HOW CALCULUS CAN PREDICT HUMAN BEHAVIOR

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Introduction

Every day, we make hundreds of decisions without thinking twice. Should you start revising now, or scroll for “just five more minutes”? Should you spend your money today, or save it for later? These choices feel personal, unpredictable perhaps even irrational. But what if they are not as random as they seem?

What if, beneath the surface, every decision you make follows a pattern. One that can be described, analysed, and even predicted using mathematics?

At first glance, this idea sounds far fetched. Human behaviour is often seen as too complex to be reduced to numbers and equations. Emotions, habits, and impulses seem to resist any kind of precise measurement. Yet in many fields, such as economics or technology, mathematicians model human decisions with remarkable accuracy. Streaming platforms anticipate what you will watch next, online stores predict what you are likely to buy, and algorithms determine how long you will stay engaged with a piece of content. Humans can make decisions using mathematical functions not just logic (Kahneman, D. Tversky, A. 1979)

The key to this predictive power lies in calculus: the mathematics of change. While calculus is often associated with motion, curves, and physics, its real strength is far broader. It provides a framework for understanding how quantities evolve over time and crucially how to identify the point at which one choice becomes better than another.

This essay explores how calculus can be used to model everyday decisions. By translating certain ideas like “reward” and “cost” into measurable quantities, we can construct mathematical functions that represent different choices. These functions can be analysed to reveal something unexpected: even ordinary decisions: whether to scroll, study, spend, or take risks can be understood as optimization problems.

In other words, each time you make a choice, you may be solving a calculus problem without even realizing it. Decision making is a good example that can be understood through reinforcement learning models, where behaviour is shaped over time using prediction errors, reflecting a mathematical process of continuous change. (Dayan, P. Daw, N. 2008)

From Feelings to Functions

To apply calculus to human behaviour, we must first address a fundamental problem: how can something as subjective as a decision be expressed mathematically?

Concepts like happiness, motivation, or satisfaction cannot be measured directly. However, mathematics does not require perfect measurements, it only requires consistent ones. Instead of attempting to quantify emotions themselves, we assign numerical values to outcomes that reflect them. These values form what is known as a *utility function*: a mathematical representation of how beneficial a particular choice is.

For example, consider the decision between studying and scrolling on a phone, we can define measurable variables. Let time, measured in minutes, be the independent variable. We then assign a numerical "benefit" score to each activity based on observable effects. For scrolling, this might include immediate engagement (such as time spent actively watching content) balanced against longer term costs like fatigue or lost productivity. For studying, the benefit could be linked to measurable outcomes such as improved understanding or expected exam performance.

Using this approach, we can construct functions that model each choice. A simplified model for scrolling might look like this:

- Rapid initial benefit due to instant entertainment
- Gradually decreasing additional benefit over time
- A steady increase in cost as time is wasted

In contrast, studying can be modelled differently:

- A low or even negative initial value, reflecting effort and resistance
- Gradual improvement as understanding increases
- Accelerating long term benefits as knowledge accumulates

Although these functions are simplifications, they capture an important truth: different choices produce different patterns of value over time. By representing these patterns mathematically, we transform an abstract decision into something that can be analysed.

This is where calculus becomes essential. Once a decision is expressed as a function, we can examine how it changes, compare it with alternatives, and determine the exact point at which one option becomes more beneficial than another. What initially appears to be a vague, emotional choice is revealed to have an underlying structure, one that can be explored with precision.

By turning feelings into functions, we take the first step towards understanding how calculus can predict human behaviour.

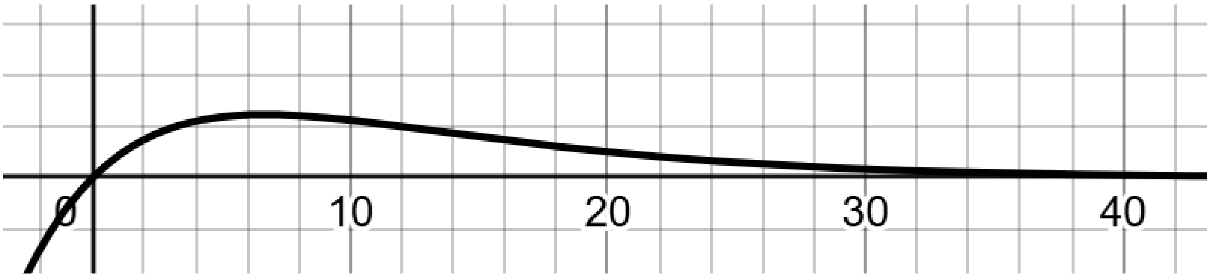
Modelling Decisions with Functions

Once we represent decisions as mathematical functions, we can begin to analyse them using the tools of calculus. The key idea is that every choice has a changing value over time, and calculus allows us to study exactly how that value increases or decreases (Busemeyer, J.R. Townsend, J.T, 1993)

