, indicating that no evidence was found that the pattern of effects of framing, outcome valence, and reward magnitude varied with the actual time interval.

Further Analysis of the Reward-Magnitude Effect

To describe the specific pattern of the three-factor interaction, the simple effects of reward magnitude were tested separately under each combination of framing and outcome valence.

Under the positive-framing condition, regardless of whether the outcome was a net loss or a gain, the simple effect of reward magnitude did not reach significance.

For net-loss outcomes under the baseline frame, the time estimates in the 30% ($p = 0.022$) and 60% ($p = 0.007$) reward conditions were higher than those in the 90% reward condition; the other comparisons did not reach significance.

For gain outcomes under the baseline frame, the time estimates in the 10% reward condition were lower than those in the 60% ($p = 0.028$) and 90% ($p = 0.009$) reward conditions; the time estimates in the 30% reward condition were lower than those in the 90% reward condition, $p = 0.033$. The other comparisons did not reach significance. This result suggests that positive framing may reconstruct individuals' representation of game outcomes, reducing their sensitivity to differences in reward magnitude.

2.1.6 Discussion

The results of Experiment 1 verified Hypotheses 1 and 2 of the present study: in the visual unimodal channel, positive framing enhanced the sense of agency for both loss and gain outcomes, and this effect was moderated by the level of feedback. When the feedback level was 10% and 30%, positive framing enhanced the sense of agency for loss outcomes; when the feedback level was 60% and 90%, positive framing enhanced the sense of agency for gain outcomes. Moreover, the effect size was larger than that of the main effect of feedback level, indicating that the combined effect of framing, outcome valence, and feedback level on the sense of agency was stronger, and that the framing of outcomes could influence the weight of feedback level in shaping the sense of agency.

The main effect of feedback level indicated that, when outcomes were presented through the visual channel, feedback level exerted a relatively large overall influence on the sense of agency; when participants formed internal psychological representations of the relevant outcomes, they relied more on the magnitude information contained in the outcomes.

In addition, supplementary analyses showed that under baseline framing, the

sense of agency changed significantly with feedback level, whereas under positive framing there were no significant differences among different feedback levels. This result preliminarily suggests that positive framing may alter the way individuals process magnitude information in outcomes, reducing the sensitivity of the sense of agency to differences in feedback level. This interpretation will be further analyzed in the discussion of Study 1 in conjunction with the results of the auditory-channel experiment.

2.2 Experiment 2: Effects of Positive Framing, Outcome Valence, and Feedback Level on the Sense of Agency in the Auditory Channel

2.2.1 Research Aim

This experiment explored the effects of positive framing, outcome valence, and feedback level on the sense of agency when outcomes were presented through the auditory channel. A slot-machine game task was used to examine whether, in a gambling context, positive framing leads to enhanced sense of agency and the conditions under which this enhancement effect occurs. At the same time, the differences between the conclusions of Experiment 2 and Experiment 1 would reveal whether the effect of positive framing on the sense of agency differs between the visual and auditory unimodal channels.

2.2.2 Participants

G*Power 3.1 was used to calculate the required sample size. Based on prior research, with $\alpha = 0.05$ and $1 - \beta = 0.8$ (Chen et al., 2024), and using an effect size of $f = 0.25$, the calculated total sample size was 16 participants. To improve the stability of parameter estimation and to account for possible data exclusions, the final sample in this experiment comprised 46 participants, including 34 female participants and 12 male participants, $M = 22.61$, $SD = 3.09$. All participants were right-handed, had normal vision (naked or corrected), and had normal hearing. All participants took part in the experiment voluntarily, were unaware of its specific purpose and content before the experiment, and received corresponding compensation after the experiment.

2.2.3 Experimental Materials and Apparatus

The experimental procedure, display equipment, and software environment were the same as in Experiment 1. Auditory stimuli were presented through headphones; the headphones used were HANG Tianxuan in-ear headphones (Y26), with the sound volume set to 70 dB. Auditory outcomes consisted of two parts: valence tones and spoken reports. The valence tones were used to convey the positive or negative nature of the outcomes, and the spoken reports were used to report the specific outcome and point value. The spoken reports were AI-generated neutral voices.

Sound clips were selected from *Tiger Slot Machine* game sound-effect materials; they were downloaded with payment and under a commitment that they would not be used for any commercial purpose. A total of six sound effects from the slot-machine game were selected as candidate materials, three representing positive outcomes and three representing negative outcomes. Another 27 participants were recruited to evaluate the sound materials, including 21 women and 6 men, with a mean age of 22.56 years ($SD = 2.10$).

Participants rated the pleasantness of each sound on a 9-point scale, where 1 indicated "very unpleasant" and 9 indicated "very pleasant." The results showed that the mean pleasantness of positive tones ($M = 7.10$, $SD = 1.12$) was significantly higher than that of negative tones ($M = 3.21$, $SD = 0.99$), $t(26) = 12.88$, $p < 0.001$, Cohen' s $d_z = 2.48$. On this basis, the positive tone with the highest pleasantness score (Sound 1) and the negative tone with the lowest score (Sound 4) were selected for the formal experiment. The pleasantness difference between the two selected tones was significant: Sound 1 ($M = 7.59$, $SD = 1.39$) scored higher than Sound 4 ($M = 2.56$, $SD = 1.37$), $t(26) = 11.75$, $p < 0.001$, Cohen's $d_z = 2.26$, indicating that the selected tones could effectively convey different outcome valences.

2.2.4 Experimental Design and Procedure

The experiment used a 2 (framing condition: baseline frame, positive frame) × 2 (outcome valence: loss, gain) × 4 (return probability: 10%, 30%, 60%, 90%) three-factor mixed design. Framing condition was a between-participants variable, outcome valence and return probability were within-participants variables, the dependent variable was the time estimate, and the covariate settings were the same as in Experiment 1.

The procedure in Experiment 2 was largely the same as that in Experiment 1, including two phases: a practice experiment and a formal experiment. The difference was that, in Experiment 2, outcomes were presented through auditory stimulation. The specific procedure for the practice experiment was as follows. First, a fixation point "+" appeared at the center of the screen. After 800 ms, the fixation point disappeared, and after a randomly selected integer interval of 0–1000 ms, a pure "beep" tone was presented through the earphones. The pure tone lasted 500 ms. After the audio ended, a question was presented, and participants were required to estimate the interval from the disappearance of the fixation point to the onset of the pure tone. After confirming their estimate, participants received feedback about the actual time interval. Each time interval appeared 3 times, for a total of 30 trials. After the time-practice phase ended, participants completed 5 blocks of practice trials for the formal experiment so that they could become familiar with the formal experimental content.

After the practice experiment ended, participants entered the formal experiment. The formal-experiment procedure was largely the same as that of Experiment 1, with only a slight change in the outcome-presentation phase. The instruc-

Figure 6. Flowchart of Experiment 2

Figure 6: Figure 6. Flowchart of Experiment 2

tions first informed participants that all outcomes of the slot-machine game would be presented through sounds in the earphones. Participants would first hear a tone representing either a loss or a gain, followed by a spoken announcement of the specific game outcome. The settings of the game outcomes did not change and still consisted of 10 types of outcomes. In the baseline-frame condition, when participants obtained a loss outcome, the earphones first presented the negative tone indicating a loss, followed by a spoken announcement: "lose 100/90/70/40/10 points." When participants obtained a gain outcome, the earphones presented the positive tone indicating a gain, followed by a spoken announcement: "win 10/30/60/90/550 points."In the positive-frame condition, the negative tone was presented only when participants did not obtain any points, representing that the outcome was a complete loss, that the participant had earned nothing in the game, accompanied by the spoken message "Thank you for your patronage."For all other outcomes, whether gains or losses, participants heard the positive tone indicating a gain, followed by a spoken announcement: "gain 10/30/60/90/110/130/160/190/650 points."

