Threshold: Designing A Serious Tabletop Game For Neural Dynamics

Introduction

Threshold is an educational tabletop game designed to introduce players to foundational principles in computational neuroscience through interaction with simplified dynamical systems. Rather than presenting content through instruction, *Threshold* operationalises abstract theories as playable mechanics that players engage with while participating in short, repeatable games. The main challenge was to preserve its fidelity to dynamical systems theory while maintaining accessibility and engagement. This essay explains and justifies the learning objectives, design and aesthetic choices, and future development prospects of *Threshold*, demonstrating how the game functions as both an effective learning environment and a serious educational tool.

1. Learning outcomes

Threshold was developed around two core learning objectives: to compare the two principal dichotomies in neural dynamics, monostable versus bistable and integrator versus resonator, and to create and interpret phase portraits to understand the structure and stability of trajectories in phase space. These objectives align with higher levels of bloom's taxonomy; to compare corresponds to analysis, while to create phase portraits corresponds to synthesis. These outcomes move beyond factual recall and require players to integrate concepts, use abstract representations, and reason about system behaviour.

The game includes 13 mission cards that function as subsidiary learning tasks. While each mission constitutes a standalone objective, collectively they build progression towards the two core outcomes. Missions guide players to look at rule structures, identify patterns, and relate observed gameplay outcomes to theory. The cumulative effect of exposure to varied mission prompts supports the transfer and depth of understanding.

Importantly, *Threshold* does not evaluate learning through in-game scoring. Instead, assessment occurs during a structured post-session discussion. After a series of rounds, players reveal their missions and reconcile their observations. The quality of these discussions, including accuracy, use of terminology, and ability to justify interpretations, provides a meaningful indicator of learning. This design reflects constructivist educational principles, where knowledge emerges through shared interpretation and collaborative reasoning rather than numerical performance metrics (2).

2. Role of the mission system

The mission card system is central to the serious function of *Threshold*. Without explicit guidance, players may focus exclusively on surface gameplay actions without reflecting on their conceptual meaning. Missions provide structured prompts that encourage players to interrogate the mechanics rather than merely execute them. Questions like why state thresholds change between modes or why card decks recycle under bistable conditions draw attention to the intentional modelling embedded within the rules.

Each mission links directly to the learning objectives and remains deliberately open-ended. This structure promotes explanation, interpretation, and discussion rather than rote memorisation. Some missions require players to apply more advanced concepts, such as using limit cycle attractors to explain repetitive spiking in bistable neurons. While these tasks are difficult, they remain achievable through peer discussion. The game therefore supports mixed ability groups, including secondary students and undergraduates, by allowing entry points at multiple levels of prior knowledge (see appendix a.iii.).

A session combines independent reasoning with group work. Players reflect on their mission during gameplay, then contribute their perspective or findings during the discussion. This structure mirrors effective educational practice in which learners first process information individually before participating in shared understanding (3). Since missions directly reference game mechanics, they also ensure that learning remains embedded within gameplay rather than detached from it.

3. Modelling neural dynamics via game mechanics

Every core mechanic in *Threshold* directly corresponds to principles of dynamical systems as applied to neuronal excitability. In computational neuroscience, neurons may be described as excitable systems characterised by two principal features: the coexistence of resting and spiking states, and the presence or absence of subthreshold oscillations (1). These features define the four canonical classifications: monostable integrator, bistable integrator, monostable resonator, and bistable resonator. *Threshold* operationalises this framework by offering four distinct game modes based on these classifications.

The central variable in the game, referred to as the count, represents cumulative synaptic input or perturbation to the system. Influence cards simulate individual contributions, analogous to synaptic events, that accumulate toward a threshold. When the count crosses this threshold, the system produces a spike output. In computational neuroscience, this is described as the trajectory of a dynamical system leaving one attraction basin and entering another (1).

Monostable modes reset the count to 0 after each round, reflecting systems that return to a stable resting state following excitation. Bistable modes preserve state across rounds. Once a superthreshold count triggers repetitive spiking, the system remains in an active state until a sufficiently strong perturbation forces a transition back to rest. This behaviour models limit cycle attractors and hysteresis effects observed in bistable neurons (1). The recycling of card decks during bistable play suggests the persistence of this active state and conveys the idea of sustained oscillatory behaviour.