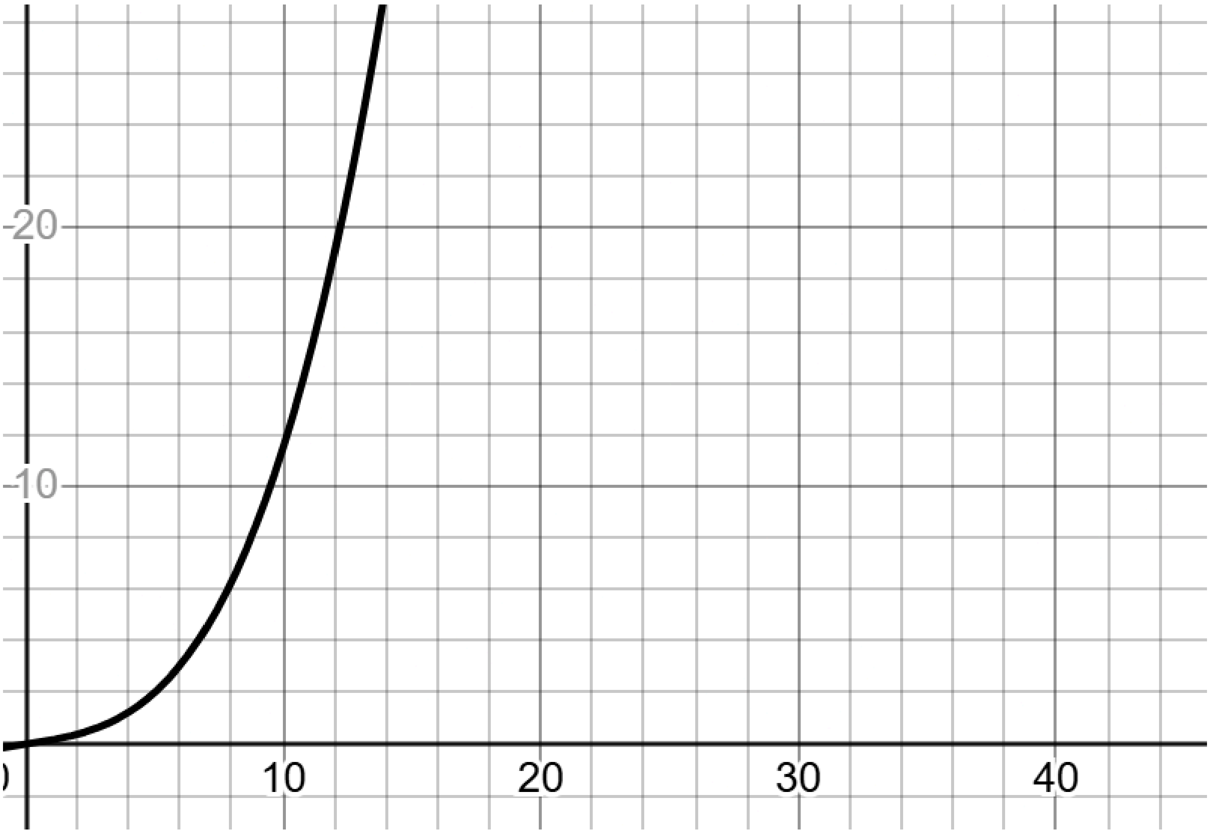
Consider the decision between scrolling and studying. Let time, t, represent minutes spent on an activity. Instead of describing outcomes vaguely, we assign each activity a function that represents its “net benefit” over time.

For scrolling, the benefit can be modelled as something that rises quickly at first but then slows down as the novelty wears off. A simple representation of this behaviour is a function that increases rapidly at the beginning but gradually levels off. At the same time, the cost, lost time and reduced productivity continues to grow steadily with time. When combined, this produces a curve that eventually flattens or even declines. This steady increase in benefit represents instant gratification, followed by a slow, steady decline. This graph is shown below, where the x axis is time, and the y axis is benefit (gratification). Time is t. e is a special number in maths called Euler’s number. It shows up whenever you have: growth, decay, or continuous change.

The graph looks like this ($y=te^{-0.15}$):



Studying behaves differently. Initially, the benefit may be low or even negative, since effort and concentration are required before any visible progress is made. However, as time increases, understanding builds, and the rate of improvement accelerates. This means the function representing studying starts slowly but increases more consistently over time. The graph looks like this ($y = 0.15t+0.01t^3$):



When we plot these two functions on the same axes, a striking pattern appears. The scrolling curve begins above the studying curve, reflecting its immediate appeal. However, at a certain point, the studying curve crosses and surpasses it. This intersection represents a critical moment: the exact point in time where studying becomes more beneficial than scrolling. As an advocate of cognitive behavioural therapy (CBT) it would be great to explore further how to stop the youth becoming addicted to screens. If companies do use math to create a system where the youth become addicted to scrolling then this is unethical.