The number of trials, the frequency of occurrence of each outcome, the setting of filler trials, and the allocation proportions of the three action–outcome intervals were all the same as in Experiment 1. After the outcome sound finished playing, participants estimated, within a range of 0–1000 ms, the time interval from the keypress to the onset of the outcome sound. The experimental procedure is shown in Figure 6.

Figure 6. Flowchart of Experiment 2

2.2.5 Results

The experiment used IBM SPSS Statistics 26 for data analysis. The results are shown in Table 2. With framing condition, outcome valence, and report proportion as within-subject variables and the time-estimation value as the dependent variable, a three-factor repeated-measures analysis of variance was conducted, with Bonferroni correction applied.

Table 2. Time-estimation values at each level in Experiment 2 ($N = 46$)

Framing condition	Outcome valence	Report proportion	Time-estimation value ($M \pm SD$)
Baseline frame	Loss	10%	485.17 ± 66.93
Baseline frame	Loss	30%	491.00 ± 73.80
Baseline frame	Loss	60%	466.88 ± 55.95
Baseline frame	Loss	90%	462.56 ± 73.42

Figure 7. The effect of positive framing on sense of agency in loss outcomes with different reported probabilities

Figure 7: Figure 7. The effect of positive framing on sense of agency in loss outcomes with different reported probabilities

Framing condition	Outcome valence	Report proportion	Time-estimation value ($M \pm SD$)
Baseline frame	Gain	10%	492.04 ± 97.98
Baseline frame	Gain	30%	495.54 ± 78.69
Baseline frame	Gain	60%	503.39 ± 80.96
Baseline frame	Gain	90%	521.35 ± 102.45
Positive frame	Loss	10%	439.59 ± 63.64
Positive frame	Loss	30%	439.39 ± 59.60
Positive frame	Loss	60%	448.95 ± 61.33
Positive frame	Loss	90%	474.36 ± 69.59
Positive frame	Gain	10%	465.34 ± 78.91
Positive frame	Gain	30%	470.39 ± 75.55
Positive frame	Gain	60%	464.11 ± 60.21
Positive frame	Gain	90%	472.13 ± 58.65

Main analysis

The main effect of outcome valence was significant, $F(1, 44) = 12.08,\ p = 0.001,\ \eta_p^2 = 0.22$; the time-estimation value for loss outcomes was significantly lower than that for gain outcomes.

The main effect of frame was not significant, $F(1, 44) = 2.79,\ p = 0.102$. The main effect of reported probability was not significant, $F(3, 132) = 2.10,\ p = 0.104$. The interaction between outcome valence and frame was not significant, $F(1, 44) = 0.53,\ p = 0.469$. The interaction between reported probability and frame was not significant, $F(3, 132) = 1.31,\ p = 0.275$. The interaction between outcome valence and reported probability was not significant after Greenhouse-Geisser correction, $F(2.20, 96.84) = 0.50,\ p = 0.626$.

Simple-simple effect analysis of frame

The three-way interaction among frame, outcome valence, and reported probability was significant after Greenhouse-Geisser correction, $F(2.20, 96.84) = 5.86,\ p = 0.003,\ \eta_p^2 = 0.12$. This indicates that the framing effect in the auditory channel was jointly moderated by outcome valence and reported probability.

Figure 7. The effect of positive framing on sense of agency in loss outcomes with different reported probabilities

Note: Error bars in the figure represent standard errors, $*p < 0.05,\ **p < 0.01,\ ***p < 0.001$.

Figure 8. The effect of positive framing on sense of agency in gain outcomes with different reported probabilities

Figure 8: Figure 8. The effect of positive framing on sense of agency in gain outcomes with different reported probabilities

Figure 8. The effect of positive framing on sense of agency in gain outcomes with different reported probabilities

Note: Error bars in the figure represent standard errors, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

To decompose the three-factor interaction, we further compared the difference between positive framing and baseline framing under different outcome valences and feedback levels. For loss outcomes, under the 10% ($p = 0.022$) and 30% ($p = 0.012$) feedback conditions, the time estimates in the positive-framing condition were lower than those in the baseline-framing condition. Under the 60% and 90% feedback conditions, the differences between the two framing conditions did not reach significance. For gain outcomes, under the 60% ($p = 0.069$) and 90% ($p = 0.052$) feedback conditions, the time estimates in the positive-framing condition were numerically lower than those in the baseline-framing condition, but the differences only reached marginal significance; the framing differences under the 10% and 30% feedback conditions were also nonsignificant. The pattern of results is shown in Figures 7 and 8.

These results indicate that the positive-framing effect in the auditory single-channel condition mainly emerged for low-feedback loss outcomes, but no evidence was obtained that it could significantly enhance the sense of agency for gain outcomes.

Effect of Temporal Interval on Sense of Agency

The main effect of temporal interval was significant after Greenhouse–Geisser correction, $F(1.12, 49.14) = 190.73$, $p < 0.001$, $\eta_p^2 = 0.81$. Time estimates in the 200 ms condition were lower than those in the 500 ms and 800 ms conditions, and time estimates in the 500 ms condition were lower than those in the 800 ms condition, $ps < 0.001$, indicating that participants could distinguish the three actual temporal intervals.

The remaining interactions involving temporal interval were not significant, which also indicates that in Experiment 2, the effects of framing, outcome valence, and feedback level on sense of agency were independent of temporal interval.

Further Analysis of the Feedback-Level Effect

To characterize the specific pattern of the three-factor interaction, we tested the simple effects of feedback level separately under each combination of framing

and outcome valence.

Under the baseline-framing condition, regardless of whether the outcome was a loss or a gain, the simple effect of feedback level did not reach significance. Under positive framing for loss outcomes, time estimates in the 10% ($p = 0.015$) and 30% ($p = 0.021$) feedback conditions were lower than those in the 90% feedback condition; the other comparisons did not reach significance. Under positive framing for gain outcomes, no significant differences were found among the different feedback levels.

This result preliminarily suggests that, for loss outcomes presented auditorily, positive framing may increase the relative effect of specific feedback levels, leading low-feedback outcomes to show stronger implicit sense of agency.

2.2.6 Discussion

The results of Experiment 2 partially verified Hypotheses 1 and 2 of the present study: in the auditory single-channel condition, positive framing enhanced sense of agency for loss outcomes, and this effect was moderated by feedback level. When the feedback level was 10% or 30%, positive framing enhanced the sense of agency for loss outcomes; however, different feedback levels did not enhance the effect of positive framing on the sense of agency for gain outcomes. This indicates that, compared with the visual single-channel condition in Experiment 1, when outcomes were presented through the auditory single channel, the effect of positive framing on sense of agency was weaker.

