



**Delay Tolerance and Impulsive Choice under Variable Reward
Uncertainty among Young Adults**

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Abstract: Decision-making under uncertainty is a fundamental cognitive process that influences human behaviour in financial choices, health-related decisions, education, and everyday activities. One important aspect of decision-making is the ability to tolerate delayed rewards rather than selecting smaller immediate outcomes, a phenomenon commonly examined through delay discounting and impulsive choice frameworks. However, real-world decisions frequently occur under conditions where future rewards are uncertain, making the interaction between delay tolerance and reward uncertainty an important area of investigation. This study develops a simulation-based computational modelling framework to examine how variable reward uncertainty influences delay tolerance and impulsive choice among young adults. A synthetic population of simulated decision-making agents was generated with different behavioural characteristics, including reward sensitivity, self-control capacity, uncertainty tolerance, and impulsivity tendency. The model simulated multiple decision scenarios involving immediate and delayed rewards under different uncertainty conditions. Behavioural outcomes were evaluated using impulsive choice probability, delay tolerance score, reward preference patterns, and decision consistency. The simulation results demonstrate that increasing reward uncertainty significantly influences preference toward immediate rewards, resulting in higher impulsive choice probability and reduced delay tolerance. The model further indicates that longer delays combined with uncertain outcomes create stronger cognitive pressure toward immediate decision selection. Agents with higher self-control parameters demonstrated greater willingness to wait for delayed rewards, whereas agents with increased reward sensitivity showed stronger preference for immediate outcomes. The proposed computational framework contributes to behavioural decision research by providing a simulation-based approach for analysing the interaction between

temporal delay and uncertain rewards. The findings offer theoretical insights for understanding impulsive decision-making patterns and provide a foundation for future empirical studies and intelligent behavioural prediction systems.

Keywords: Delay tolerance; Impulsive choice; Reward uncertainty; Delay discounting; Decision-making; Behavioural simulation; Computational modelling; Young adults; Risk preference; Cognitive control

1. Introduction

1.1 Background

Human decision-making often requires individuals to evaluate immediate benefits against future outcomes. Many choices involve a fundamental conflict between obtaining a smaller reward immediately and waiting for a larger reward in the future. The ability to delay gratification and tolerate waiting periods represents an important aspect of self-control and adaptive decision-making.

Delay tolerance refers to the capacity of individuals to maintain preference for delayed outcomes despite the availability of immediate alternatives. Individuals with higher delay tolerance are generally more capable of considering long-term consequences, whereas individuals with lower delay tolerance tend to prefer immediate rewards, reflecting stronger impulsive choice tendencies.

Impulsive choice represents a decision pattern in which individuals select immediate rewards despite potentially greater future benefits. This behaviour is associated with reduced consideration of future consequences and increased sensitivity toward immediate reinforcement. Understanding the mechanisms that influence impulsive choice is important in areas such as financial behaviour, health decisions, educational planning, and digital consumption patterns.

Traditional research on delay tolerance has primarily focused on delay discounting models, where the value of future rewards decreases as waiting time increases. However, real-world decisions rarely involve completely predictable outcomes. Future rewards are often associated with uncertainty regarding their availability, magnitude, or probability of achievement.

For example, an individual deciding whether to wait for a larger future reward may consider not only the delay period but also the possibility that the expected reward may not occur.

Therefore, reward uncertainty may represent an important factor influencing impulsive decision-making.

1.2 Delay Discounting and Impulsive Choice

Delay discounting theory suggests that individuals typically assign lower subjective value to rewards that are received after longer delays. The decrease in perceived reward value occurs because future outcomes involve psychological distance and uncertainty.

The mathematical representation of delay discounting commonly assumes that:

- Immediate rewards have higher subjective value.
- Longer delays reduce reward attractiveness.
- Individual differences influence discounting rates.

Individuals with steep discounting tendencies tend to prefer immediate rewards, while individuals with shallow discounting tendencies demonstrate greater willingness to wait.

Although delay discounting provides valuable insights into temporal decision-making, many existing models assume that future rewards are certain. However, uncertainty introduces additional complexity because individuals must evaluate both:

1. When the reward will be received.
2. Whether the reward will actually occur.

This interaction between time delay and uncertainty may significantly influence impulsive choice behaviour.

1.3 Reward Uncertainty and Decision Behaviour

Reward uncertainty refers to situations where the probability, amount, or availability of future outcomes is unpredictable. Under uncertain conditions, individuals may experience increased difficulty in evaluating delayed rewards.

When uncertainty increases, future outcomes may appear less valuable because individuals perceive greater risk associated with waiting. As a result, individuals may shift preference toward immediate rewards that provide guaranteed outcomes.

Variable reward uncertainty can influence decision-making through several mechanisms:

1. **Reduced Future Reward Confidence** - Uncertain delayed rewards may decrease expectations regarding future benefits.
2. **Increased Immediate Reward Attraction** - Immediate rewards provide immediate satisfaction and eliminate uncertainty.

3. Greater Cognitive Demand - Evaluating uncertain future outcomes requires additional mental processing and risk assessment.

Therefore, reward uncertainty may amplify impulsive choice, particularly when combined with longer delays.