This is where calculus can become powerful. Rather than guessing when this turning point occurs, we can find it precisely by comparing the two functions mathematically. Even more importantly, calculus allows us to examine the *rate of change* of each function. The slope of the scrolling function decreases over time, while the slope of the studying function increases. In other words, not only does studying eventually become better, it becomes increasingly better with time.

This idea of a "crossing point" is not limited to studying and scrolling. It appears in many everyday decisions. Whenever two competing choices evolve differently over time, there exists a moment where one overtakes the other. Calculus provides the tools to locate and understand these moments with precision.

Life as an Optimization Problem

Once we begin viewing decisions as functions, a deeper pattern emerges: many human choices are not simply comparisons between two options, but problems of optimization. In other words, we are constantly trying to maximize benefit and minimize cost, even if we are not aware of it.

This is where calculus becomes especially important. One of its central ideas is the concept of a maximum or minimum point, a value at which a function reaches its highest or lowest outcome. In real world terms, this corresponds to the "best possible decision" under given conditions.

Take the example of risk versus reward. If we define risk as a variable xxx, we can construct a function where reward initially increases with risk, since taking some risk is necessary to achieve meaningful outcomes. However, beyond a certain point, excessive risk leads to failure or loss, causing the reward to decrease. This creates a curve that rises, reaches a peak, and then falls.

The most important feature of this curve is its highest point, the optimal level of risk. Using calculus, this point can be found precisely by identifying where the rate of change becomes zero, meaning the function stops increasing and starts decreasing. At this point, any additional risk would reduce the overall reward.

What is remarkable is that this structure appears repeatedly in real life. Whether we are deciding how much time to study, how much money to spend, or how much risk to take, the underlying pattern is the same: there is often a point of balance where the outcome is maximized.

This leads to a powerful interpretation. Human decision making, while appearing emotional and unpredictable, can often be described in terms of optimization. We are constantly navigating trade offs, and calculus provides a framework for identifying the exact points where those trade offs are most favourable.

Of course, this does not mean human beings are mathematical machines or that every decision is consciously calculated. Rather, calculus reveals a deeper structure beneath our behaviour. It shows that even in systems as complex as human choice, there are hidden patterns, points of balance, turning points, and optimal solutions, that can be described with surprising precision.

Limits of the Model and What It Really Means

While calculus provides a powerful way to model decision making, it is important to recognize the limitations of this approach. Human behaviour is not governed by simple equations alone. Emotions, uncertainty, habits, and external influences all play a role in shaping our choices, and these factors are difficult to capture perfectly in mathematical form.

The functions used in this essay are therefore not exact representations of reality, but simplified models. They do not claim to predict every individual decision with certainty. Instead, they aim to capture general patterns: how reward changes over time, how costs accumulate, and how trade offs influence behaviour.

This distinction is important. In mathematics, a model does not need to be perfectly true in order to be useful. It only needs to reflect reality closely enough to reveal structure. In the same way that physics uses idealized assumptions like frictionless surfaces, we use simplified utility functions to study decision making. The goal is not perfection, but insight.

Even with these simplifications, the patterns remain meaningful. Across many different scenarios, whether studying, scrolling, spending, or taking risks, we repeatedly see the same structure: initial appeal, long term cost or benefit, and a turning point where one option becomes more favourable than another. Calculus allows us to identify and analyze these turning points systematically.

Conclusion: The Mathematics Behind Choice

At first glance, human decisions appear unpredictable, shaped by emotion and circumstance rather than logic. Yet when we translate these decisions into mathematical terms, a surprising structure emerges. Choices can often be represented as functions, changing over time in ways that can be analysed using calculus.

However, the purpose of this approach is not to reduce human life to equations. Rather, it is to reveal that beneath the complexity of behaviour, there are underlying patterns that mathematics can illuminate. Calculus does not remove the human element from decision making it provides a lens through which that complexity becomes more understandable.

To conclude as a CBT advocate calculus could be used to design healthier social media algorithms by modelling used benefit and harm over time. Instead of maximising total engagement, platforms could optimise the point at which scrolling provides diminishing returns and begins to undermine wellbeing. Tech firms should and must use algorithms to reduce addictive behaviours and replace with balanced behaviour's (Stray, J. 2020). I would like to research this concept further and use my knowledge to develop human centred and ethical tech.

References

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