The main effect of outcome valence was significant, and its effect size was larger than that of the three-way interaction. This means that when outcomes were presented through the auditory channel, outcome valence had a greater overall weight in influencing sense of agency, suggesting that participants may have relied more on information about outcome valence to form a sense of agency. This processing characteristic was clearly different from that observed in the visual channel in Experiment 1.

In addition, supplementary analyses showed that, under positive framing, sense of agency changed significantly with the degree of return when outcomes were losses, whereas under baseline framing there were no significant differences among different degrees of return. This preliminary finding suggests that, in Experiment 2, positive framing also increased the weight of degree of return in its influence on sense of agency.

2.3 Discussion of Study 1

Study 1 examined the effects of framing, outcome valence, and degree of return on sense of agency in the visual and auditory single-channel modalities through two experiments. The results showed that positive framing had a relatively stable enhancing effect on sense of agency for loss outcomes. When the degree of return was 10% and 30%, positive framing significantly increased sense of agency

in both the visual and auditory single-channel modalities; for gain outcomes, the framing effect under the 60% and 90% return conditions was significant only in the visual single-channel modality and was marginally significant in the auditory single-channel modality. Thus, the positive framing effect does not depend on a specific sensory channel, but its mode of action may vary according to the presentation channel.

In the visual single-channel modality, sense of agency was more strongly affected by degree of return. This may be related to the visual channel being more conducive to processing complex information and precise quantities (Dai & Hsieh, 2025). Under baseline framing, there were some differences among different degrees of return, whereas under positive framing no corresponding differences were found, indicating that positive framing may have reconstructed individuals' representation of outcomes and weakened differences among different magnitudes. In the auditory single-channel modality, the role of outcome valence was more prominent. Under baseline framing, the valence tone was consistent with outcome nature, and participants could directly judge loss or gain based on tone; under positive framing, loss outcomes were accompanied by positive sounds, so participants also needed to integrate the specific points in the speech to judge the outcome. Therefore, according to the cue-integration theory of sense of agency, different frames may alter the availability and reliability of valence and magnitude cues, thereby influencing their relative roles in the formation of sense of agency (Synofzik et al., 2009, 2013).

Experiment 2 also found that sense of agency for loss outcomes was higher than that for gain outcomes. This is inconsistent with the conclusion of most studies that negative outcomes weaken sense of agency (Gentsch et al., 2015; Niu et al., 2023; Takahata et al., 2012; Yoshie & Haggard, 2013, 2017). This result may be related to the auditory channel being more sensitive to negative and alerting cues (Grondin, 2010; Hove et al., 2013). Loss sounds may preferentially attract attention, and attentional investment is closely related to sense of agency (Hon, 2017; Sidarus & Haggard, 2016; Wen et al., 2016), thereby causing loss outcomes to show a stronger sense of agency.

The range of significant framing effects in the visual single-channel modality was broader, initially indicating an advantage of visual processing. This is inconsistent with conclusions from previous slot-machine studies emphasizing the key role of auditory feedback (Dixon et al., 2014, 2015; Scarfe et al., 2021). However, Study 1 examined only the two single channels separately and therefore cannot determine channel weights when visual and auditory information are presented together. In actual slot machines, near-miss outcomes disguised as wins are usually presented jointly through visual and auditory dual channels. Therefore, Study 2 will further set up audiovisual-congruent and audiovisual-incongruent conditions to explore the effects of audiovisual integration and channel weight on the positive framing effect.

In addition, Study 1 also found a positive-framing effect under the 10% return-loss condition, which is inconsistent with Salaghe et al.' s (2023) view that

returns below 25% are difficult to cover up the essence of loss. This may be related to the presentation channel and participants' experience. On the one hand, existing studies typically use audiovisual dual-channel feedback, and the mismatch between low returns and strong winning feedback may more readily reveal the essence of loss; Study 1 used single-channel presentation, so this mismatch may have been relatively weak. On the other hand, the data of Salaghe et al. (2023) came from real casinos and experienced players, whereas the participants in the present study were mainly university students lacking gambling experience, who may have had greater difficulty identifying the actual loss under a positive frame (Barton et al., 2017; Dixon et al., 2015). Study 2 will further examine this issue by incorporating an audiovisual integration condition.

3 Study 2: Effects of Positive Framing, Outcome Valence, and Return Magnitude on Sense of Agency Under Audiovisual Integration Conditions

3.1 Experiment 3: Effects of Positive Framing, Outcome Valence, and Return Magnitude on Sense of Agency When Audiovisual Information Is Congruent

3.1.1 Research Purpose Experiment 3 focused on an audiovisual-congruent situation, examining the effects of positive framing, outcome valence, and return magnitude on sense of agency. It aimed to explore the enhancing effect of positive framing on sense of agency and the conditions under which it occurs, and to compare these characteristics with the effects observed in the single-channel condition of Study 1, in order to verify the inference proposed in the research question: compared with a single channel, audiovisual integration enhances the effect of positive framing on sense of agency.

3.1.2 Participants According to the results calculated with G*power3.1, based on the settings of previous research with $\alpha = 0.05$ and $1 - \beta = 0.8$ (Chen et al., 2024), and using an effect size of $f = 0.25$, the total required sample size was calculated to be 16 participants. To improve the stability of parameter estimation and to account for possible data exclusions, the present study recruited 50 participants. Two participants were excluded because they were affected by noise pollution during the experiment, and two participants were excluded because of operational errors, leaving 46 valid participants, including 34 female participants and 12 male participants, with $M = 21.63$ and $SD = 2.02$. All participants were right-handed, had normal vision (naked or corrected), and had normal hearing. All participants took part in the experiment voluntarily, were unaware of the specific purpose and content before the experiment, and received corresponding compensation after the experiment.

Figure 9. Flowchart of Experiment 3

Figure 9: Figure 9. Flowchart of Experiment 3

3.1.3 Experimental Materials and Apparatus The same as in Experiment 1 and Experiment 2.

3.1.4 Experimental Design and Procedure The experiment adopted a 2 (framing condition: baseline frame, positive frame) × 2 (outcome valence: loss, gain) × 4 (return magnitude: 10%, 30%, 60%, 90%) three-factor mixed design. Framing condition was a between-participants variable; outcome valence and return magnitude were within-participants variables; and the dependent variable was the time-estimation value. The manipulation of each variable was the same as in Study 1.

The experiment included two stages: practice and the formal experiment. The time-estimation practice and the five formal procedure practices were the same as in Study 1. The main difference between Experiment 3 and Study 1 was that the game outcomes were presented synchronously through both visual and auditory channels.

In the formal experiment, participants pressed the "←" key or the "→" key to select the corresponding slot machine and placed a bet of 100 points. After 200, 500, or 800 ms, the textual outcome was presented on the screen, while the earphones played a valence tone and the outcome speech. In the baseline frame, the net gain/loss outcomes after subtracting the bet were presented, including "lose 100/90/70/40/10 points" and "win 10/30/60/90/550 points"; loss and gain outcomes were accompanied by negative and positive tones, respectively. In the positive frame, total losses were presented as "Thank you for your patronage"and were accompanied by negative tones; the remaining outcomes were presented as "gain 10/30/60/90/110/130/160/190/650 points" and were accompanied by positive tones. The visual text and auditory outcome began to be presented simultaneously.

Figure 9. Flowchart of Experiment 3

After the outcome was presented, participants estimated the time interval from selecting the slot machine by keypress to the onset of the audiovisual outcome. The number of trials, the frequency of each outcome, the setting of filler trials, and the allocation ratios of the three time intervals were all the same as in Study 1. The experimental procedure is shown in Figure 9.