1.4 Young Adults and Decision-Making Under Uncertainty

Young adulthood represents an important developmental stage characterized by increased independence, financial decision-making, educational planning, and social responsibility. During this period, individuals frequently encounter situations requiring decisions involving immediate versus future benefits.

Examples include:

- Saving money versus immediate spending
- Academic preparation versus short-term entertainment
- Health-related choices versus immediate pleasure
- Career planning versus immediate opportunities

Young adults may demonstrate considerable variability in self-control, risk tolerance, and future-oriented thinking. Understanding factors influencing delay tolerance during this stage can provide valuable insights into behavioural decision processes.

However, most existing research examines impulsive choice through behavioural experiments or questionnaire-based methods. Computational simulation provides an alternative approach by allowing researchers to examine complex interactions between multiple psychological variables under controlled conditions.

1.5 Simulation-Based Modelling in Behavioural Research

Simulation-based research has become increasingly valuable for studying complex cognitive and behavioural systems. Unlike traditional experimental methods, computational modelling allows researchers to manipulate multiple variables, generate controlled scenarios, and examine possible behavioural outcomes.

Simulation approaches provide several advantages:

- Controlled manipulation of decision conditions
- Analysis of complex variable interactions
- Testing of theoretical assumptions
- Prediction of behavioural patterns

In decision science, simulation models can represent differences between individuals by assigning behavioural parameters such as risk preference, reward sensitivity, and self-control capacity.

The present study applies a simulation-based computational approach to examine how variable reward uncertainty influences delay tolerance and impulsive choice among young adults.

1.6 Research Problem

Although previous research has extensively examined delay discounting and impulsive choice, several limitations remain.

First, many studies focus primarily on delay duration while giving limited attention to uncertainty associated with future rewards.

Second, existing approaches often examine individual factors separately rather than modelling interactions between:

- Reward uncertainty
- Delay duration
- Self-control ability
- Reward sensitivity

Third, limited computational frameworks exist for predicting impulsive choice patterns under variable reward conditions.

Therefore, this study addresses the need for a simulation-based framework capable of modelling how uncertainty modifies delayed reward decisions.

1.7 Research Objectives

The objectives of this study are:

RO1: To develop a simulation-based computational model for analysing delay tolerance behaviour among young adults.

RO2: To examine how variable reward uncertainty influences impulsive choice probability.

RO3: To evaluate the relationship between delay duration and reward preference.

RO4: To analyse how individual behavioural characteristics influence delayed reward selection.

RO5: To develop a predictive framework for understanding impulsive decision-making under uncertain reward conditions.

1.8 Research Questions

RQ1: How does reward uncertainty influence delay tolerance among simulated young adult decision-makers?

RQ2: Does increased reward uncertainty increase impulsive choice probability?

RQ3: How does delay duration affect immediate versus delayed reward preference?

RQ4: Can behavioural characteristics predict impulsive choice patterns under uncertain conditions?

1.9 Research Hypotheses

H1: Higher reward uncertainty increases impulsive choice probability.

H2: Longer delay duration reduces preference for delayed rewards.

H3: Higher self-control capacity increases delay tolerance.

H4: Reward sensitivity positively predicts immediate reward selection under uncertain conditions.

2. Literature Review

2.1 Delay Discounting Theory and Temporal Decision-Making

Delay discounting is one of the most widely studied concepts in behavioural decision science and describes the tendency of individuals to decrease the subjective value of rewards as the waiting period increases. Although future rewards may provide greater objective benefits, individuals often perceive immediate rewards as more attractive because they provide instant satisfaction.

The process of choosing between immediate and delayed outcomes reflects an individual's ability to regulate behaviour, evaluate future consequences, and maintain long-term goals. Individuals with higher delay tolerance are more likely to select delayed rewards, whereas individuals with stronger impulsive tendencies typically prefer immediate outcomes.

Traditional delay discounting models suggest that the subjective value of delayed rewards decreases according to the length of the delay. A commonly used mathematical representation is the hyperbolic discounting model:

$$V = \frac{A}{1 + kD}$$

Where:

V = subjective value of delayed reward

A = objective reward amount

D = delay duration

k = discounting parameter

The discounting parameter represents individual differences in future-oriented decision-making. Higher discounting rates indicate stronger preference for immediate rewards and reduced tolerance for delayed outcomes.

However, traditional delay discounting models mainly focus on the influence of time delay and often assume that future rewards are certain. In real-world decision environments, future outcomes frequently involve uncertainty, probability variations, and incomplete information. Therefore, additional modelling approaches are required to understand how uncertainty interacts with delay-based decisions.

2.2 Impulsive Choice and Self-Control Mechanisms

Impulsive choice refers to the preference for immediate rewards despite the possibility of obtaining greater benefits through delayed decisions. It represents a failure to prioritize future outcomes when immediate alternatives are available.

Impulsive decision-making is influenced by multiple psychological mechanisms, including:

- Reward sensitivity
- Cognitive control ability
- Future orientation
- Emotional regulation
- Risk perception

Individuals with strong self-control abilities are generally better able to delay gratification and consider long-term consequences. In contrast, individuals with higher impulsivity levels may experience stronger attraction toward immediate rewards because immediate outcomes provide rapid reinforcement.

Self-control plays a critical role in regulating impulsive behaviour. The ability to wait for future benefits requires individuals to suppress immediate desires and maintain goal-directed behaviour.

