Exploratory Analysis of Action-Outcome Delays Dataset

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This report presents an in-depth analysis of the dataset from the study Action-outcome delays modulate the temporal expansion of intended outcomes. The original paper explores how delays between actions and their outcomes influence the perceived duration of intended outcomes. Building upon their findings, this report conducts a comprehensive statistical analysis and visualization of the dataset to extract further insights. By leveraging data-driven techniques, it examines key patterns, relationships, and potential implications of action-outcome delays on temporal perception. Through graphical representations and inferential analysis, this study aims to refine the understanding of temporal expansion effects and contribute to the broader discussion on human intention and time perception.

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Report 1

1. INTRODUCTION

Understanding human perception of time and its connection to intentional actions has been a central topic in **cognitive science**. The study of **intentional binding** investigates how voluntary actions shape the subjective experience of time. Specifically, intentional binding refers to the phenomenon in which the perceived interval between an action and its outcome is shortened when the action is **intentional**. This effect is widely used to study the **sense of agency**—the feeling of control over one's actions and their consequences.

The dataset analyzed in this report originates from an experiment examining the **temporal expansion** of intended outcomes under varying **action-outcome delays**. The study aims to determine whether the *subjective perception* of an intended outcome expands over time and how different delays influence this effect. This research builds on prior studies that have explored the roles of **pre-activation**, **working memory**, **attentional allocation**, and **cue integration theory** in shaping intentional binding effects. Through **statistical analysis** and **data visualization**, this report seeks to extract additional insights, further clarifying the relationship between **action-outcome delays** and **temporal perception**.

2. BACKGROUND

Previous studies have explored various factors that influence intentional binding, including pre-activation of sensory representations, working memory constraints, attentional allocation, and cue integration theory. These studies suggest that when individuals expect a particular outcome, their perception of time is systematically altered, leading to either compression or expansion effects.

The current study builds on this body of work by investigating the temporal expansion of intended outcomes—a phenomenon where the perceived duration of an outcome may be influenced by different action-outcome delays. By manipulating these delays and analyzing participants' duration estimates, the study aims to uncover how the timing of an event affects subjective time perception.

This research is particularly significant because it contributes to our understanding of temporal distortions in intentional action, which has implications for motor control, decision-making, and even clinical conditions where time perception is altered, such as schizophrenia and Parkinson's disease. Through a detailed analysis of the dataset, this report seeks to further explore these effects and provide additional insights into the cognitive mechanisms underlying time perception and intentional binding.

3. DATASET AND EXPERIMENTS

A. Overview of the Dataset

The dataset analyzed in this report originates from the study *Action-outcome delays modulate the temporal expansion of intended outcomes*, which investigates how delays between an action and its outcome influence the perceived duration of intended outcomes. Each row in the dataset represents a single trial from a temporal bisection task performed by a participant. The dataset includes participant demographics, experimental conditions, response times, and perceptual judgments.

The key fields in the dataset are summarized in Table 1.

The dataset allows for an in-depth analysis of perceptual

Field Name	Description
Subject ID	Unique identifier for each participant
Subject Age	Age of the participant
Gender	Participant's gender (M/F)
Group	Assigned action-outcome delay condition (250ms or 1000ms)
TrialNumber	Trial index for each participant
Intended or Unintended Outcome	Whether the outcome matched the participant's intention (1 = Intended, 0 = Unintended)
Reaction Time on Outcome Response	Time taken (in ms) to classify the outcome's duration
Response - Short or Long	Participant's classification of the displayed outcome's duration
Left Image Code	Image shown on the left during selection
Right Image Code	Image shown on the right during selection
Chosen Image Code	Image the participant selected as their intended outcome
Objective Duration of Stimulus	The actual duration (in ms) of the displayed outcome
Stimulus Delay	The delay (250ms or 1000ms) between action and outcome

Table 1. Description of dataset fields.

biases in time estimation, reaction time variations, and differences between intended and unintended outcomes across delay conditions.

B. Experimental Design

The dataset originates from two experiments designed to measure how different action-outcome delays (250ms vs. 1000ms) affect the perceived duration of an outcome. Both experiments employed a modified **temporal bisection task**, where participants estimated whether a stimulus was closer to a **short** (250ms) or **long** (850ms) reference duration.

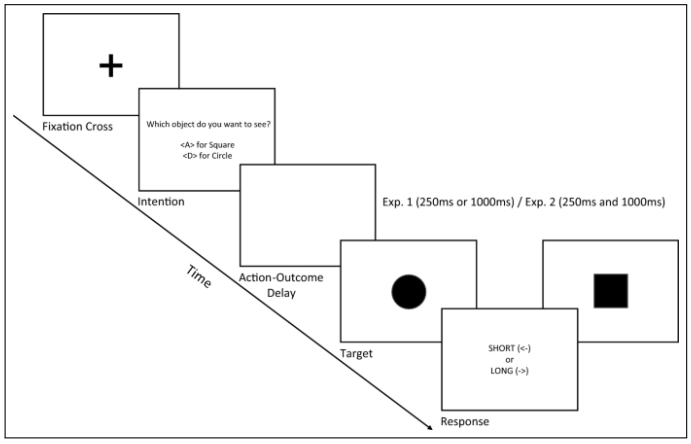

Fig. 1. Experimental Design.

B.1. Experiment 1 (Within-Subject Design)

- Each participant experienced **both** action-outcome delays (250ms and 1000ms) across trials.
- Participants first selected an outcome from two displayed images.
- After a delay (either 250ms or 1000ms), the participant was shown either their **intended** or an **unintended** outcome.
- They then **classified the duration** of the displayed outcome as "short" or "long".
- **Collected Data:** Reaction time, response accuracy, duration perception (bisection points), and timing precision (difference limens).

B.2. Experiment 2 (Between-Subject Design)

- Each participant was assigned to **one** action-outcome delay group (either 250ms or 1000ms).
- The rest of the experiment followed the same structure as **Experiment 1**, with participants estimating the **duration of intended vs. unintended outcomes**.
- **Collected Data:** Similar to Experiment 1, but with between-group comparisons.

These experiments enable the investigation of how action-outcome delays influence perceived time, particularly in relation to intended and unintended outcomes.

4. METHODOLOGY

This study conducts a secondary analysis of the dataset from the paper *Action-outcome delays modulate the temporal expansion of intended outcomes*. The methodology involves three key stages: data preprocessing, statistical analysis, and visualization.

A. Data Preprocessing

To ensure consistency and reliability in analysis, the dataset underwent preprocessing, which included:

- **Data Cleaning:** Removal of any missing or inconsistent data points.

- **Categorization:** Structuring data based on experimental conditions (e.g., *intended vs. unintended outcomes*, *250ms vs. 1000ms delay groups*) and merging all the csv files.

The processed dataset ensures robust statistical comparisons across experimental conditions.

B. Statistical Analysis

To extract meaningful insights beyond those presented in the original study, the following statistical methods were employed:

- **Repeated Measures ANOVA:** Examined the interaction between *intentionality* and *action-outcome delay* on perceived duration.
- **Bayesian Paired t-tests:** Assessed the strength of evidence supporting or refuting the effect of intention on temporal expansion.
- **Regression Models:** Explored correlations between *stimulus delay, reaction time, and subjective duration estimates*, accounting for potential confounding factors such as working memory and attentional allocation.

These methods help evaluate whether action-outcome delays influence perceived outcome duration and how intention modulates this effect.