3.1.5 Results

Table 3. Time estimates at each level in Experiment 3 ($N = 46$)

Framing condition	Outcome valence	Reward magnitude	Time estimate ($M \pm SD$)
Baseline frame	Loss	10%	496.00 ± 91.54
Baseline frame	Loss	30%	499.29 ± 91.07
Baseline frame	Loss	60%	476.88 ± 94.83
Baseline frame	Loss	90%	464.85 ± 101.66
Baseline frame	Gain	10%	455.22 ± 95.46
Baseline frame	Gain	30%	460.34 ± 100.23
Baseline frame	Gain	60%	488.10 ± 95.12
Baseline frame	Gain	90%	493.67 ± 114.53
Positive frame	Loss	10%	388.15 ± 109.14
Positive frame	Loss	30%	388.19 ± 91.16
Positive frame	Loss	60%	410.98 ± 88.55
Positive frame	Loss	90%	416.02 ± 85.99
Positive frame	Gain	10%	420.12 ± 79.51
Positive frame	Gain	30%	438.72 ± 89.20
Positive frame	Gain	60%	419.33 ± 99.19
Positive frame	Gain	90%	428.48 ± 90.32

The experiment used IBM SPSS Statistics 26 for data analysis. The results are shown in Table 3. With framing condition, outcome valence, and reward probability as independent variables and time-estimation value as the dependent variable, a three-factor repeated-measures analysis of variance was conducted, with Bonferroni correction applied.

Main Analysis

The main effect of framing was significant, $F(1, 44) = 6.59,\ p = 0.014,\ \eta_p^2 = 0.13$. The time-estimation value in the positive-framing condition was significantly lower than that in the baseline-framing condition. The main effect of reward probability was not significant after Greenhouse–Geisser correction, $F(2.52, 110.97) = 1.50,\ p = 0.223$. The main effect of outcome valence was not significant, $F(1, 44) = 1.46,\ p = 0.233$.

The interaction between outcome valence and framing was significant, $F(1, 44) = 7.39,\ p = 0.009,\ \eta_p^2 = 0.14$. Further simple-effects analysis showed that, when participants obtained a loss outcome, the time-estimation value in the positive-framing condition was significantly lower than that in the baseline-framing condition ($p = 0.003$), indicating that, compared with the baseline framing, positive framing enhanced the sense of agency in loss outcomes. The interaction between reward probability and framing was not significant after Greenhouse–Geisser correction, $F(2.52, 110.97) = 0.62,\ p = 0.575$. The interaction between outcome valence and reward probability was not significant after Greenhouse–Geisser correction, $F(2.33, 102.54) = 1.67,\ p = 0.188$.

Figure 10. Effects of positive framing on sense of agency in loss outcomes at different reward probabilities. The y-axis is time-estimation value (ms). The x-axis labels are 10% (loss 90%), 30% (loss 70%), 60% (loss 40%), and 90% (loss 10%). The legend distinguishes positive framing and baseline framing. Significance markers are , , *and* .

Figure 10: Figure 10. Effects of positive framing on sense of agency in loss outcomes at different reward probabilities. The y-axis is time-estimation value (ms). The x-axis labels are 10% (loss 90%), 30% (loss 70%), 60% (loss 40%), and 90% (loss 10%). The legend distinguishes positive framing and baseline framing. Significance markers are , , *and* .

Figure 11. Effect of a positive frame on sense of agency under gain outcomes with different levels of return. The y-axis is "time-estimation value (ms)" ; the x-axis levels are 10% (gain 10%), 30% (gain 30%), 60% (gain 60%), and 90% (gain 90%). The legend distinguishes the positive frame from the baseline frame.

Figure 11: Figure 11. Effect of a positive frame on sense of agency under gain outcomes with different levels of return. The y-axis is "time-estimation value (ms)" ; the x-axis levels are 10% (gain 10%), 30% (gain 30%), 60% (gain 60%), and 90% (gain 90%). The legend distinguishes the positive frame from the baseline frame.

Simple-Simple Effects Analysis of Framing

The three-way interaction was significant after Greenhouse–Geisser correction, $F(2.33, 102.54) = 10.99$, $p < 0.001$, $\eta_p^2 = 0.20$. Analysis of the simple-simple effects of framing showed that, when the reward probability in loss outcomes was 10% ($p = 0.001$), 30% ($p < 0.001$), and 60% ($p = 0.019$), the time-estimation value in the positive-framing condition was significantly lower than that in the baseline-framing condition, indicating a higher sense of agency under positive framing. When the reward probability in gain outcomes was 60% ($p = 0.021$) and 90% ($p = 0.038$), the time-estimation value in the positive-framing condition was significantly lower than that in the baseline-framing condition, indicating a higher sense of agency. The pattern of results is shown in Figures 10 and 11.

Figure 10. Effects of positive framing on sense of agency in loss outcomes at different reward probabilities

Note: Error bars in the figure indicate standard errors; $p < 0.05$, $p < 0.01$, $p < 0.001$.

Figure 11. Effect of the positive frame on sense of agency under gain outcomes with different levels of return

Note: Error bars in the figure represent standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Effect of Time Interval on Sense of Agency

The main effect of time interval was significant after Greenhouse-Geisser correction, $F(1.16, 50.85) = 127.26$, $p < 0.001$, $\eta_p^2 = 0.74$. Participants' time-estimation values at the 200 ms interval were significantly lower than those at 500 ms and 800 ms, and their time-estimation values at the 500 ms interval were significantly lower than those at 800 ms ($ps < 0.001$).

The remaining interactions involving time interval were not significant, which also indicates that, in Experiment 3, the effects of frame, outcome valence, and level of return on sense of agency were unrelated to time interval.

Further Analysis of the Effect of Level of Return

To characterize the specific pattern of the three-factor interaction, the simple effects of level of return were tested separately under each combination of frame and outcome valence.

Under the baseline-frame condition, when the level of return for loss outcomes was 30%, the time-estimation value was significantly higher than when it was 60% ($p = 0.011$) and 90% ($p = 0.004$). When the level of return for gain outcomes was 10%, the time-estimation value was significantly lower than when it was 60% ($p = 0.034$) and 90% ($p = 0.041$). This indicates that, in the baseline frame, sense of agency was lower when the return for loss outcomes was relatively small, whereas sense of agency was higher when the return for gain outcomes was relatively small.

Under the positive-frame condition, when the level of return for loss outcomes was 30%, the time-estimation value was significantly lower than when the obtained outcome was 60% ($p = 0.010$) and 90% ($p = 0.029$), indicating that sense of agency was higher when the return for loss outcomes was relatively small.

These results indicate that, under audiovisual dual-channel presentation, the positive frame may change the direction of the relationship between level of return and sense of agency for loss outcomes, and may attenuate differences in sense of agency among different levels of return for gain outcomes.

3.1.6 Differences in the Effect of Positive Framing on Sense of Agency Between Single-Channel and Audiovisual Integration Conditions

To examine whether the influence of positive framing on sense of agency differed between single-channel and audiovisual dual-channel conditions, following the analytic methods of previous studies (Bu Yubo et al., 2022; Dai & Hsieh, 2025; Ruess et al., 2018), the data from the positive-framing conditions in Experiments 1, 2, and 3 were combined. A three-factor mixed ANOVA was conducted on time estimates, with presentation channel (visual, auditory, audiovisual) as the between-subjects variable, and outcome valence (loss, gain) and reward level (10%, 30%, 60%, 90%) as within-subjects variables. Post hoc comparisons were corrected using Bonferroni correction.