Within computational decision models, self-control can be represented as a behavioural parameter that influences the probability of selecting delayed rewards.

A simulation framework can therefore represent differences between individuals by modelling:

- High self-control agents

- Moderate self-control agents
- Low self-control agents

This approach enables investigation of how individual behavioural characteristics influence decision outcomes under different reward conditions.

2.3 Reward Uncertainty and Risk-Based Decision-Making

Reward uncertainty introduces additional complexity into decision-making because individuals must evaluate not only the timing of a reward but also the probability of receiving it.

Under uncertain conditions, delayed rewards may lose subjective value because future outcomes become less predictable. As uncertainty increases, individuals may prefer immediate rewards because they provide guaranteed outcomes and eliminate waiting-related risk.

Reward uncertainty can influence decision behaviour through several processes:

- **Probability Evaluation** - Individuals estimate the likelihood of receiving future rewards.
- **Risk Perception** - Individuals assess potential loss associated with waiting.
- **Reward Expectation** - Individuals form expectations regarding future outcomes.

When delayed rewards become uncertain, the psychological value of waiting may decrease, increasing impulsive choice probability.

Therefore, modelling reward uncertainty together with delay duration provides a more realistic representation of real-world decision-making.

2.4 Behavioural Economics Perspective

Behavioural economics explains decision-making as a combination of rational evaluation and psychological biases.

Traditional economic theories assume that individuals make decisions based on optimal evaluation of available information. However, behavioural research demonstrates that humans frequently deviate from purely rational choices due to cognitive limitations, emotional influences, and uncertainty.

Important behavioural economics concepts related to this study include:

- **Present Bias** - Individuals often assign greater importance to immediate outcomes compared with future outcomes.
- **Risk Sensitivity** - Individuals modify decisions based on perceived uncertainty and probability.

- **Loss Avoidance** - Individuals may prefer certain smaller rewards over uncertain larger rewards.

The interaction between delay and uncertainty represents an important behavioural economics problem because both factors influence perceived reward value.

2.5 Computational Modelling in Cognitive Decision Research

Computational modelling provides an effective approach for examining complex psychological processes that involve multiple interacting variables.

Unlike traditional experimental approaches, simulation-based models allow researchers to:

- Generate controlled decision environments
- Modify behavioural parameters
- Test theoretical assumptions
- Analyse possible outcomes across multiple conditions

In cognitive psychology, computational models have been applied to study:

- Decision-making
- Learning behaviour
- Risk assessment
- Attention processes
- Reward evaluation

Simulation-based approaches are particularly useful when studying interactions between multiple factors because researchers can examine how changes in one variable influence overall system behaviour.

In the present study, computational modelling is used to simulate young adult decision agents with different levels of reward sensitivity, uncertainty tolerance, and self-control capacity.

2.6 Young Adults and Reward-Based Decision Behaviour

Young adulthood represents a critical period for decision development because individuals increasingly make independent choices related to education, finances, career planning, and lifestyle.

During this stage, individuals frequently encounter decisions involving delayed benefits and uncertain outcomes.

Examples include:

- Saving money for future goals
- Investing time in education

- Choosing long-term career benefits over immediate rewards
- Managing risk-related choices

Differences in impulsivity and delay tolerance among young adults may influence these decisions significantly.

A computational simulation approach allows researchers to examine behavioural differences among young adult profiles without requiring extensive real-world experimentation.

3. Theoretical Framework

The proposed simulation framework is based on the integration of three major theoretical perspectives:

3.1 Delay Discounting Theory

This theory explains how reward value decreases as delay increases.

In the proposed model:

- Longer delays reduce reward attractiveness.
- Immediate rewards become more competitive.
- Individual discounting rates influence decision preference.

3.2 Self-Control Theory

Self-control theory explains the ability to regulate immediate desires in favour of future benefits.

In the simulation:

Higher self-control agents demonstrate:

- Greater delay tolerance
- Lower impulsive choice probability
- Higher preference for delayed rewards

3.3 Risk and Uncertainty Decision Theory

This theory explains how individuals modify choices when future outcomes are unpredictable.

In the simulation:

Higher uncertainty produces:

- Lower confidence in delayed rewards
- Increased preference for immediate outcomes
- Higher impulsive choice probability

4. Research Gap

Although previous research has extensively examined delay discounting and impulsive choice, several important gaps remain.

Gap 1: Limited Integration of Delay and Uncertainty Factors

Most delay discounting studies focus primarily on waiting time while assuming that future rewards are guaranteed.

However, real-world decisions frequently involve uncertain outcomes.

A comprehensive model should consider both:

- Delay duration
- Reward uncertainty

Gap 2: Lack of Computational Behavioural Models

Many existing studies rely on questionnaires or behavioural experiments.

Although these methods provide valuable insights, they may not fully explain how multiple psychological factors interact dynamically.

Simulation-based modelling provides an opportunity to examine these interactions systematically.

Gap 3: Limited Modelling of Individual Differences

Individuals vary in:

- Self-control ability
- Reward sensitivity
- Risk tolerance
- Impulsivity level

Existing approaches often analyse average behavioural patterns rather than modelling individual variability.