Resonator modes introduce temporal sensitivity. In real resonator neurons, the timing of input relative to intrinsic oscillatory phase determines whether perturbations amplify or cancel system responses (1). *Threshold* represents this phenomenon using position tokens that assign phase polarity to players. When players contribute influence out of phase, positive and negative effects cancel; when contributions align in phase, their effects amplify. Unlike integrator modes, resonator modes apply influence immediately rather than summing it at round end. This design choice captures the time-dependent nature of resonance and ensures that positional mechanics remain meaningful.

The 4-in-1 structure of *Threshold* is therefore not a marketing feature but a necessity. Removing any mode would fragment the conceptual narrative of neuronal classification. Together, the modes form a coherent model that mirrors how neuroscientists conceptualise excitability dynamics.

4. Balancing fidelity and accessibility

Threshold necessarily simplifies real neural dynamics. Several advanced features, including bifurcation mechanisms that define excitability transitions, were excluded to preserve accessibility and flow. While bifurcation is a cornerstone of dynamical systems, implementation of it would introduce complexity that could obscure learning objectives. The decision prioritised intuition over exhaustive representation.

Earlier iterations included additional noise-similar influence cards to simulate persistent experimental artefacts. These elements were removed during development because they distracted players from the core features and introduced unnecessary mechanical burden. The final design favours clarity, consistency, and focus.

This balancing act reflects a fundamental principle of serious game design: educational effectiveness depends not on maximal realism, but on purposeful abstraction that highlights the most important relationships while preserving player engagement.

5. Visual design

The visual identity of *Threshold* reinforces both accessibility and thematic coherence. The design uses high contrast neon colour palettes on dark backgrounds to maximise readability while maintaining aesthetic appeal. Colour selections were optimised for colour vision accessibility, ensuring that information remains distinguishable across populations (see appendix a.ii.). The minimalist aesthetic aligns with the preferences of older adolescent and adult learners while preserving memorability.

The rulebook structure follows a modular, colour coded format inspired by Klaus Teuber's Catan. Sections are clearly separated, allowing new players to follow step-by-step setup instructions while experienced users can access specific rule components efficiently. A dedicated glossary separates technical definitions from procedural instructions, reducing cognitive load during initial play through.

The front cover incorporates neuron inspired line art (Fig. 1) and a chandelier neuron schematic to establish the scientific context.

Fig. 1. While symbolic typography such as the loop on the "*D*" of "*THRESHOLD*" references bistable dynamics, their primary function is aesthetic coherence rather than explicit instructional content. *Design was created using Procreate.*

Transferability of the design allows for visual consistency across cards, packaging, rulebook, and sell sheet, and helps recognisability and professional presentation.

3d modelling of components guided physical design decisions, including token size, card dimensions, and container layout (Fig. 2). These considerations prioritised handling comfort, table visibility, and efficient storage.

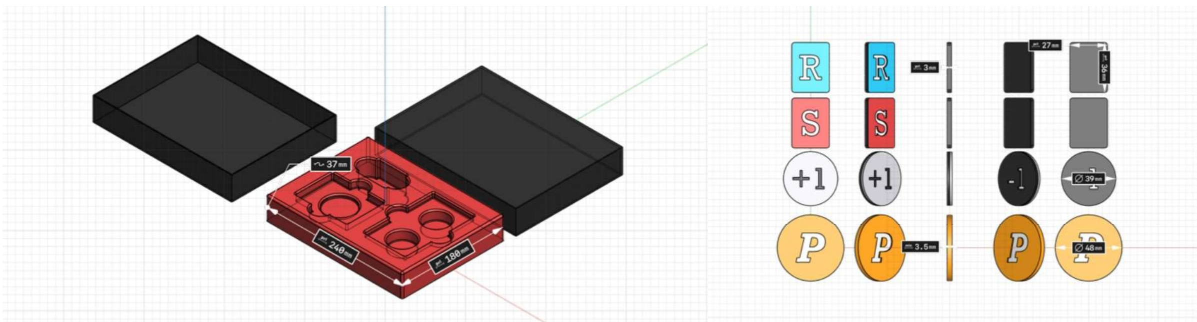

Fig. 2. Given the number of small components required for gameplay, organised packaging was essential for usability and classroom compatibility. *Items were modelled and visualised using Shapr3d.*

6. Managing randomness and player scaling

Randomness in *Threshold* was implemented selectively to preserve educational reliability while sustaining replayability. Drive cards introduce variability in initial system input, preventing repeated rounds from becoming monotonous without destabilising consistency. Card quantities were calibrated to support up to eight players while maintaining a balanced distribution across extended bistable games.