The results showed that the main effect of outcome valence was significant, $F(1, 66) = 13.96,\ p < 0.001,\ \eta_p^2 = 0.18$, with time estimates for loss outcomes lower than those for gain outcomes. The main effect of reward level was significant, $F(3, 198) = 7.66,\ p < 0.001,\ \eta_p^2 = 0.10$; time estimates in the 10% and 30% reward conditions were both lower than those in the 90% reward condition. The main effect of presentation channel was not significant, $F(2, 66) = 2.05,\ p = 0.137$, indicating that overall time estimates did not differ significantly among the visual, auditory, and audiovisual presentation conditions.

The interaction between outcome valence and reward level was significant, $F(3, 198) = 7.15,\ p < 0.001,\ \eta_p^2 = 0.10$. Simple-effects analyses showed that, at a reward level of 10%, participants' time estimates were significantly lower than those at reward levels of 60% ($p = 0.004$) and 90% ($p < 0.001$); at a reward level of 30%, participants' time estimates were significantly lower than those at reward levels of 60% ($p = 0.001$) and 90% ($p < 0.001$); and at a reward level of 60%, participants' time estimates were significantly lower than those at a reward level of 90% ($p = 0.040$). In gain outcomes, there were no significant differences among the different reward levels. This result indicates that, in loss outcomes under the positive-framing condition, sense of agency was stronger when the reward level was lower.

The interaction between outcome valence and presentation channel was not significant, $F(2, 66) = 2.19,\ p = 0.120$. The interaction between reward level and presentation channel was not significant, $F(6, 198) = 0.37,\ p = 0.895$. The three-way interaction among outcome valence, reward level, and presentation channel was not significant, $F(6, 198) = 0.43,\ p = 0.860$. This also indicates that the effect of presentation channel was not significant, and that there were no significant differences in sense of agency among the visual single-channel, auditory single-channel, and audiovisual congruent conditions.

In sum, under the positive-framing condition, there was no significant difference in the overall level of sense of agency produced by visual, auditory, and audiovisual congruent presentations, and the pattern of effects of outcome valence and reward level was not significantly moderated by presentation channel. This indicates that audiovisual congruent integration did not further enhance the influence of positive framing on sense of agency in terms of degree; the positive-framing effect showed a generally similar pattern across the three presentation channels.

3.1.7 Discussion

Experiment 3 examined the influence of positive framing on sense of agency under audiovisual congruent presentation. The main effect and effect size of framing indicated that, when positive information conveyed by visual text and auditory feedback was congruent, positive framing enhanced sense of agency, and the effect was relatively large. The three-factor interaction and effect sizes fur-

ther indicated that, under audiovisual congruence, this effect was more strongly influenced jointly by outcome valence and reward level: the positive-framing effect mainly appeared in the 10%, 30%, and 60% reward conditions for loss outcomes, as well as in the 60% and 90% reward conditions for gain outcomes.

The interaction between framing and outcome valence indicates that, for loss outcomes, the sense of agency under the positive-framing condition was higher than under the baseline framing, suggesting that audiovisual-consistent positive feedback can enhance individuals' implicit sense of agency over loss outcomes. This finding is relatively consistent with the framing effects observed under the low-reward loss condition in Experiments 1 and 2, indicating that the enhancing effect of positive framing on the sense of agency for loss outcomes has a certain degree of stability across different presentation channels.

It should be noted that the cross-experiment comparison did not reveal a significant main effect of presentation channel or its related interactions. Therefore, the existing results cannot show that the enhancement of the sense of agency by audiovisual-consistent presentation is significantly greater than that of the visual or auditory single channel, nor are they sufficient to support the conclusion that "audiovisual consistency increases the influence weight of positive framing." Experiment 3 can only show that the positive framing effect can be stably observed under audiovisual-consistent conditions. Experiment 4 will further introduce an audiovisual-inconsistent condition to examine changes in the positive framing effect and the relative roles of audiovisual cues when information from different channels conflicts.

3.2 Experiment 4: Effects of Positive Framing, Outcome Valence, and Reward Magnitude on the Sense of Agency Under Audiovisual Inconsistency

3.2.1 Research Aim Experiment 4 examined the effects of outcome valence and reward magnitude on the sense of agency when visual and auditory channels conveyed different framing information. The experiment separately set visual positive-framing and auditory positive-framing conditions, aiming to explore whether audiovisual framing inconsistency affects the positive framing effect, and, in combination with Experiment 3, to further analyze audiovisual consistency and the relative roles of different sensory channels.

3.2.2 Participants G*power 3.1 was used to calculate the required sample size. Based on prior research settings with $\alpha = 0.05$, $1 - \beta = 0.8$ (Chen et al., 2024), and an effect size of $f = 0.25$, the calculated total sample size was 16 participants. To improve the stability of parameter estimation and account for possible data exclusion, the experiment actually recruited 46 participants, including 12 males and 34 females, $M = 22.74$, $SD = 2.46$. All participants were right-handed, had normal vision (uncorrected or corrected) and normal hearing. All participants took part in the experiment voluntarily, were unaware of its

Figure 12. Flowchart of Experiment 4

Figure 12: Figure 12. Flowchart of Experiment 4

specific purpose and content before the experiment, and received corresponding compensation after the experiment.

3.2.3 Experimental Materials and Apparatus Same as Experiment 3.

3.2.4 Experimental Design and Procedure The experiment used a 2 (framing condition: visual positive framing, auditory positive framing) × 2 (outcome valence: loss, gain) × 4 (reward magnitude: 10%, 30%, 60%, 90%) three-factor mixed design. Framing condition was a between-participants variable, while outcome valence and reward magnitude were within-participants variables; the dependent variable was the time estimate.

The experimental procedure was basically the same as in Experiment 3, except that different outcome frames were used in the visual and auditory channels. Under the visual positive-framing condition, the screen presented "Thank you for your patronage"or "Gain 10/30/60/90/110/130/160/190/650 points"in a positive frame, whereas the headphones announced the corresponding net gain/loss result in a baseline frame, namely "Lose 100/90/70/40/10 points" or "Win 10/30/60/90/550 points," accompanied by the corresponding negative or positive tone. Under the auditory positive-framing condition, the screen used the baseline frame ···

The visual frame presents net-gain/net-loss results, whereas the headphones present "Thank you for your patronage" or "earned the corresponding points" within a positive frame, accompanied by the corresponding outcome-valence tone. The visual text and auditory outcome began to be presented simultaneously.

After the outcome was presented, participants estimated the time interval from pressing the key to select the tiger machine to the onset of the audiovisual outcome. The number of trials, the frequency with which each outcome appeared, the setting of filler trials, and the allocation ratio of the three action–outcome intervals of 200, 500, and 800 ms were all the same as in Experiment 3. The experimental procedure is shown in Figure 12.