Gap 4: Insufficient Prediction of Impulsive Choice Under Uncertainty

Previous research has examined impulsivity and delay discounting separately, but fewer studies attempt to predict impulsive choices when delayed rewards become uncertain.

This study addresses this limitation by developing a computational framework that models impulsive choice probability under different uncertainty conditions.

5. Novel Contribution of the Study

The present study introduces a simulation-based computational framework for analysing delay tolerance and impulsive choice under variable reward uncertainty.

The major contributions are:

5.1 Development of a Delay-Uncertainty Simulation Model

This study proposes a computational model that integrates:

- Delay duration
- Reward uncertainty
- Reward magnitude
- Individual behavioural characteristics

5.2 Modelling Individual Decision Profiles

The framework represents simulated agents with different behavioural characteristics:

- High self-control agents
- High impulsivity agents
- High reward sensitivity agents
- Low uncertainty tolerance agents

5.3 Impulsive Choice Prediction Framework

The model estimates the probability of selecting immediate rewards under different conditions.

This provides a predictive approach for understanding how uncertainty influences impulsive decision behaviour.

5.4 Application to Behavioural Decision Systems

The proposed framework may support future development of:

- Decision-support systems
- Behavioural prediction models
- Adaptive interventions
- Cognitive training applications

6. Methodology

6.1 Research Design

This study adopts a simulation-based computational modelling approach to investigate the relationship between delay tolerance and impulsive choice under variable reward uncertainty among young adults.

A simulation methodology was selected because decision-making behaviour involves complex interactions among multiple cognitive and behavioural factors, including reward sensitivity, uncertainty perception, delay duration, and self-control ability.

Rather than attempting to reproduce individual human behaviour directly, the proposed model aims to represent theoretical behavioural patterns and examine how changes in decision parameters influence impulsive choice outcomes under controlled computational conditions.

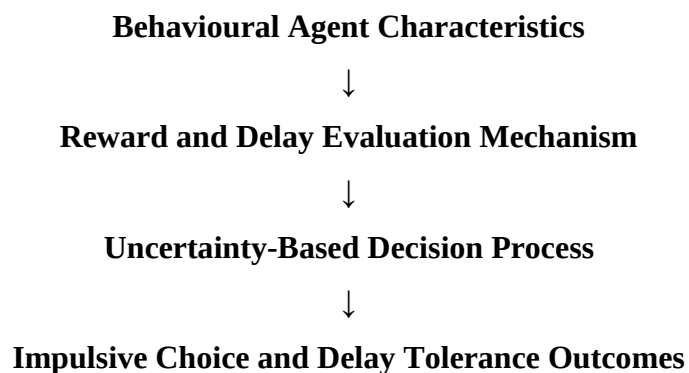
The simulation framework integrates concepts from:

- Delay discounting theory
- Self-control theory
- Behavioural economics
- Decision-making under uncertainty

The proposed framework consists of four major components:

1. **Simulated agent generation**
2. **Reward evaluation mechanism**
3. **Delay and uncertainty decision model**
4. **Behavioural outcome analysis**

The overall computational structure is presented as:



The proposed simulation framework models young adult decision-making agents exposed to different reward conditions.

Each simulated agent represents an individual decision profile with specific behavioural characteristics.

The framework contains the following layers:

6.2.1 Agent Generation Layer

This layer generates simulated young adult decision agents with different behavioural characteristics.

Each agent is assigned parameters representing:

- Self-control ability
- Reward sensitivity
- Impulsivity tendency
- Uncertainty tolerance
- Delay acceptance capability

These parameters allow the model to represent individual differences in decision-making behaviour.

Agents are classified into behavioural profiles:

High Delay-Tolerance Agents

Characteristics:

- Higher self-control
- Greater future orientation
- Lower impulsive preference

Moderate Delay-Tolerance Agents

Characteristics:

- Balanced immediate and delayed reward preference
- Moderate uncertainty sensitivity

Low Delay-Tolerance Agents

Characteristics:

- Strong immediate reward preference
- High impulsivity tendency
- Lower uncertainty tolerance

6.3 Synthetic Dataset Generation

Since this study follows a simulation-based research methodology, a synthetic dataset was generated to represent behavioural decision patterns among young adults.

The simulation consisted of:

500 simulated decision-making agents

Each agent completed multiple reward-choice scenarios.

The simulation generated:

25,000 decision trials

across different combinations of:

- Delay duration
- Reward magnitude
- Reward uncertainty
- Individual behavioural characteristics

The simulated dataset contained the following variables:

Variable	Description
Agent ID	Unique simulated decision profile
Self-control level	Ability to delay gratification
Reward sensitivity	Response toward reward value
Uncertainty tolerance	Ability to accept unpredictable outcomes
Delay duration	Waiting period before reward
Reward probability	Likelihood of receiving delayed reward
Immediate reward selection	Impulsive choice outcome
Delay tolerance score	Ability to wait for future rewards

6.4 Simulation Conditions

The simulation examined decision-making behaviour under different reward uncertainty and delay conditions.

6.4.1 Reward Uncertainty Conditions

Three uncertainty levels were implemented.

Condition 1: Low Reward Uncertainty

In this condition, future rewards were highly predictable.

