Exploratory Analysis of Action-Outcome Delays Dataset

DILEEP KUMAR. A

International Institute of Information Technolgy, Hyderabad, Gachibowli, Telanagana, India, 500032

Compiled March 4, 2025

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.

http://dx.doi.org/10.1038/s41598-024-52287-x

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

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.

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.

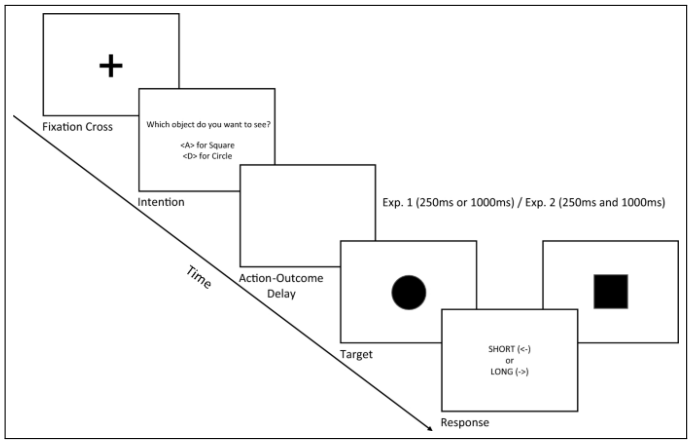

Fig. 1. Experimental Design.

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.

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.

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.

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.

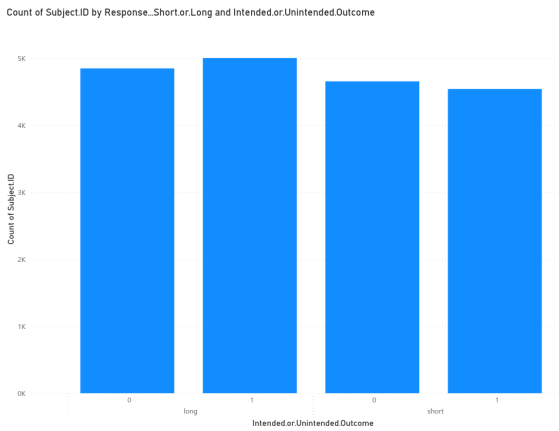

Fig. 2. Histogram of "long" and "short" response proportions across experimental conditions.

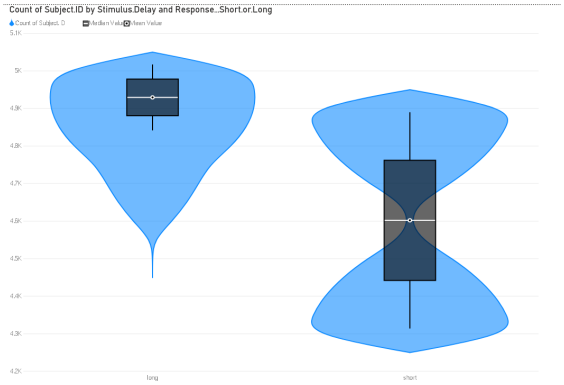

Fig. 3. Violin plot of "long" and "short" response proportions across experimental conditions.

Figure 3 suggests that participants were more likely to perceive outcomes as "long" under certain conditions, potentially indicating a temporal expansion effect. Figure 3 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.

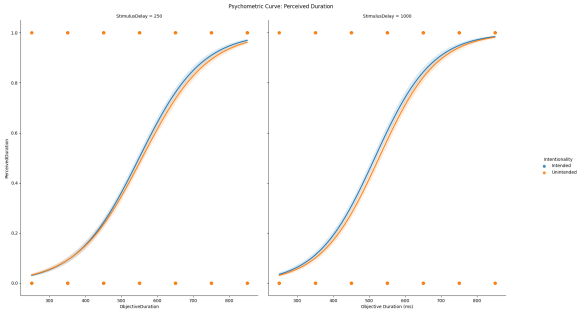

Fig. 4. Psychometric curves depicting shifts in perceived duration for intended and unintended outcomes at different action-outcome delays.