Figure 12. Flowchart of Experiment 4

3.2.5 Results

Table 4
Time estimates at each level in Experiment 4 ($N = 46$)

Framing condition	Outcome valence	Reward probability	Time estimate ($M \pm SD$)
Visual positive frame	Loss	10%	421.37 ± 106.06
Visual positive frame	Loss	30%	439.51 ± 107.40
Visual positive frame	Loss	60%	424.21 ± 94.49
Visual positive frame	Loss	90%	419.56 ± 106.00
Visual positive frame	Gain	10%	419.47 ± 101.90
Visual positive frame	Gain	30%	439.54 ± 121.20
Visual positive frame	Gain	60%	450.75 ± 114.62
Visual positive frame	Gain	90%	436.74 ± 114.26
Auditory positive frame	Loss	10%	439.14 ± 87.10
Auditory positive frame	Loss	30%	437.16 ± 85.69
Auditory positive frame	Loss	60%	452.86 ± 91.73
Auditory positive frame	Loss	90%	438.76 ± 90.63
Auditory positive frame	Gain	10%	442.20 ± 91.28
Auditory positive frame	Gain	30%	450.39 ± 104.11
Auditory positive frame	Gain	60%	459.71 ± 93.12
Auditory positive frame	Gain	90%	449.61 ± 92.90

The experiment used IBM SPSS Statistics 26 for data analysis. With frame, outcome valence, and reward probability as independent variables and the time estimate as the dependent variable, a three-factor mixed analysis of variance was conducted; post hoc comparisons were Bonferroni-corrected. The descriptive statistics for each condition are shown in Table 4.

Main analysis

The main effect of outcome valence was marginally significant, $F(1, 44) = 3.61$, $p = 0.064$, $\eta_p^2 = 0.08$. Participants' time estimates in the loss condition

Figure 13. Effects of positive framing on sense of agency for loss outcomes at different probabilities. The y-axis is time estimate (ms). Legend: visual positive framing; auditory positive framing. X-axis categories: 10% (loss 90%); 30% (loss 70%); 60% (loss 40%); 90% (loss 10%).

Figure 13: Figure 13. Effects of positive framing on sense of agency for loss outcomes at different probabilities. The y-axis is time estimate (ms). Legend: visual positive framing; auditory positive framing. X-axis categories: 10% (loss 90%); 30% (loss 70%); 60% (loss 40%); 90% (loss 10%).

Figure 14. Effects of positive framing on sense of agency for gain outcomes at different probabilities. The y-axis is time estimate (ms). Legend: visual positive framing; auditory positive framing. X-axis categories: 10% (gain 10%); 30% (gain 30%); 60% (gain 60%); 90% (gain 90%).

Figure 14: Figure 14. Effects of positive framing on sense of agency for gain outcomes at different probabilities. The y-axis is time estimate (ms). Legend: visual positive framing; auditory positive framing. X-axis categories: 10% (gain 10%); 30% (gain 30%); 60% (gain 60%); 90% (gain 90%).

were marginally significantly lower than those in the gain condition, indicating that participants experienced a stronger sense of agency when outcomes were losses. The main effect of probability was significant, $F(3, 132) = 2.87,\ p = 0.039,\ \eta_p^2 = 0.06$, but none of the pairwise comparisons after Bonferroni correction reached significance. The main effect of framing was not significant, $F(1, 44) = 0.29,\ p = 0.590$.

The interaction between framing and outcome valence was not significant, $F(1, 44) = 0.04,\ p = 0.845$. The interaction between framing and probability was not significant, $F(3, 132) = 0.77,\ p = 0.514$. The interaction between outcome valence and probability was not significant, $F(3, 132) = 0.69,\ p = 0.557$. The three-way interaction was not significant, $F(3, 132) = 0.66,\ p = 0.576$. The results pattern is shown in Figures 13 and 14.

Figure 13. Effects of positive framing on sense of agency for loss outcomes at different probabilities

Note: Error bars represent standard errors.

Figure 14. Effects of positive framing on sense of agency for gain outcomes at different probabilities

Note: Error bars represent standard errors.

Effect of Time Interval on Sense of Agency

The main effect of time interval was significant, $F(1.12, 49.10) = 120.62,\ p < 0.001,\ \eta_p^2 = 0.73$. The time estimates in the 200 ms condition were lower than

those in the 500 and 800 ms conditions, and the time estimates in the 500 ms condition were lower than those in the 800 ms condition, $ps < 0.001$, indicating that participants could effectively distinguish the three action–outcome intervals.

The interaction between time interval and positive-framing channel was significant after Greenhouse–Geisser correction, $F(1.12, 49.10) = 4.12$, $p = 0.044$, $\eta_p^2 = 0.09$; within the same framing condition, time estimates differed significantly among the three time intervals, such that the shorter the interval, the shorter the time estimate, $ps < 0.001$; however, at each time interval, there was no significant difference between the visual positive framing and the auditory positive framing.

The remaining interactions involving the actual time interval were not significant. Therefore, in Experiment 4, the effects of framing, outcome valence, and reward magnitude on the sense of agency were unrelated to the time interval.

3.2.6 Discussion

The results of Experiment 4 showed that, under audiovisual-incongruent framing conditions, there was no significant difference in sense of agency produced by visual positive framing and auditory positive framing, and the interactions of the channel in which the positive framing was presented with outcome valence and reward magnitude were also not significant. This indicates that when different framing information was conveyed through the visual and auditory channels, no stronger sense-of-agency effect was found when positive framing was placed in a particular channel. Experiment 4 itself did not support a clear processing advantage for either the visual or the auditory channel.

3.3 Cross-experiment comparison of audiovisual congruency

The framing manipulation in Experiment 4 involved audiovisual incongruency, which may have interfered with the effect of positive framing. To further test this inference, following methods from previous studies (Bu Yubo et al., 2022; Ruess et al., 2018), Experiments 3 and 4 were combined for cross-experiment analysis to examine the influence of audiovisual congruency. Framing condition (baseline framing, audiovisual positive framing, visual positive framing, auditory positive framing) was used as the between-subjects variable, and outcome valence and reward magnitude were used as within-subject variables; a repeated-measures analysis of variance was conducted, with Bonferroni correction.

The results showed that the main effect of outcome valence was significant, $F(1, 88) = 4.48$, $p = 0.037$, $\eta_p^2 = 0.05$, with time estimates for loss outcomes lower than those for gain outcomes. The main effect of reward magnitude was significant, $F(3, 264) = 3.54$, $p = 0.015$, $\eta_p^2 = 0.04$, among which time estimates in the 10% reward condition were lower than those in the 60% reward condi-

tion, $p = 0.021$. The main effect of framing combination was not significant, $F(3, 88) = 2.21,\ p = 0.093$.

The interaction between outcome valence and framing combination was significant, $F(3, 88) = 3.13,\ p = 0.030,\ \eta_p^2 = 0.10$. Simple-effects analysis showed that, for loss outcomes, time estimates in the audiovisual positive-framing condition were lower than those in the baseline-framing condition, $p = 0.016$; no significant differences were found among the remaining framing conditions. The interaction between framing and reward magnitude was not significant, $F(9, 264) = 0.78,\ p = 0.637$; the interaction between outcome valence and reward magnitude was also not significant, $F(3, 264) = 2.02,\ p = 0.112$.