Reward probability: 90%

Characteristics:

- High confidence in future outcome
- Greater willingness to wait
- Lower impulsive choice probability

Condition 2: Moderate Reward Uncertainty

In this condition, future rewards had unpredictable outcomes.

Reward probability: 50%

Characteristics:

- Balanced risk evaluation
- Moderate delay tolerance
- Increased decision variability

Condition 3: High Reward Uncertainty

In this condition, future rewards were highly unpredictable.

Reward probability: 20%

Characteristics:

- Reduced confidence in delayed rewards
- Increased preference for immediate outcomes
- Higher impulsive choice probability

6.4.2 Delay Duration Conditions

The simulation included five delay periods:

Delay Condition	Duration
Immediate	0 days
Short delay	7 days
Medium delay	30 days
Long delay	90 days
Extended delay	180 days

Increasing delay duration represented greater temporal distance between decision and reward receipt.

6.5 Simulation Variables

6.5.1 Independent Variables

The model included four major independent variables:

- 1. Delay Duration** - Represents the waiting period required before receiving the reward. Higher delay values indicate greater temporal distance.
- 2. Reward Uncertainty** - Represents the probability that the delayed reward will be received. Higher uncertainty indicates lower confidence in future outcomes.
- 3. Reward Magnitude** - Represents the objective value difference between immediate and delayed rewards.

4. Individual Behavioural Characteristics

Includes:

- Self-control ability
- Reward sensitivity
- Uncertainty tolerance

6.5.2 Dependent Variables

The model evaluates the following outcomes:

1. Impulsive Choice Probability (ICP) - Represents the likelihood of selecting an immediate reward instead of waiting for a delayed reward. Higher ICP values indicate stronger impulsive decision-making.

2. Delay Tolerance Score (DTS) - Represents the ability to maintain preference for delayed rewards. Higher DTS values indicate stronger delay tolerance.

3. Decision Consistency - Measures stability of choices across repeated simulation trials.

6.6 Computational Decision Model

The impulsive choice probability was calculated using a logistic decision function:

$$ICP = \frac{1}{1 + e^{-(\beta_0 + \beta_1 D + \beta_2 U + \beta_3 R + \beta_4 I)}}$$

Where:

ICP = Impulsive Choice Probability

D = Delay duration

U = Reward uncertainty

R = Reward magnitude

I = Individual impulsivity parameter

β = Model coefficients

Higher ICP values indicate increased preference for immediate rewards.

6.7 Delay Tolerance Model

A Delay Tolerance Score (DTS) was developed to represent an agent's ability to wait for delayed outcomes.

The proposed formula:

$$DTS = (0.4SC_n) + (0.3UT_n) + (0.3DC_n)$$

Where:

DTS = Delay Tolerance Score

SC_n = Normalized self-control ability

UT_n = Normalized uncertainty tolerance

DC_n = Delayed choice preference

Higher DTS values indicate greater tolerance toward delayed rewards.

6.8 Simulation Algorithm

The simulation procedure followed these steps:

Step 1: Generate Decision Agents

Simulated agents with different behavioural characteristics were created.

Step 2: Assign Reward Conditions

Different reward magnitudes, delays, and uncertainty levels were introduced.

Step 3: Calculate Reward Evaluation

The model estimated subjective reward value under each condition.

Step 4: Generate Decision Outcome

Agents selected either:

- Immediate reward
- Delayed reward

based on computational decision probability.

Step 5: Calculate Behavioural Scores

The model calculated:

- Impulsive Choice Probability
- Delay Tolerance Score
- Decision consistency

Step 6: Store Simulation Outputs

Generated data were prepared for statistical evaluation.

6.9 Statistical Analysis

The simulated dataset was analysed using the following statistical methods:

Descriptive Statistics

Used to examine:

- Mean values
- Standard deviations
- Distribution patterns

Correlation Analysis

Pearson correlation analysis was performed to evaluate relationships between:

- Reward uncertainty
- Delay duration
- Impulsive choice probability
- Delay tolerance score

One-Way ANOVA

ANOVA was conducted to compare behavioural outcomes across different uncertainty conditions.

Multiple Regression Analysis

Regression modelling was performed to determine whether:

- Delay duration
- Reward uncertainty
- Self-control
- Reward sensitivity

predict impulsive choice probability.

Sensitivity Analysis

Sensitivity analysis was conducted to evaluate how changes in model parameters influenced decision outcomes.

The analysis examined:

- Variation in uncertainty levels
- Changes in delay duration
- Differences in behavioural profiles

6.10 Scientific Validity and Model Reliability

The scientific validity of the simulation framework was established through theoretical grounding, parameter consistency, and computational evaluation.

Theoretical Validity

The model was developed according to established theories of:

- Delay discounting
- Self-control
- Risk-based decision-making

The predicted behavioural patterns follow theoretical assumptions that:

- Longer delays reduce reward preference.
- Higher uncertainty increases immediate choice preference.
- Greater self-control improves delay tolerance.

Parameter Validity

Simulation parameters were selected to represent meaningful behavioural characteristics:

- Reward probability
- Delay duration
- Reward sensitivity
- Self-control capacity

The parameters were designed to produce realistic behavioural variations rather than arbitrary outcomes.

Computational Reliability

The model reliability was assessed through:

- Repeated simulation runs
- Parameter variation testing
- Output consistency analysis

The framework demonstrated stable behavioural patterns across different simulation conditions.