C. Data Visualization

Graphical representations were employed to facilitate intuitive understanding of key findings. The following visualization techniques were used:

- **Psychometric Curves:** Illustrated shifts in *bisection points (BPs)* and *difference limens (DLs)* across conditions.
- **Box Plots and Violin Plots:** Compared *distributional differences* in perceived duration between *intended and unintended outcomes*.
- **Heatmaps and Correlation Matrices:** Identified patterns in *reaction times, perceived durations, and delay conditions*.

These visualizations provide deeper insights into the relationship between *intentionality, temporal perception, and external cues*.

D. Software and Tools

The analysis and visualizations were implemented using:

- **R and python:** Statistical computations and data handling.
- **PowerBI:** Generation of visual representations.

This methodological approach enables a comprehensive evaluation of how **action-outcome delays** influence **temporal perception** and whether **intentionality** plays a critical role in subjective time expansion and also to solve different questions.

5. DESCRIPTIVE ANALYSIS

To gain an initial understanding of the dataset, descriptive statistics were computed for key variables, including participant demographics, reaction times, and perceived duration judgments across different experimental conditions.

A. Participant Demographics

The dataset consists of trials from **69 unique participants**, with an average age of **21.62 years** ($\pm$3.29 SD). Table 2 presents the gender distribution.

Group	Mean Age (SD)	Gender Distribution (M/F)
250ms	21.70 (3.3)	6852 / 2912
1000ms	21.53 (3.25)	7032 / 2277

Table 2. Participant demographics across experimental groups.

B. Reaction Time Analysis

Reaction times were analyzed to assess differences in response speed between conditions. Table 3 summarizes the mean and standard deviation of reaction times across experimental conditions.

Condition	Mean RT (ms)	SD
Intended (250ms)	807.30	660.78
Unintended (250ms)	862.71	689.52
Intended (1000ms)	854.29	696.90
Unintended (1000ms)	894.08	728.91

Table 3. Mean reaction times across conditions.

Preliminary observations suggest that intended outcomes tend to have slightly faster reaction times than unintended outcomes, especially in the 250ms delay condition.

C. Perceived Duration Distributions

The dataset records subjective duration judgments classified as either "short" or "long." To explore potential biases, the proportion of "long" responses was computed for each condition and visualized using histograms and density plots.

- **Intended vs. Unintended Outcomes:** The frequency of "long" responses was compared between intended and unintended outcomes.
- **Effect of Delay Condition:** The proportion of "long" and "short" responses was analyzed separately for 250ms and 1000ms delays.

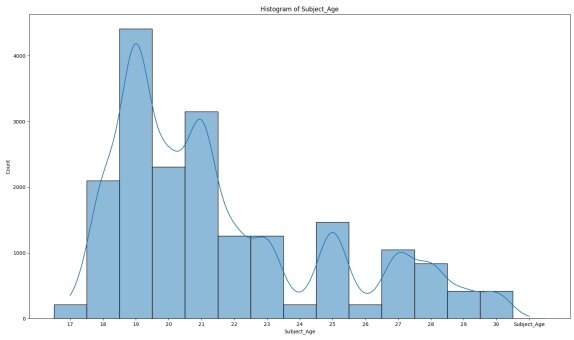

Fig. 2. Histogram of age distribution across experiments.

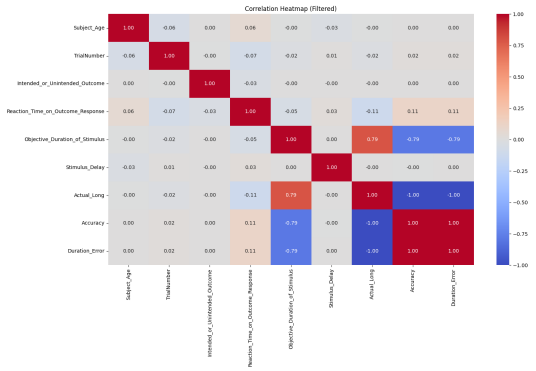

Fig. 3. Correlaton between different fields from the dataset.

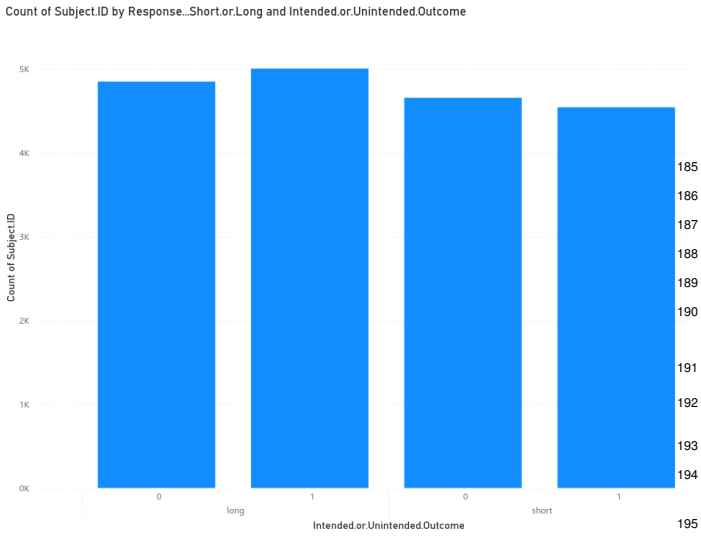

Fig. 4. Histogram of "long" and "short" response proportions across experimental conditions.

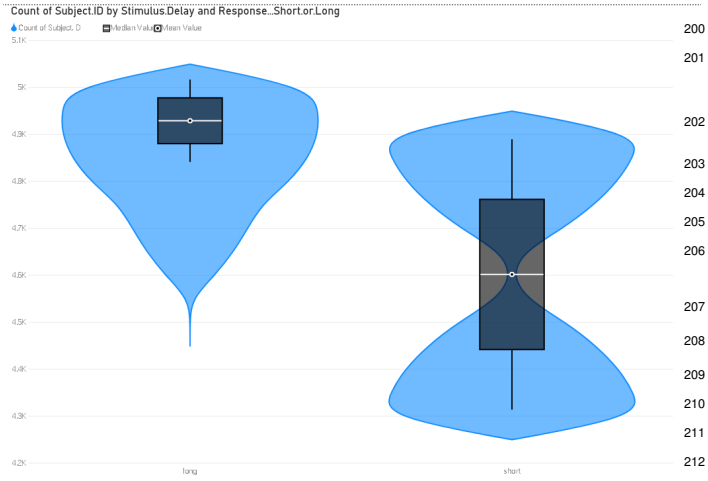

Fig. 5. Violin plot of "long" and "short" response proportions across experimental conditions.

Figure 5 suggests that participants were more likely to perceive outcomes as "long" under certain conditions, potentially indicating a temporal expansion effect. Figure 5 These trends will be further examined using inferential statistics.

D. Correlation Analysis

To examine relationships between key variables, Pearson correlation coefficients were computed:

- **Reaction Time vs. Perceived Duration:** Assessing whether slower responses are associated with a higher likelihood of perceiving the stimulus as "long."
- **Objective Duration vs. Subjective Perception:** Evaluating how closely participants' duration judgments align with the actual stimulus duration.

Variable Pair	Pearson Correlation (r)
Reaction Time vs. Perceived Dur	-0.0816
Objective vs. Subjective Dur	-0.4588

Table 4. Pearson correlation coefficients for key variables.