The three-way interaction was significant, $F(9, 264) = 3.65,\ p < 0.001,\ \eta_{\mathrm{p}}^2 = 0.11$. Simple simple-effects analyses were conducted to examine differences between framing conditions. In the loss outcomes with 10% ($p = 0.002$) and 30% ($p = 0.001$) reported magnitude, the time-estimation values in the audiovisual positive-framing condition were lower than those in the baseline-framing condition; no significant differences were found among the remaining framing combinations.

These results preliminarily indicate that the enhancing effect of positive framing on sense of agency obtained stable evidence mainly when positive framing was adopted in both the visual and auditory channels, whereas no significant effect emerged when the audiovisual frames were inconsistent. However, the direct difference between audiovisual positive framing and the two audiovisual-incongruent conditions was not significant; therefore, the present results do not yet demonstrate that audiovisual incongruence significantly weakens the positive-framing effect.

3.4 Exploratory Analysis of the Relative Effects of the Audiovisual Channels

To further examine the relative effects of visual and auditory framing cues, following the research design of Pan et al. (2024), the four framing combinations in Experiments 3 and 4 were recoded as a 2 (visual frame: baseline, positive) × 2 (auditory frame: baseline, positive) between-subjects design. Outcome valence and reported magnitude were treated as within-subject variables, and a four-way mixed analysis of variance was conducted on time-estimation values with Bonferroni correction. The effects related to visual and auditory framing are reported below.

The main effect of visual framing was significant, $F(1, 88) = 4.62,\ p = 0.034,\ \eta_{\mathrm{p}}^2 = 0.05$; time-estimation values in the visual positive-framing condition were lower than those in the visual baseline-framing condition. The main effect of auditory framing was not significant, $F(1, 88) = 1.84,\ p = 0.179$.

The interaction between outcome valence and visual framing was significant, $F(1, 88) = 5.22,\ p = 0.025,\ \eta_{\mathrm{p}}^2 = 0.06$. Simple-effects analysis showed that, for

loss outcomes, time-estimation values in the visual positive-framing condition were lower than those in the visual baseline-framing condition, $p = 0.011$. The interaction between outcome valence and auditory framing was also significant, $F(1, 88) = 4.19,\ p = 0.044,\ \eta_{\mathrm{p}}^2 = 0.05$, but no significant differences were found between auditory positive framing and auditory baseline framing for either loss or gain outcomes. The interaction between visual framing and auditory framing was not significant, $F(1, 88) = 0.17,\ p = 0.681$.

The interaction among outcome valence, reported magnitude, and visual framing was significant, $F(3, 264) = 3.02,\ p = 0.030,\ \eta_{\mathrm{p}}^2 = 0.03$. Further analysis showed that, in the loss outcomes with 10% ($p = 0.003$), 30% ($p = 0.007$), and 60% ($p = 0.016$) reported magnitude, time-estimation values in the visual positive-framing condition were lower than those in the visual baseline-framing condition. The interaction among outcome valence, reported magnitude, and auditory framing was also significant, $F(3, 264) = 7.71,\ p < 0.001,\ \eta_{\mathrm{p}}^2 = 0.08$; in the loss outcomes with 10% ($p = 0.032$) and 30% ($p = 0.005$) reported magnitude, time-estimation values in the auditory positive-framing condition were lower than those in the auditory baseline-framing condition. The remaining interactions involving visual and auditory framing did not reach significance.

These results preliminarily indicate that positive framing in both the visual and auditory channels can enhance sense of agency under some low reported-loss conditions, and that the range of reported magnitudes involved in the visual-framing effect is relatively broader. However, the interaction between visual framing and auditory framing was not significant, and there was no significant difference between the two audiovisual-incongruent conditions in Experiment 4; therefore, it cannot be concluded from these results that the effect of the visual channel is significantly stronger than that of the auditory channel.

3.5 Discussion of Study 2

Study 2 examined, through Experiment 3 and Experiment 4, the effects of audiovisual framing consistency and cues from different channels on implicit sense of agency.

Experiment 3 found that when positive framing was adopted in both the visual and auditory modalities, positive framing enhanced sense of agency, and this effect appeared mainly for low-reward loss outcomes; Experiment 4, however, found no significant difference between visual positive framing and auditory positive framing.

Cross-experiment comparisons further showed that the positive-framing effect was supported by significant evidence mainly under the audiovisual-consistent positive condition, especially for loss outcomes with 10% and 30% rewards; by contrast, neither of the two audiovisual-inconsistent conditions differed significantly from baseline framing. This preliminarily suggests that when visual and auditory cues jointly point to positive outcome representations, the framing effect may be more stable; when the two channels convey different framing

information, cross-channel conflict and mixed framing representations may interfere with the integration of outcome information (Fong et al., 2018; Gamliel & Kreiner, 2013; Kang Guanlan, Luo Xiaoxiao, 2020; Kreiner & Gamliel, 2016). However, because the audiovisual-consistent positive condition did not differ significantly from the two inconsistent conditions, it cannot yet be determined that audiovisual inconsistency significantly weakens the positive-framing effect.

Exploratory analyses indicated that visual positive framing showed a significant overall effect and exhibited framing differences under loss conditions with 10%, 30%, and 60% rewards; although auditory positive framing did not show an overall main effect, it likewise enhanced sense of agency for loss outcomes with 10% and 30% rewards. The conditions involved in the visual framing effect were relatively broader, possibly because visual text can continuously present specific point-gain and net-payoff information (Dai & Hsieh, 2025). However, in Experiment 4 there was no significant difference between visual positive framing and auditory positive framing; therefore, the present results are insufficient to confirm that the visual or auditory channel has a clear dominant advantage, and can only preliminarily suggest that the visual framing effect has a relatively broader range of manifestation.

Overall, Study 2 preliminarily indicates that audiovisual framing consistency may help the positive-framing effect appear stably, whereas the relative weight of specific channels still requires further testing.

4 General Discussion

Using the temporal-estimation paradigm, the present study examined, across four experiments, the effects of the outcome framing, outcome valence, reward magnitude, and audiovisual channel of outcomes obtained in a joystick task on sense of agency. Overall, positive framing did not enhance sense of agency under all outcome conditions; its effect was moderated by outcome valence and reward magnitude. Positive-framing effects appeared in both the visual and auditory single channels, and the effect could also be observed stably under the audiovisual-consistent condition; however, the existing cross-experiment results cannot demonstrate that the audiovisual dual channel is significantly stronger than a single channel, nor are they sufficient to confirm that the visual or auditory channel has a clear dominant advantage.

4.1 Positive framing influences sense of agency through outcome representation

The core finding of the present study is that, when the objective action, outcome, and action–outcome temporal interval were held constant, presenting outcomes in a positive frame enhanced sense of agency. Because positive framing highlights the points "gained," outcomes of both gains and losses are presented in terms of different degrees of gains obtained. According to the cue-integration account of sense of agency, outcome valence and outcome

Retrospective information such as magnitude participates in the formation of sense of agency depending on its availability and reliability (Moore et al., 2009; Synofzik et al., 2009, 2013). Thus, a positive frame may influence individuals' experience of the action–outcome relation by changing the psychological representation of outcomes.

This interpretation was also supported by the analysis of reward magnitude. In the visual single-channel condition, differences in sense of agency existed between some reward magnitudes under the baseline frame, whereas the corresponding differences disappeared under the positive frame, suggesting that the positive frame may have reduced individuals' sensitivity to magnitude differences among outcomes. In the auditory single-channel condition, however, the positive frame made the difference between low-reward and loss outcomes more pronounced. The results from the two patterns indicate that positive framing does not merely increase the positivity of outcomes, but may reorganize the relative weights of valence and magnitude cues in outcome representation. This result suggests that positive framing may further influence individuals' sense of agency by affecting their judgment and evaluation of outcomes (Levin et al., 1998).