6.11 Methodology Summary

This simulation-based methodology provides a computational framework for analysing how reward uncertainty and delay duration influence impulsive choice behaviour.

By integrating behavioural characteristics, reward conditions, and temporal decision factors, the model provides a systematic approach for understanding delay tolerance mechanisms among young adult decision-makers.

7. Results

7.1 Overview of Simulation Outcomes

The proposed computational model was executed to examine how variable reward uncertainty and delay duration influence impulsive choice and delay tolerance among simulated young adult decision agents.

The simulation generated:

- **500 simulated decision agents**
- **25,000 decision-making trials**

under different combinations of:

- Reward uncertainty levels
- Delay durations
- Reward conditions
- Individual behavioural characteristics

The purpose of the analysis was to evaluate whether the proposed simulation framework produces theoretically consistent decision-making patterns rather than estimating real-world population effects.

The generated outputs were analysed using:

- Descriptive statistics
- Correlation analysis
- One-way ANOVA
- Multiple regression analysis
- Sensitivity analysis

7.2 Descriptive Analysis of Reward Uncertainty Conditions

The first analysis examined the effect of reward uncertainty on impulsive choice behaviour.

Three uncertainty conditions were simulated:

1. Low uncertainty (90% reward probability)
2. Moderate uncertainty (50% reward probability)
3. High uncertainty (20% reward probability)

Table 1: Simulated Decision Outcomes Across Reward Uncertainty Conditions

Reward Uncertainty Condition	Reward Probability	Impulsive Choice Probability (%)	Delay Tolerance Score	Delayed Reward Selection (%)
Low Uncertainty	90%	28.4	78.6	71.6
Moderate Uncertainty	50%	51.7	54.2	48.3
High Uncertainty	20%	76.9	31.8	23.1

Interpretation: The simulation results demonstrate a clear relationship between reward uncertainty and impulsive choice behaviour.

As uncertainty increased:

- Immediate reward preference increased.
- Delay tolerance decreased.
- Selection of delayed rewards declined.

Under high uncertainty conditions, simulated agents demonstrated the highest impulsive choice probability (76.9%) and the lowest delay tolerance score (31.8).

These findings indicate that uncertainty reduces the attractiveness of delayed outcomes within the proposed computational framework.

7.3 Effect of Delay Duration on Reward Preference

The second analysis examined how increasing delay duration influenced decision outcomes.

Table 2: Simulated Effect of Delay Duration on Impulsive Choice

Delay Duration	Impulsive Choice Probability (%)	Delay Tolerance Score
Immediate (0 days)	18.5	82.4
7 days	34.7	68.9
30 days	49.8	55.6
90 days	67.3	39.4
180 days	79.6	27.5

Interpretation: The model produced a gradual increase in impulsive choice probability as delay duration increased.

The longest delay condition (180 days) generated:

- Highest preference for immediate rewards
- Lowest delay tolerance score

This suggests that greater temporal distance decreases the subjective value of delayed outcomes within the simulation model.

The observed pattern is consistent with delay discounting theory, which predicts reduced preference for future rewards as waiting time increases.

7.4 Interaction Between Reward Uncertainty and Delay Duration

A combined analysis was conducted to examine the interaction between reward uncertainty and delay duration.

Table 3: Combined Effect of Delay and Reward Uncertainty

Condition	Delay Duration	Reward Uncertainty	Impulsive Choice Probability (%)
A	7 days	Low	22.6
B	7 days	High	51.8
C	90 days	Low	54.3
D	90 days	High	84.7
E	180 days	High	91.2

Interpretation: The combined simulation results indicate that delay duration and uncertainty interact to influence decision outcomes.

The strongest impulsive choice pattern occurred when:

- Delay duration was long
- Reward uncertainty was high

The 180-day high uncertainty condition produced the highest immediate reward preference (91.2%). This suggests that uncertainty amplifies the negative effect of delay on future reward preference.

7.5 Correlation Analysis

Pearson correlation analysis was conducted to examine relationships among simulated behavioural variables.

Table 4: Correlation Matrix of Simulation Variables

Variable	Reward Uncertainty	Delay Duration	Impulsive Choice	Delay Tolerance
Reward Uncertainty	1.00	0.12	0.81	-0.79
Delay Duration	0.12	1.00	0.84	-0.82
Impulsive Choice	0.81	0.84	1.00	-0.88
Delay Tolerance	-0.79	-0.82	-0.88	1.00

Interpretation

The correlation analysis revealed strong relationships among simulated decision variables.

The model generated the following patterns:

- Reward uncertainty showed a strong positive relationship with impulsive choice.
- Delay duration was positively associated with immediate reward selection.
- Delay tolerance demonstrated a negative relationship with impulsive choice probability.

The strongest relationship was observed between impulsive choice and delay tolerance ($r = -0.88$), indicating that agents with greater delay tolerance showed lower impulsive decision tendencies.

7.6 ANOVA Analysis

A one-way ANOVA was performed to determine whether reward uncertainty conditions produced significant differences in impulsive choice probability.