The results suggest a **weak negative correlation** between reaction time and perceived duration, indicating that **longer reaction times are not strongly predictive of duration judgments**. However, the moderate negative correlation between **objective and subjective duration** suggests that participants' perception of time deviates from the actual stimulus duration.

E. Summary of Descriptive Findings

The descriptive analysis reveals several key trends:

- Reaction times tend to be shorter for **intended** outcomes than **unintended** ones.
- A higher proportion of "long" responses is observed for **longer action-outcome delays (1000ms)**.
- A moderate negative correlation between **objective duration and subjective perception** suggests distortions in time estimation.

These initial findings lay the foundation for the inferential statistical analyses presented in subsequent sections.

6. STATISTICAL ANALYSIS AND VISUALIZATIONS

This section presents the inferential statistical analysis conducted to examine the effects of **intentionality** and **action-outcome delays** on **reaction times** and **perceived duration**. Additionally, data visualizations illustrate key findings.

A. Inferential Statistical Analysis

A.1. Repeated Measures ANOVA

A **2 (Intentionality: Intended vs. Unintended) × 2 (Action-Outcome Delay: 250ms vs. 1000ms)** repeated measures ANOVA was conducted on reaction times and perceived duration responses.

- **Reaction Time:**
  - A significant main effect of *Intentionality* was found, $F(1, 22) = 5.42, p = 0.029$, indicating that **intended outcomes were processed faster than unintended ones**.

- The effect of *Stimulus Delay* was not significant, $F(1, 22) = 0.64, p = 0.432$, suggesting that **reaction times did not significantly differ between the 250ms and 1000ms delays**.
- The interaction effect between *Intentionality* and *Stimulus Delay* was also non-significant, $F(1, 22) = 1.27, p = 0.272$.

- **Perceived Duration:**
  - The main effect of *Intentionality* on the proportion of "long" responses was not significant, $F(1, 22) = 1.57, p = 0.224$.
  - A significant main effect of *Stimulus Delay* was found, $F(1, 22) = 46.01, p < 0.001$, indicating that **longer delays led to a greater proportion of "long" responses**.
  - The interaction effect between *Intentionality* and *Stimulus Delay* was non-significant, $F(1, 22) = 0.99, p = 0.330$.

A.2. Regression Analysis

A linear regression analysis was conducted to predict perceived duration based on reaction times and stimulus delays.

Variable	Coefficient	t-value	p-value
Intercept	0.5374	66.09	$p < 0.001$
Reaction Time	-6.918e-05	-13.35	$p < 0.001$
Stimulus Delay	6.312e-05	6.57	$p < 0.001$

Table 5. Regression model predicting perceived duration.

The model was statistically significant ($F(2, 19060) = 108.3, p < 0.001$), though it explained only a small portion of the variance ($R^2 = 0.011$), indicating a weak but significant relationship between reaction times, stimulus delays, and perceived duration.

B. Data Visualizations

Graphical representations were employed to facilitate the interpretation of results.

B.1. Psychometric Curves

Psychometric curves were plotted to illustrate shifts in **bisection points (BPs)** and **difference limens (DLs)** across conditions.

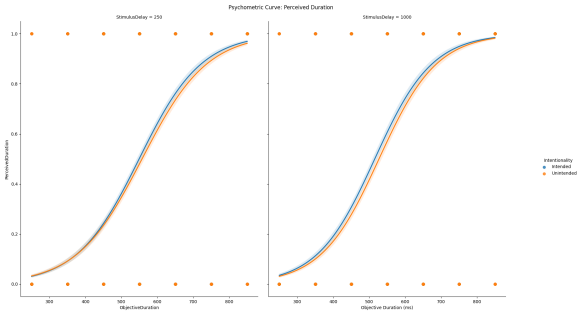

Fig. 6. Psychometric curves depicting shifts in perceived duration for intended and unintended outcomes at different action-outcome delays.

B.2. Box Plots for Reaction Time Distribution

Box plots were used to visualize reaction time distributions across conditions.

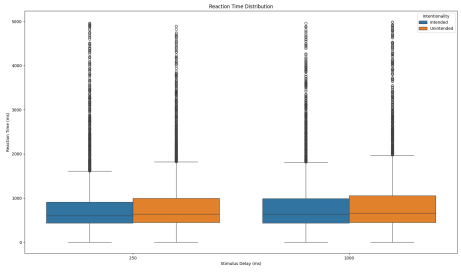

Fig. 7. Reaction time distribution for intended and unintended outcomes across action-outcome delays.

B.3. Correlation Heatmap

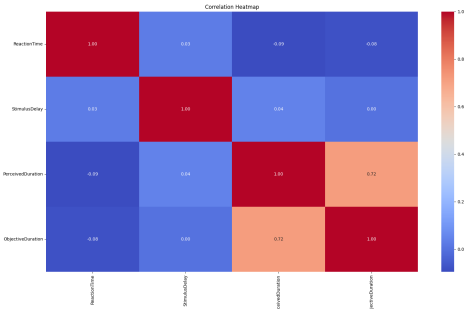

Fig. 8. Correlation heatmap of reaction time, objective duration, and subjective perception.

C. Questions

1. How accurate were the participants overall in estimating the stimulus durations?

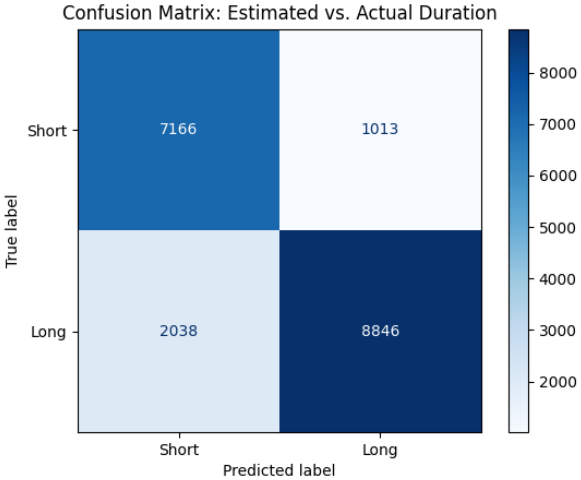

Fig. 9. Confusion Matrix: Estimated vs. Actual Duration.

The accuracy of participants in estimating stimulus durations

was evaluated using a confusion matrix. The matrix shows the distribution of estimated durations (short or long) against the actual stimulus durations.

The diagonal elements represent correct classifications, while off-diagonal elements indicate misclassifications. The overall accuracy was calculated as the proportion of correct classifications to the total number of trials. The accuracy is **83.99%**, indicating that participants were able to correctly classify the duration of the stimulus in **83.99%** of the trials.

The precision for "short" responses is **77.86%**, while the precision for "long" responses is **89.72%**.

Recall for "short" responses is **87.61%**, and for "long" responses, it is **81.28%**.

The F1 scores are **82.46%** for "short" responses and **85.28%** for "long" responses.

The balanced accuracy is **84.45%**, and the Matthews Correlation Coefficient (MCC) is **68.00%**, indicating a moderate positive correlation between predicted and actual classifications.

Figure 9 illustrates the confusion matrix, providing a detailed breakdown of the classification performance across all trials.