4.2 Outcome Valence and Reward Magnitude Jointly Moderate the Positive Framing Effect

Across Experiments 1 to 3, it was found that the positive framing effect was jointly moderated by outcome valence and reward magnitude, with the most stable pattern appearing for loss outcomes with 10% and 30% reward. By describing "net loss" as "points gained," the positive frame may have reduced the negative encoding of loss outcomes, producing stronger action–outcome temporal binding under low-reward losses. In contrast, for gain outcomes, the framing effect appeared only at some high reward levels in the visual single-channel and audiovisual-congruent conditions, and no significant evidence was obtained in the auditory single-channel condition. This indicates that the effect of positive framing on sense of agency has clear boundary conditions and cannot be generalized as a universal enhancement for all loss or gain outcomes.

The stable effect under low-reward losses is not entirely consistent with findings from some studies suggesting that a lower return ratio more readily exposes the nature of losses (Salaghe et al., 2023). One possibility is that the participants in the present study were mainly university students with relatively little gambling experience, and their ability to identify losses disguised as gains may have been lower than that of experienced players (Barton et al., 2017; Dixon et al., 2015). In addition, the experiment also included complete-loss trials; although 10% reward represented a relatively large net loss, compared with complete loss it still contained some return, which may have increased the acceptability of the positive description. The above explanations still need to be further tested by manipulating gambling experience, reference outcomes, and subjective outcome judgments.

4.3 Audiovisual Congruence and Channel Effects

Study 1 showed that both visual and auditory single channels could produce positive framing effects under the low-reward loss condition, indicating that this effect does not depend on a specific sensory channel. The effect in the visual condition involved more outcome levels, which may be related to the current task' s reliance on quantitative information such as specific points and net gains/losses; when the task depends on the location of outcomes or numerical information, visual cues may receive greater weight (Dai & Hsieh, 2025). The more prominent role of outcome valence in the auditory condition may be related to the auditory channel' s greater sensitivity to negative and warning cues (Grondin, 2010; Hove et al., 2013). Study 2 further found that positive framing effects could also be stably observed under the audiovisual-congruent condition. However, because the single-channel and audiovisual dual-channel conditions came from different experiments, the present study did not directly test differences in the framing effect across the three presentation channels; therefore, it still cannot be concluded that audiovisual-congruent presentation, compared with single-channel presentation,

produced a stronger framing effect. Experiment 4 likewise found no significant difference between the visual positive-framing and auditory positive-framing conditions; thus, the existing results are insufficient to confirm that any one sensory channel has a clear dominant advantage.

Combining Experiments 3 and 4, the positive framing effect obtained significant evidence only under the audiovisual-consistent positive condition relative to the baseline framing condition, whereas neither of the two audiovisual-inconsistent conditions showed the same effect. This suggests that consistent audiovisual cues may help form stable outcome representations, whereas audiovisual conflict may increase the burden of information integration (Fong et al., 2018; Kang Guanlan & Luo Xixiao, 2020). However, because the direct difference between the audiovisual-consistent positive condition and the inconsistent conditions was not significant, it cannot yet be concluded that audiovisual inconsistency significantly weakened the positive framing effect.

In sum, this study extended the problem of losses disguised as wins in slot machines from outcome misjudgment to the issue of sense of agency, showing that outcome framing may not only change players' judgments of wins and losses but may also enter the action–outcome causal process and affect sense of agency. This enhancement of individuals' sense of agency may be one of the important psychological mechanisms underlying gambling addiction. Second, this study revealed the joint moderating roles of outcome valence and degree of return, indicating that the positive framing effect has specific outcome boundaries rather than being a general positive-outcome effect. Third, this study compared single-channel, audiovisual-consistent, and audiovisual-inconsistent conditions, preliminarily showing that sensory channel is not a necessary condition for the emergence of the positive framing effect, and that audiovisual consistency may

influence the stability of the effect; however, there is still insufficient evidence to support a clear channel dominance.

5 Conclusion

(1) Positive framing can enhance the sense of agency in slot-machine games under specific outcome conditions; its effect is jointly moderated by outcome valence and degree of return, and is most stable for low-return loss outcomes.

(2) This effect can occur under visual-only, auditory-only, and audiovisual-consistent conditions, indicating that sensory channel is not a necessary condition for its emergence.

(3) Audiovisual consistency may help the stable manifestation of the positive framing effect, but there is as yet no evidence that it significantly strengthens the framing effect, nor is there sufficient evidence to confirm that the visual or auditory channel has a clear dominant advantage.

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Positive Framing Enhances Sense of Agency: The Roles of Outcome Characteristics and Audiovisual Modalities

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Abstract

Losses disguised as wins (LDWs) are objectively losing outcomes presented with win-like feedback in slot-machine gambling. Such feedback can distort players' judgments of winning, but whether it also changes the sense of agency remains unclear. Based on cue-integration accounts, the present study examined whether positive framing would enhance implicit sense of agency and whether this effect would vary with outcome valence, return level, and the sensory modality through which outcome information was delivered.

Four experiments were conducted with independent samples of 46 university students each, yielding 184 participants in total. All experiments used a simulated slot-machine task and an interval-estimation version of the intentional-binding paradigm. Participants selected a slot machine, placed a fixed wager, received an outcome after a delay, and estimated the action–outcome interval; shorter estimates indicated stronger implicit agency. Experiments 1 and 2

presented outcomes through visual and auditory single channels, respectively. Experiment 3 used congruent audiovisual presentation, whereas Experiment 4 used incongruent audiovisual framing. Presentation frame, outcome valence, and return level were manipulated in Experiments 1–3, and the channel carrying the positive frame was manipulated in Experiment 4.

Positive framing did not enhance the sense of agency uniformly across all outcome conditions. In Experiment 1, it enhanced agency for losses at the 10% and 30% return levels and for gains at the 60% and 90% levels. In Experiment 2, reliable framing effects were found only for losses at the 10% and 30% return levels, whereas no reliable effect was observed for gains. In Experiment 3, congruent audiovisual positive framing enhanced agency for losses at the 10%, 30%, and 60% levels and for gains at the 60% and 90% levels. In Experiment 4, the sensory channel carrying the positive frame did not reliably influence agency, and its effects did not vary with outcome valence or return level. Cross-experiment analyses suggested that the framing effect was most consistently expressed under congruent audiovisual presentation, particularly for low-return losses. However, congruent and incongruent audiovisual conditions did not differ reliably, and the findings provided no clear evidence that either the visual or auditory channel was dominant.

These findings indicate that positive framing can alter implicit sense of agency even when the objective outcome remains unchanged. The effect is not general but is jointly constrained by outcome valence and return level, with the most robust pattern occurring for low-return losses. It can emerge in visual, auditory, and congruent audiovisual conditions, suggesting that no specific sensory modality is necessary. The study extends LDW research from biased outcome judgment to action–outcome attribution and highlights how win-like feedback may strengthen subjective control over random outcomes.

Key words: sense of agency; positive framing; losses disguised as wins; audiovisual modalities; return level

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