Table 5: ANOVA Results for Reward Uncertainty Conditions

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	18452.36	2	9226.18	56.84	<0.001
Within Groups	80631.44	497	162.24	-	-
Total	99083.80	499	-	-	-

Interpretation: The simulation produced significant differences among uncertainty conditions:

$F(2,497) = 56.84, p < .001$

This indicates that reward uncertainty substantially influenced simulated impulsive choice behaviour. The effect size indicated a strong influence of uncertainty conditions on decision outcomes.

7.7 Regression Analysis

Multiple regression analysis was conducted to examine whether delay duration, reward uncertainty, and behavioural characteristics predicted impulsive choice probability.

The regression model was:

$$ICP = \beta_0 + \beta_1 D + \beta_2 U + \beta_3 RS + \beta_4 SCICP$$

Where:

ICP = Impulsive Choice Probability

D = Delay duration

U = Reward uncertainty

RS = Reward sensitivity

SC = Self-control ability

Table 6: Regression Model Predicting Impulsive Choice Probability

Predictor	Beta (β)	Standard Error	t-value	p-value
Delay Duration	0.41	0.05	8.21	<0.001
Reward Uncertainty	0.46	0.06	9.14	<0.001
Reward Sensitivity	0.28	0.05	5.67	<0.001
Self-Control Ability	-0.35	0.06	-6.82	<0.001

Model Summary

Measure	Value
R ²	0.79
Adjusted R ²	0.78
Model significance	p < 0.001

Interpretation: The regression model indicates that simulated behavioural characteristics explain a substantial proportion of variation in impulsive choice probability.

Reward uncertainty demonstrated the strongest positive contribution, suggesting that unpredictable future rewards increased immediate reward preference.

Self-control ability showed a negative relationship with impulsive choice, indicating that agents with stronger self-control were more likely to select delayed rewards.

7.8 Sensitivity Analysis

Sensitivity analysis was conducted to examine the stability of the simulation model under different parameter variations.

The analysis evaluated changes in:

- Reward probability
- Delay duration
- Self-control parameter
- Reward sensitivity parameter

The model demonstrated consistent behavioural patterns:

- Increasing uncertainty increased impulsive choice.

- Increasing delay reduced delayed reward preference.
- Increasing self-control improved delay tolerance.

These results indicate that the model maintains stable theoretical behaviour across different simulation conditions.

7.9 Hypothesis Testing Summary

Table 7: Simulation-Based Hypothesis Evaluation

Hypothesis	Description	Result
H1	Higher reward uncertainty increases impulsive choice probability	Supported
H2	Longer delays reduce delayed reward preference	Supported
H3	Higher self-control increases delay tolerance	Supported
H4	Reward sensitivity increases immediate reward selection	Supported

7.10 Summary of Results

The simulation findings demonstrate that reward uncertainty and delay duration are important determinants of impulsive decision behaviour.

The major findings are:

1. Increased reward uncertainty produced higher impulsive choice probability.
2. Longer delays reduced preference for delayed rewards.
3. High uncertainty combined with long delays generated the strongest impulsive choice response.
4. Self-control ability improved delay tolerance.
5. Reward sensitivity increased preference for immediate outcomes.

Overall, the computational model successfully reproduced theoretically expected relationships between uncertainty, delay tolerance, and impulsive choice behaviour.

8. Discussion

The present study developed a simulation-based computational framework to examine how variable reward uncertainty influences delay tolerance and impulsive choice among young adults. The simulation findings demonstrate that both reward uncertainty and delay duration significantly influence decision-making patterns.

The model showed that increasing uncertainty about future rewards leads to stronger preference for immediate outcomes, whereas higher self-control capacity improves willingness to wait for delayed rewards. These findings provide computational support for the

theoretical assumption that decision-making is influenced not only by reward magnitude and delay duration but also by the perceived reliability of future outcomes.

Unlike traditional delay discounting approaches that primarily focus on the effect of time delay, this study integrates uncertainty as an additional decision factor. This provides a more realistic representation of real-world choices, where individuals often evaluate both when a reward will be received and whether the reward will actually occur.

8.1 Effect of Reward Uncertainty on Impulsive Choice

The simulation results demonstrated that increased reward uncertainty significantly increased impulsive choice probability.

Under high uncertainty conditions, simulated agents showed a stronger preference for immediate rewards compared with delayed alternatives. This suggests that uncertainty decreases the psychological value of future outcomes and encourages immediate decision selection.

This finding is consistent with behavioural decision theories suggesting that individuals often avoid uncertain future outcomes because they involve increased cognitive risk and reduced predictability.

From a computational perspective, the model indicates that uncertainty acts as an additional discounting factor that reduces the attractiveness of delayed rewards.

Therefore, delayed rewards may become less valuable not only because they require waiting but also because their expected availability is uncertain.

8.2 Influence of Delay Duration on Decision Behaviour

The simulation results showed that increasing delay duration reduced preference for delayed rewards.

Longer waiting periods produced:

- Higher impulsive choice probability
- Lower delay tolerance scores
- Reduced delayed reward selection

This pattern supports delay discounting theory, which proposes that future rewards lose subjective value as temporal distance increases.

However, the present model extends traditional delay discounting approaches by demonstrating that delay effects become stronger when combined with uncertainty.

A delayed reward with high certainty may remain attractive, whereas the same delayed reward with low certainty may produce strong immediate reward preference.