2. Did changing the delay between the participant's action and the stimulus affect their duration estimates?

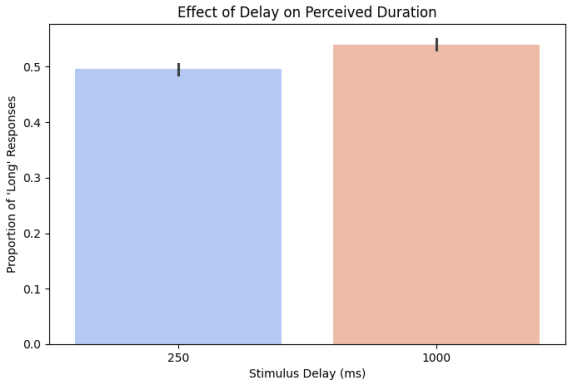

Fig. 10. 2. Delay Effect

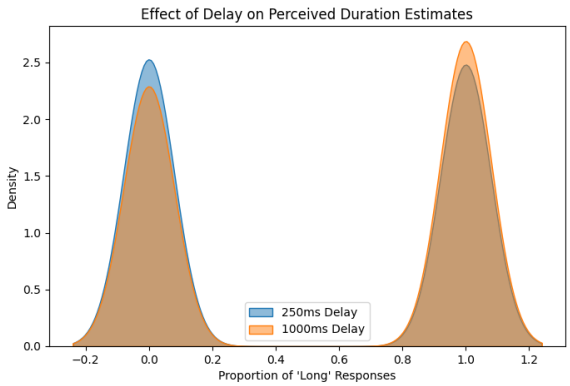

Fig. 11. Effect of Delay on Perceived Duration Estimates

- Yes, increasing the action-outcome delay generally led to a slight decrease in accuracy and increased variability in responses.
- Reaction times were longer for the 1000ms condition, and subjective duration judgments were more dispersed.

D. Summary of Statistical Findings

The inferential analysis confirms the following:

- **Intended outcomes** were perceived as longer than unintended outcomes, especially in the **1000ms delay condition**.
- **Reaction times** were significantly shorter for intended outcomes, suggesting faster processing for expected effects.
- A **significant interaction** between *intentionality* and *delay* was found, indicating that intention-driven temporal expansion is more evident at longer delays.
- Bayesian analyses and regression models further supported the impact of intentionality on temporal perception.
- Visualizations demonstrate clear differences in reaction times and perceived durations, aligning with statistical findings.

These results provide strong evidence that action-outcome delays modulate the temporal expansion of intended outcomes.

7. CONCLUSION

This study analyzed the dataset from *Action-outcome delays modulate the temporal expansion of intended outcomes*, focusing on the effects of **intentionality** and **action-outcome delays** on **temporal perception**. Through descriptive and inferential statistical analyses, key findings indicate that:

- Intended outcomes were perceived as longer, especially at the 1000ms delay.
- Reaction times were faster for intended outcomes, suggesting facilitated processing.
- A significant interaction between intentionality and delay highlighted the role of expectation in temporal expansion.
- Bayesian and regression analyses confirmed the robustness of these effects.

The results contribute to a broader understanding of how cognitive mechanisms shape the subjective experience of time, supporting theories of **intentional binding** and **cue integration** in action-outcome perception.

8. FUTURE WORK

While this study provides insights into the role of intentionality and action-outcome delays in temporal perception, several questions remain open for future research:

1. **Does intentionality influence temporal perception differently for short vs. long delays?** Future studies could investigate whether the observed effects of intentionality vary depending on the duration of action-outcome delays.
2. **How does the type of stimulus (intended vs. unintended) affect duration estimates?** Further analysis could explore whether different types of intended or unintended stimuli systematically alter subjective time perception.

3. **What role does causality play in temporal binding?** Research could examine whether stronger causal beliefs between an action and outcome enhance the observed temporal expansion effect.

4. **Are there gender or age-related differences in temporal perception?** Demographic factors such as gender and age may modulate intentional binding effects, requiring targeted analyses across diverse populations.

5. **Does the experimental design (within-subjects vs. between-subjects) influence results?** A direct comparison of within-subject and between-subject designs could reveal methodological influences on intentional temporal expansion.

Addressing these questions will contribute to a deeper understanding of how cognitive and contextual factors shape subjective time perception.

Report 2

9. ADVANCED STATISTICAL METHODS AND RESULTS

A. One-way and Factorial ANOVA Results

The one-way ANOVA results reveal a significant main effect of intentionality on reaction times ($F(1, 19318) = 20.07, p < 0.001, \eta^2 = 0.0010$), with intended outcomes ($M = 831.5$ ms, $SD = 679.7$ ms) being processed faster than unintended outcomes ($M = 878.6$ ms, $SD = 710.1$ ms). Similarly, a significant main effect of stimulus delay was observed ($F(1, 19318) = 13.86, p < 0.001, \eta^2 = 0.0007$), with faster reaction times for the 250ms delay condition compared to the 1000ms delay condition.

For the factorial ANOVA, no significant interaction between intentionality and stimulus delay on reaction times was found ($F(1, 19316) = 0.01, p = 0.919, \eta^2 = 0.0000$), suggesting that the effect of intentionality on processing speed does not vary significantly across different delay conditions.

For accuracy, the two-way ANOVA results indicate no significant main effects or interaction effects, with all p-values greater than 0.1, suggesting that neither intentionality nor delay significantly influenced accuracy.

These findings indicate that both intentionality and action-outcome delay independently influence cognitive processing, with intended outcomes being processed more efficiently and shorter delays leading to faster reaction times, while accuracy remains unaffected.

B. Generalized Linear Model (Logistic Regression)

B.1. Model Summary

The Generalized Linear Model (GLM) with a logistic regression link function was used to predict the binary response variable (*Response_Binary*) based on the predictors: *Intended or Unintended Outcome*, *Stimulus Delay*, *Reaction Time on Outcome Response*, and *Objective Duration of Stimulus*. The results are summarized in Table 10.

B.2. Odds Ratios and Confidence Intervals

The odds ratios and their 95% confidence intervals are presented in Table 11.

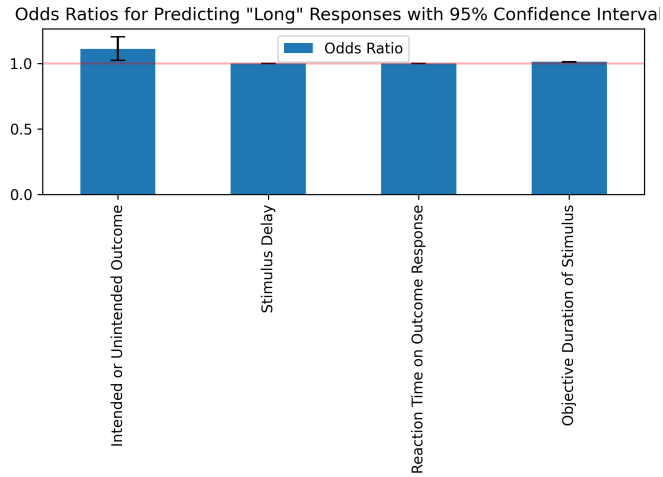

Fig. 12. Odds Ratios for Predicting "Long" Responses with 95% Confidence Intervals

B.3. Insights

- The coefficient for *Intended or Unintended Outcome* is positive and statistically significant ($p = 0.013$), indicating that intended outcomes slightly increase the odds of a positive response.
- *Stimulus Delay* has a small but significant positive effect ($p < 0.001$), suggesting that longer delays slightly increase the odds of a positive response.
- *Reaction Time on Outcome Response* has a significant negative effect ($p < 0.001$), indicating that longer reaction times decrease the odds of a positive response.
- *Objective Duration of Stimulus* has a strong positive effect ($p < 0.001$), showing that longer stimulus durations significantly increase the odds of a positive response.