B.2. Box Plots for Reaction Time Distribution

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

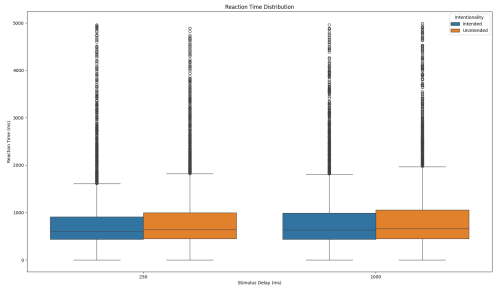

Fig. 5. Reaction time distribution for intended and unintended outcomes across action-outcome delays.

B.3. Correlation Heatmap

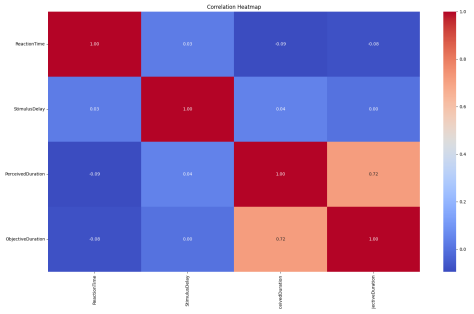

Fig. 6. Correlation heatmap of reaction time, objective duration, and subjective perception.

C. Questions

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

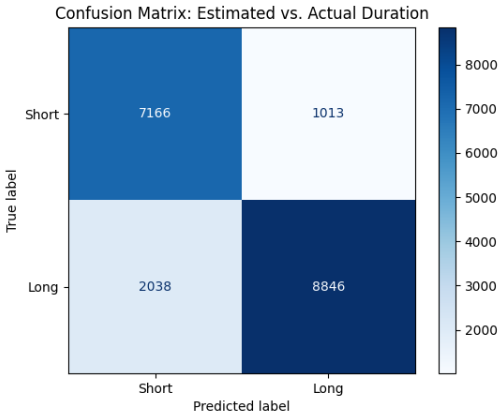

Fig. 7. Confusion Matrix: Estimated vs. Actual Duration.

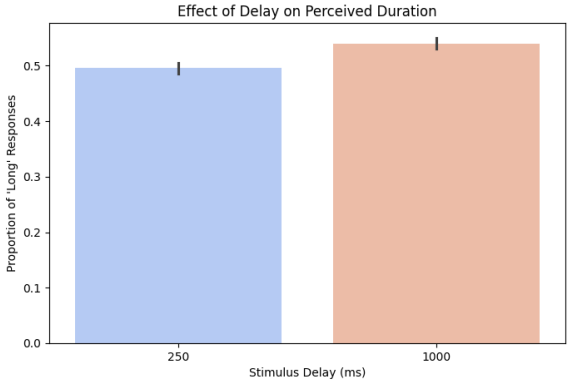

Fig. 8. 2. Delay Effect

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

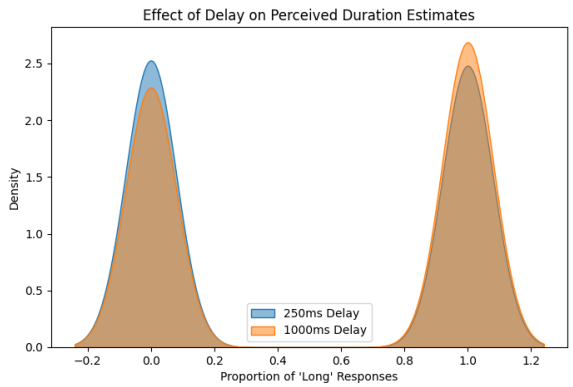

Fig. 9. Effect of Delay on Perceived Duration Estimates

- 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. **How does reaction time correlate with duration estimates?** While initial correlations were observed, further modeling could clarify whether reaction time predicts subjective duration perception.
6. **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.

9. 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.

10. 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 are mentioned in the document. Refer to https://github.com/Dileepadari/BRSM_Mini_Project_Report

11. 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