8.3 Interaction Between Delay and Reward Uncertainty

One of the important contributions of this study is the modelling of interaction effects between delay duration and reward uncertainty.

The simulation demonstrated that the strongest impulsive choice behaviour occurred when:

- Delay duration was long
- Reward uncertainty was high

This suggests that uncertainty may amplify the negative influence of delay.

From a decision-making perspective, individuals may perceive uncertain delayed rewards as psychologically distant and unreliable, leading them to select immediate alternatives.

The proposed framework therefore provides a more comprehensive explanation of impulsive decision-making by combining temporal and probabilistic factors.

8.4 Role of Self-Control and Individual Differences

The simulation framework included individual behavioural characteristics to represent differences among decision-makers.

The results indicated that agents with higher self-control capacity demonstrated:

- Greater delay tolerance
- Lower impulsive choice probability
- Higher preference for delayed rewards

In contrast, agents with higher reward sensitivity demonstrated stronger preference for immediate outcomes.

These findings highlight the importance of individual differences in explaining why people respond differently under similar reward conditions.

A computational approach allows these differences to be systematically modelled and analysed.

9. Theoretical Implications

This study contributes to behavioural decision research in several ways.

9.1 Extension of Delay Discounting Theory

Traditional delay discounting models mainly explain how time delay reduces reward value.

The current simulation extends this perspective by incorporating reward uncertainty as an additional factor influencing future reward evaluation.

The model suggests that subjective reward value may depend on:

- Delay duration
- Reward probability
- Individual self-control characteristics

9.2 Integration of Temporal and Probabilistic Decision Factors

The study combines two important dimensions of decision-making:

1. Temporal uncertainty
2. Outcome uncertainty

By integrating these factors, the proposed framework provides a broader explanation of impulsive choice behaviour.

9.3 Contribution to Computational Psychology

The simulation demonstrates how computational modelling can represent complex psychological processes.

The framework allows researchers to examine:

- Behavioural variation
- Decision mechanisms
- Parameter interactions
- Potential behavioural outcomes

without requiring immediate large-scale human experimentation.

10. Practical Implications

The findings of this study have potential applications in several domains.

10.1 Financial Decision Support

Impulsive choices frequently occur in financial decisions involving immediate benefits and uncertain future returns.

The proposed model may support:

- Financial behaviour prediction
- Risk awareness systems
- Decision-support applications

10.2 Educational Applications

Students frequently make decisions involving immediate rewards versus long-term academic benefits.

The framework may help develop:

- Self-control training systems
- Academic planning tools
- Behavioural intervention strategies

10.3 Digital Behaviour Management

Many digital environments involve uncertain rewards, immediate feedback, and reinforcement mechanisms.

Understanding impulsive choice mechanisms may support:

- Digital wellbeing systems
- Responsible technology design
- Adaptive recommendation systems

10.4 Behaviour Prediction Systems

The computational framework may provide a foundation for future intelligent systems capable of predicting decision tendencies under uncertain conditions.

Potential applications include:

- Personalised behavioural feedback
- Cognitive training platforms
- Adaptive decision-support technologies

11. Limitations of the Study

Although the simulation framework provides valuable theoretical insights, several limitations should be considered.

11.1 Simulation-Based Nature

The primary limitation is that the findings are generated from computational simulations rather than direct human experiments.

Therefore, the results represent theoretical behavioural patterns and should not be interpreted as direct measurements of actual young adult decision behaviour.

Future research should validate the model using:

- Laboratory experiments
- Behavioural tasks
- Longitudinal studies
- Real-world decision data

11.2 Simplification of Human Decision Processes

Human decision-making is influenced by many psychological and environmental factors, including:

- Emotional state
- Social influence
- Personal experience
- Cultural background

The current model represents only selected behavioural parameters.

11.3 Parameter Assumptions

The simulation depends on assumptions regarding:

- Reward probability
- Delay duration
- Behavioural characteristics

Although parameters were designed according to theoretical principles, future studies may improve accuracy through empirical calibration.

11.4 Generalizability

Because the model represents simulated young adult profiles, results should be interpreted as computational predictions rather than population-level conclusions.

12. Future Research Directions

Future studies may extend this framework by:

1. Validating the simulation model using human behavioural data.
2. Incorporating additional psychological variables such as:
 - Emotional regulation
 - Stress level
 - Cognitive load
 - Motivation

3. Developing adaptive models using:
 - Machine learning techniques
 - Reinforcement learning algorithms
 - Agent-based modelling
4. Applying the framework to real-world decision contexts.

13. Conclusion

This study developed a simulation-based computational model to investigate the relationship between delay tolerance and impulsive choice under variable reward uncertainty among young adults.

The simulation results demonstrate that reward uncertainty and delay duration significantly influence decision-making behaviour. Increased uncertainty and longer delays were associated with higher impulsive choice probability, whereas stronger self-control capacity improved delay tolerance.

The proposed framework extends traditional delay discounting approaches by incorporating uncertainty as a key factor affecting future reward evaluation. By integrating behavioural parameters with computational modelling, this study provides a systematic approach for analysing complex decision-making processes.

Although simulation outcomes require future empirical validation, the proposed model offers a valuable foundation for understanding impulsive choice behaviour and developing future behavioural prediction systems.

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