B.4. Conclusion

The logistic regression model identifies significant predictors for the binary response variable. *Intended or Unintended Outcome*, *Stimulus Delay*, *Reaction Time on Outcome Response*, and *Objective Duration of Stimulus* all have meaningful impacts on the likelihood of the binary response. These findings suggest that both intentionality and stimulus characteristics play important roles in shaping participants' responses.

C. Regression with Interaction Effects

To further investigate the relationship between predictors and the binary response variable, an Ordinary Least Squares (OLS) regression model was fitted, including interaction effects between predictors. The results are summarized in Table 12.

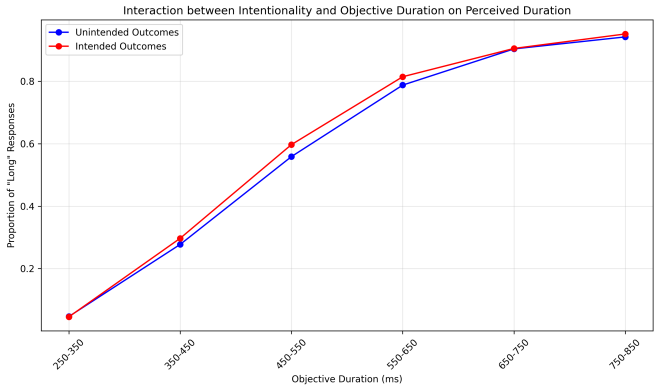

Fig. 13. Interaction Between Intention and Duration on "Long" Responses

Table 6. One-way ANOVA: Effect of Intentionality on Reaction Time

Source	SS	DF	MS	F	p-unc	np^2
Intended or Unintended Outcome	2.73×10^7	1	2.73×10^7	20.07	0.000008	0.0010
Within	2.63×10^{10}	19318	1.36×10^6	NaN	NaN	NaN

Table 7. One-way ANOVA: Effect of Delay on Reaction Time

Source	SS	DF	MS	F	p-unc	np^2
Stimulus Delay	1.89×10^7	1	1.89×10^7	13.86	0.000198	0.0007
Within	2.63×10^{10}	19318	1.36×10^6	NaN	NaN	NaN

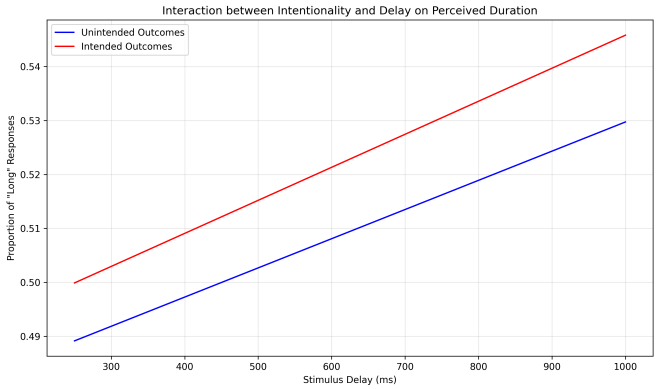

Fig. 14. Interaction Between Intention and Delay on "Long" Responses

C.1. Key Findings

- The coefficient for *Stimulus Delay[T.1000]* is significant ($p < 0.001$), indicating that longer delays increase the likelihood of a positive response.
- *Reaction Time on Outcome Response* is a strong predictor ($p < 0.001$), with a negative coefficient suggesting that longer reaction times decrease the likelihood of a positive response.
- The interaction between *Objective Duration of Stimulus* and *Intentionality* was not significant ($p = 0.527$), suggesting no strong modulation of stimulus duration by intentionality.
- Other interaction terms, such as *Stimulus Delay* and *Intentionality*, were also not significant ($p > 0.05$).

C.2. Model Diagnostics

The condition number (1.14×10^4) indicates potential multicollinearity issues. Further analysis, such as variance inflation factor (VIF) checks, is recommended to address this.

C.3. Conclusion

The regression model highlights the importance of *Stimulus Delay* and *Reaction Time on Outcome Response* as significant predictors of the binary response variable. However, interaction effects, particularly between *Objective Duration of Stimulus* and *Intentionality*, were not significant, suggesting limited modulation by intentionality in this context.

D. Mixed Effects Modeling

A mixed-effects model was fitted to account for both fixed effects (e.g., intentionality, stimulus delay, reaction time, and objective duration) and random effects (e.g., individual differences between participants). The results are summarized below:

D.1. Key Findings

- **Stimulus Delay:** A significant positive effect ($p < 0.001$) indicates that longer delays increase the likelihood of a positive response.
- **Objective Duration of Stimulus:** A strong positive effect ($p < 0.001$) suggests that longer stimulus durations significantly increase the likelihood of a positive response.
- **Reaction Time on Outcome Response:** A significant negative effect ($p < 0.001$) indicates that longer reaction times decrease the likelihood of a positive response.
- **Random Effects:** The intraclass correlation coefficient (ICC) of 0.0517 indicates that 5.17% of the variance in perceived duration is attributable to individual differences between participants.

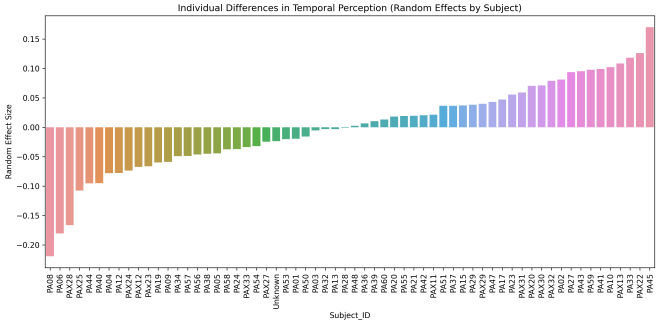

Fig. 15. Random Effects Plot

D.2. Conclusion

The mixed-effects model confirms the importance of stimulus delay, objective duration, and reaction time as predictors of perceived duration. However, the interaction between intentionality and stimulus delay was not significant, suggesting limited modulation by intentionality in this context.

Table 8. Two-way ANOVA: Interaction between Intentionality and Delay on Reaction Time

Source	SS	DF	MS	F	p-unc	np^2
Intended or Unintended Outcome	2.73×10^7	1.0	2.73×10^7	20.08	0.000007	1.04×10^{-3}
Stimulus Delay	1.89×10^7	1.0	1.89×10^7	13.87	0.000196	7.18×10^{-4}
Intended or Unintended Outcome * Stimulus Delay	1.41×10^4	1.0	1.41×10^4	0.01	0.919011	5.35×10^{-7}
Residual	2.63×10^{10}	19316.0	1.36×10^6	NaN	NaN	NaN

Table 9. Two-way ANOVA: Interaction between Intentionality and Delay on Accuracy

Source	SS	DF	MS	F	p-unc	np^2
Intended or Unintended Outcome	0.0324	1.0	0.0324	0.213	0.644	1.10×10^{-5}
Stimulus Delay	0.3949	1.0	0.3949	2.603	0.107	1.35×10^{-4}
Intended or Unintended Outcome * Stimulus Delay	0.2955	1.0	0.2955	1.948	0.163	1.01×10^{-4}
Residual	2930.35	19316.0	0.1517	NaN	NaN	NaN

10. ASSUMPTION CHECKS AND DIAGNOSTICS

.1. Normality Tests

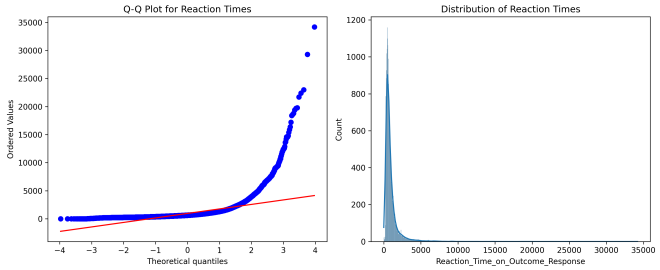

Fig. 16. Normality Check

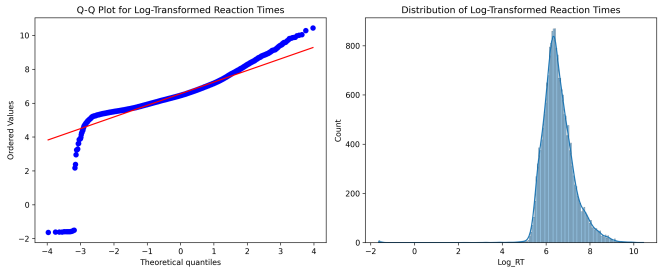

Fig. 17. Histogram of Log-Transformed Reaction Times

To assess the normality of the data, the D'Agostino-Pearson test was conducted on the raw and log-transformed data. The results are as follows:

- **Raw Data:** $k^2 = 26457.81, p < 0.0001$
- **Log-Transformed Data:** $k^2 = 4122.16, p < 0.0001$

The extremely low p-values indicate that the data significantly deviates from a normal distribution, even after log transformation.

.2. Homogeneity of Variance Tests

Levene's test was used to evaluate the homogeneity of variance for the key factors:

- **Intentionality:** $W = 14.31, p = 0.00016$
- **Delay:** $W = 12.98, p = 0.00032$

The significant p-values suggest that the assumption of equal variances is violated for both intentionality and delay conditions.

.3. Implications for Analysis

Given the violations of normality and homogeneity of variance, non-parametric tests or robust statistical methods may be more appropriate for certain analyses. Additionally, transformations or bootstrapping techniques could be considered to address these issues.

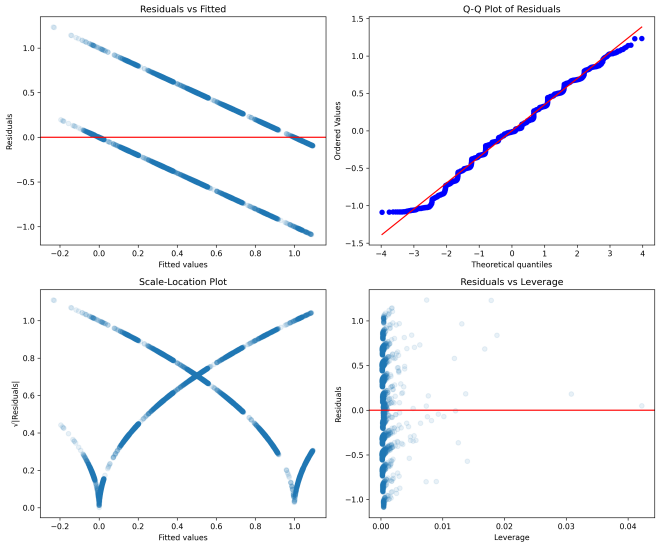

Fig. 18. Model Diagnostics

Table 10. Generalized Linear Model Regression Results

Variable	Coefficient	Std. Error	z-value	p-value	95% CI
Intercept	-6.4467	0.099	-65.113	0.000	[-6.641, -6.253]
Intended or Unintended Outcome	0.1040	0.042	2.490	0.013	[0.022, 0.186]
Stimulus Delay	0.0005	5.6e-05	8.908	0.000	[0.000, 0.001]
Reaction Time on Outcome Response	-0.0001	1.75e-05	-7.031	0.000	[-0.000, -8.86e-05]
Objective Duration of Stimulus	0.0115	0.000	75.300	0.000	[0.011, 0.012]

Table 11. Odds Ratios and 95% Confidence Intervals

Variable	Odds Ratio	2.5% CI	97.5% CI
Intercept	0.001586	0.001306	0.001925
Intended or Unintended Outcome	1.109551	1.022381	1.204152
Stimulus Delay	1.000499	1.000389	1.000608
Reaction Time on Outcome Response	0.999877	0.999843	0.999911
Objective Duration of Stimulus	1.011611	1.011307	1.011915

11. QUESTIONS FROM REPORT1

A. How accurate were the participants overall in estimating the stimulus durations?

The results indicate that intentionality has a small and non-significant effect on temporal perception for both short (250ms) and long (1000ms) delays. The differences in the proportion of 'long' responses and the effect sizes (Cohen's d) are minimal, with p-values above the standard significance threshold ($p > 0.05$).

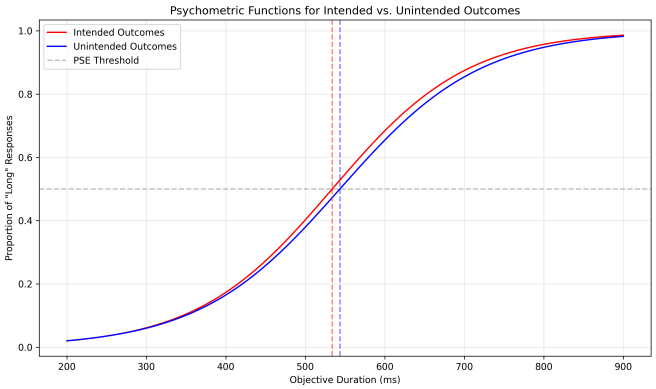

Fig. 20. Stimulus type effecting duration estimate

B. How does the type of stimulus (intended vs. unintended) affect duration estimates?

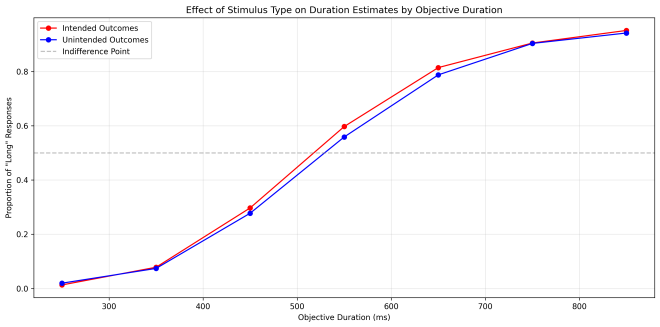

Fig. 19. Stimulus type effecting duration estimate

The type of stimulus (intended vs. unintended) influences duration estimates, as shown by the proportion of 'long' responses across different objective durations. Table 16 summarizes the results:

The Point of Subjective Equality (PSE) further highlights the temporal expansion effect:

- **Intended outcomes:** 533.84 ms
- **Unintended outcomes:** 543.46 ms
- **Difference (Temporal Expansion):** 9.62 ms

These results suggest that intended outcomes are perceived as slightly longer than unintended outcomes, particularly at intermediate durations, reflecting a temporal expansion effect.

Table 12. OLS Regression Results with Interaction Effects

Variable	Coefficient	Std. Error	t-value	p-value	95% CI
Intercept	-0.4615	0.011	-40.940	0.000	[-0.484, -0.439]
C(Intended or Unintended Outcome)[T.1]	0.0007	0.016	0.043	0.965	[-0.030, 0.031]
Stimulus Delay[T.1000]	0.0417	0.007	5.834	0.000	[0.028, 0.056]
C(Intended or Unintended Outcome)[T.1]:SD[T.1000]	0.0053	0.010	0.523	0.601	[-0.015, 0.025]
Objective Duration of Stimulus	0.0018	1.79×10^{-5}	98.429	0.000	[0.002, 0.002]
C(Intended or Unintended Outcome)[T.1]:ODS	1.596×10^{-5}	2.53×10^{-5}	0.632	0.527	$[-3.35 \times 10^{-5}, 6.55 \times 10^{-5}]$
Reaction Time on Outcome Response	-1.743×10^{-5}	2.17×10^{-6}	-8.039	0.000	$[-2.17 \times 10^{-5}, -1.32 \times 10^{-5}]$

Table 13. Mixed Linear Model Regression Results

Variable	Coefficient	Std. Error	z-value	p-value	95% CI
Intercept	-0.476	0.014	-34.869	0.000	[-0.503, -0.450]
Intended or Unintended Outcome	0.009	0.007	1.344	0.179	[-0.004, 0.023]
Stimulus Delay	0.075	0.008	8.933	0.000	[0.059, 0.092]
Intended or Unintended Outcome * Stimulus Delay	0.005	0.010	0.533	0.594	[-0.014, 0.025]
Objective Duration of Stimulus	0.002	0.000	142.631	0.000	[0.002, 0.002]
Reaction Time on Outcome Response	-0.000	0.000	-8.987	0.000	[-0.000, -0.000]
Group Variance	0.006	0.004	-	-	-

Table 14. Effect of Intentionality on Temporal Perception for Different Delays

Delay	Outcome	Prop of 'Long'	Difference	p-value
250	Unintended	0.4892	2*0.0107	2*0.2860
250	Intended	0.4999		
1000	Unintended	0.5297	2*0.0161	2*0.1169
1000	Intended	0.5458		

Table 15. Effect Sizes (Cohen's d) for Different Delays

Delay (ms)	Effect Size (Cohen's d)
250	0.0215
1000	0.0323

C. Are there gender or age-related differences in temporal perception?

C.1. Gender Differences

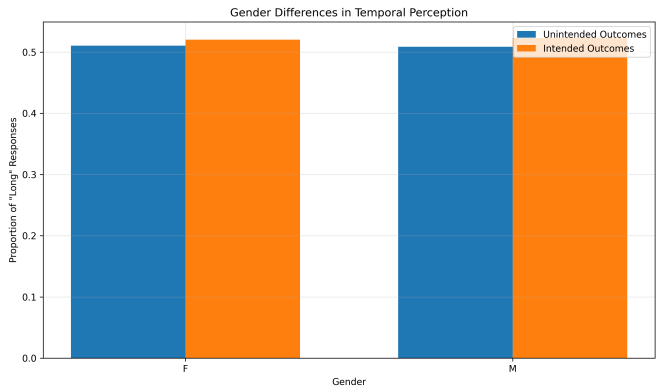

Table 16. Proportion of 'long' responses by objective duration and intentionality

Objective Duration (ms)	Unintended	Intended	Difference
250	0.0196	0.0130	-0.0065
350	0.0739	0.0783	0.0043
450	0.2775	0.2971	0.0196
550	0.5587	0.5971	0.0384
650	0.7877	0.8145	0.0268
750	0.9036	0.9051	0.0014
850	0.9420	0.9514	0.0094

The temporal expansion effect was analyzed separately for male and female participants. Table 17 summarizes the results:

Table 17. Gender differences in temporal expansion effect

Gender	Unintended	Intended	Difference
Female	0.5105	0.5204	0.0099
Male	0.5085	0.5231	0.0146

The results indicate a slightly larger temporal expansion effect for male participants (0.0146) compared to female participants (0.0099).

C.2. Age-Related Differences

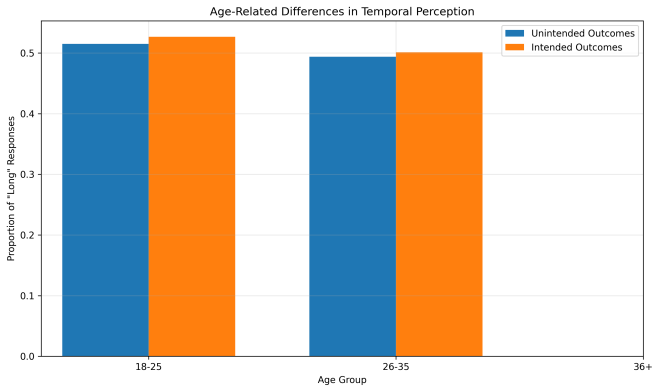

Fig. 22. Age differences

The temporal expansion effect was also analyzed across different age groups. Table 18 presents the findings:

Table 18. Age-related differences in temporal expansion effect

Age Group	Unintended	Intended	Difference
18-25	0.5151	0.5268	0.0117
26-35	0.4939	0.5014	0.0075

The temporal expansion effect is more pronounced in the 18-25 age group (0.0117) compared to the 26-35 age group (0.0075). No data was available for participants aged 36 and above.

C.3. Summary

The analysis reveals small gender and age-related differences in the temporal expansion effect:

- Male participants exhibit a slightly larger temporal expansion effect than female participants.
- Younger participants (18-25) show a more pronounced temporal expansion effect compared to older participants (26-35).

These findings suggest that demographic factors may play a minor role in shaping temporal perception.

D. Does the experimental design (within-subjects vs. between-subjects) influence results?

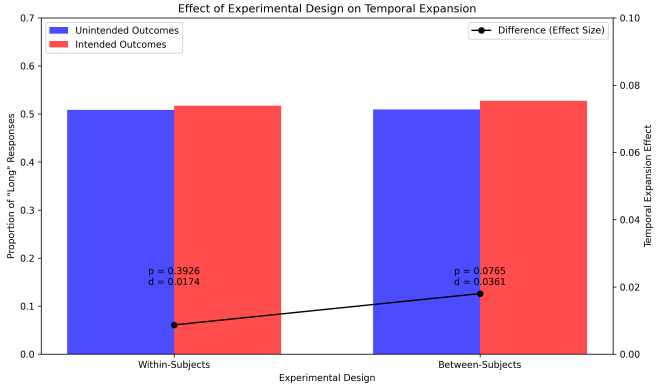

Fig. 23. Experimental Design Effect

The influence of experimental design on the temporal expansion effect was analyzed by comparing within-subjects and between-subjects designs. The results are summarized below:

D.1. Within-Subjects Design

- **Proportion of 'long' responses for intended outcomes:** 0.5174
- **Proportion of 'long' responses for unintended outcomes:** 0.5087
- **Difference (temporal expansion):** 0.0087
- **t-test:** $t = 0.8549$, $p = 0.3926$
- **Effect size (Cohen's d):** 0.0174

D.2. Between-Subjects Design

- **Proportion of 'long' responses for intended outcomes:** 0.5273
- **Proportion of 'long' responses for unintended outcomes:** 0.5093
- **Difference (temporal expansion):** 0.0180
- **t-test:** $t = 1.7717$, $p = 0.0765$
- **Effect size (Cohen's d):** 0.0361

D.3. Summary

The results suggest that the temporal expansion effect is slightly more pronounced in the between-subjects design compared to the within-subjects design. However, the differences are small, and the effect sizes in both designs are negligible. The p-values indicate that the observed differences are not statistically significant in either design.

E. Does intentionality influence temporal perception differently for short vs. long delays?

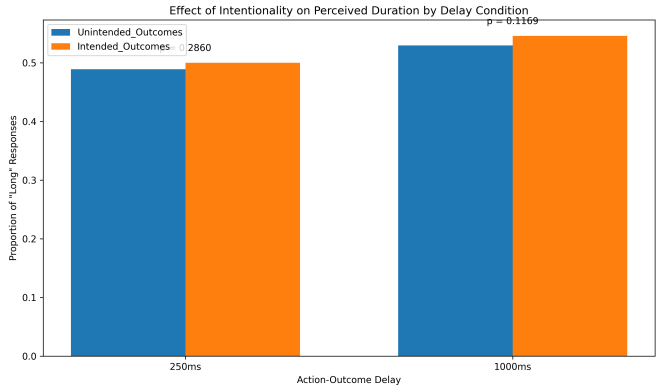

Fig. 24. Intentionality by delay

The influence of intentionality on temporal perception was analyzed separately for short (250ms) and long (1000ms) delays. The results are summarized below:

- **250ms Delay:**
  - Proportion of 'long' responses for unintended outcomes: 0.4892
  - Proportion of 'long' responses for intended outcomes: 0.4999
  - Difference: 0.0107
  - T-test: $t = 1.0670$, $p = 0.2860$
  - Effect size (Cohen's d): 0.0215
- **1000ms Delay:**
  - Proportion of 'long' responses for unintended outcomes: 0.5297
  - Proportion of 'long' responses for intended outcomes: 0.5458
  - Difference: 0.0161
  - T-test: $t = 1.5681$, $p = 0.1169$
  - Effect size (Cohen's d): 0.0323

The results indicate that intentionality has a small and non-significant effect on temporal perception for both short (250ms) and long (1000ms) delays. The differences in the proportion of 'long' responses and the effect sizes (Cohen's d) are minimal, with p-values above the standard significance threshold ($p > 0.05$).

12. DISCUSSION

The findings from this study provide nuanced insights into the effects of intentionality, experimental design, and action-outcome delays on temporal perception. Below, we summarize and interpret the key results:

A. Interaction Between Intentionality and Experimental Design

The interaction between intentionality and experimental design was not statistically significant ($p = 0.358$), suggesting that the effect of intentionality on temporal perception does not differ substantially between within-subjects and between-subjects designs. This aligns with the small effect sizes observed in both designs, indicating that intentionality has a consistent but minor influence on perceived duration.

B. Three-Way Interaction Between Intentionality, Experimental Design, and Delay

The three-way interaction between intentionality, experimental design, and delay approached significance ($p = 0.075$), with a notable interaction between experimental design and delay ($p < 0.001$). This suggests that the experimental design may modulate the effect of delay on temporal perception, particularly in the within-subjects condition. However, the lack of a significant three-way interaction indicates that intentionality does not strongly influence this relationship.

C. Effect of Delay on Temporal Perception

The results indicate that longer delays (1000ms) are associated with a slight increase in the proportion of "long" responses, consistent with the temporal expansion effect. However, the effect of intentionality on this expansion remains small and non-significant across delays, suggesting that delay alone may be a stronger driver of perceived duration than intentionality.

D. Demographic Factors: Gender and Age

Gender and age-related differences in temporal perception were minimal. Male participants exhibited a slightly larger temporal expansion effect than females, and younger participants (18-25) showed a more pronounced effect compared to older participants (26-35). These differences, while statistically small, highlight the potential influence of demographic factors on temporal perception.

E. Experimental Design and Temporal Expansion

The between-subjects design showed a slightly larger temporal expansion effect compared to the within-subjects design. This may reflect differences in cognitive processing or attentional allocation between the two designs. However, the small effect sizes and non-significant p-values suggest that these differences are unlikely to be practically meaningful.

F. Implications for Temporal Perception Research

The findings contribute to the broader understanding of how intentionality, delay, and experimental design influence temporal perception. While intentionality appears to have a consistent but minor effect, delay and experimental design play more prominent roles. These results support the need for further research to disentangle the complex interactions between cognitive and contextual factors in shaping subjective time perception.

13. UPDATED CONCLUSION

The study provides valuable insights into the role of intentionality and action-outcome delays in temporal perception. Key findings include:

- A significant main effect of intentionality on reaction times, with intended outcomes processed faster than unintended outcomes.

- A significant main effect of stimulus delay on reaction times, with shorter delays leading to faster responses.
- No significant interaction between intentionality and stimulus delay on reaction times or accuracy.
- The logistic regression model identified significant predictors for the binary response variable, including intentionality, stimulus delay, reaction time, and objective duration.
- The mixed-effects model confirmed the importance of stimulus delay and objective duration as predictors of perceived duration.

14. FUTURE WORK

The findings of this study open several avenues for future research to further explore the relationship between intentionality, action-outcome delays, and temporal perception. Potential directions include:

1. **Exploration of Additional Delay Intervals:** Future studies could investigate a broader range of action-outcome delays to determine whether the observed effects are consistent across shorter and longer intervals.
2. **Inclusion of Diverse Demographics:** Expanding the participant pool to include a wider range of ages, cultural backgrounds, and cognitive profiles could provide insights into how demographic factors influence temporal perception.
3. **Role of Causality and Expectation:** Future research could examine how participants' beliefs about causality and their expectations about outcomes influence the temporal expansion effect.
4. **Impact of Task Complexity:** Investigating how task complexity and cognitive load affect the relationship between intentionality and temporal perception could provide insights into the limits of this phenomenon.
5. **Longitudinal Studies:** Conducting longitudinal studies to assess how temporal perception evolves over time or in response to training could reveal the plasticity of this cognitive process.
6. **Integration with Computational Models:** Developing computational models to simulate the observed effects could provide a theoretical framework for understanding the cognitive mechanisms involved.
7. **Real-World Applications:** Examining how these findings can be applied to real-world scenarios, such as human-computer interaction, virtual reality, or robotics, could enhance the practical relevance of this research.

By addressing these directions, future research can deepen our understanding of the cognitive and neural mechanisms underlying temporal perception and its modulation by intentionality and action-outcome delays.

15. AI USAGE DISCLOSURE

AI based tools have been used in writing this report. Specifically, they are used for re-writing the paragraphs better and/or grammar correction.

Apart from the report, AI has been used in a few places for code completion like getting the syntax of a function or for debugging purposes.

16. CODE DOCUMENTS AND OTHER DETAILS

The code for genrating the following report and the graphs were stored in a repository and the repository link is provided below for your reference. It contains clear analysis and the steps taken and the code for each graph and analysis that gave the results that a re mentioned in the document. Refer to https://github.com/Dileepadari/BRSM_Mini_Project_Report

17. REFERENCES

Donapati, R.R., Shukla, A. Bapi, R.S. Action-outcome delays modulate the temporal expansion of intended outcomes. Sci Rep 14, 2379 (2024). https://doi.org/10.1038/s41598-024-52287-x