Two player gameplay presented a mechanical challenge. With fewer participants, threshold outcomes became overly predictable. Adjusting thresholds to accommodate smaller groups introduced instability for larger player counts. Rather than overcomplicating the core ruleset, the design prioritised optimisation for groups of 3-8 players. A dedicated two player variant remains a viable future extension with recalibrated thresholds and card distributions.

Mission card distribution also considers replayability. With 13 distinct missions, repeated sessions are unlikely to produce identical task combinations, ensuring broad conceptual exposure across playthroughs.

7. Serious game limitations and future development

One limitation of *Threshold* lies in its scoring system. Predictive accuracy during gameplay does not necessarily reflect conceptual understanding. While post-game discussion compensates for this limitation, additional assessment mechanisms could strengthen its educational value. One possible route involves adapting mission cards into simpler assessment prompts, such as multiple choice, true or false questions with self-checking solutions. This approach would enable quantitative tracking of conceptual progress but would require a shift toward lower level bloom's and reduced open-ended reasoning.

Future development also include digital adaptations. A hybrid tabletop-digital platform could automate state tracking, visualise phase portraits dynamically, and provide immediate feedback on conceptual performance. Augmented reality could further visualise trajectories and attractor states, reinforcing spatial intuition.

Additional extension mods could introduce bifurcation mechanics, stochastic noise models, or plasticity systems for more advanced, patient learners. Introducing these as mods would preserve accessibility of the base game while enabling progressive complexity.

Conclusion

Threshold demonstrates how complicated scientific concepts can become accessible through abstraction, structured play, and reflection. By integrating dynamical systems theory directly into its mechanics, the game transforms a set of classification axes into an embodied, intuitive learning experience. While simplifications were made, they preserve clarity and pedagogical effectiveness.

As a serious game, *Threshold* succeeds not because it reproduces dynamical systems in neuroscience in full detail, but because it creates an intuitive, engaging environment where learners actively build understanding independently and with each other. With targeted development, it holds strong potential as not only a standalone classroom resource, but also as an accessible serious game for wider public engagement and as a design template for future serious game development.

Appendices

a. Accessibility

i. Physical Accessibility

Threshold demonstrates moderate physical accessibility through its reliance on lightweight, standard tabletop components. The absence of explicitly timed mechanics reduces pressure on players with motor impairments or slower reaction times. However, repeated card handling, and token flipping may present challenges for players with limited hand mobility or tremor-related conditions. Introducing optional card holders and larger tokens would further improve inclusivity.

ii. Visual Accessibility

Colour coded structure improves navigability. The use of consistent iconography for components reinforces recognisability. Text is presented with strong contrast against dark backgrounds, improving readability for most users. However, reliance on colour as a primary organisational cue may disadvantage players with colour vision deficiencies. While section borders use distinct hues, the rulebook does not indicate alternative visual markers such as symbols or patterned borders to supplement colour coding. Adding icon section identifiers would improve redundancy and visual accessibility.

Additionally, while aesthetically cohesive, future iterations could offer simplified print-friendly versions of rule materials with increased font size and reduced visual decoration.

iii. Cognitive Accessibility

The rulebook explicitly guides new players to follow a staged path, beginning with setup and round overview before progressing to detailed rules and definitions. This tiered information structure reduces cognitive load and supports incremental learning.

The glossary section provides alphabetically organised definitions of core concepts such as. This design allows players to clarify terminology during gameplay without interrupting flow. Nevertheless, the conceptual complexity of the subject matter remains high. Terms such as "limit cycles" and "phase portraits," while appropriate for the stated target audience, this may pose barriers for players without prior exposure to mathematical neuroscience. The inclusion of facilitator notes partially mitigates this issue, but difficulty labels for mission cards or beginner friendly missions would further improve accessibility.

iv. Communication Accessibility

Threshold explicitly integrates collaborative discussion into its learning structure. This allows players with different strengths to contribute through verbal explanation, visual representation, or reasoning.

The game avoids time pressure and competitive elimination mechanics, which reduces social stress and anxiety. However, reliance on open discussion may disadvantage players with speech impairments or social anxiety. Incorporating written response alternatives would improve inclusivity.

v. Sensory Accessibility

The strong neon colour palette, while visually striking, may create discomfort for individuals sensitive to high contrast colour schemes. Offering an alternative low saturation print for classrooms could address this limitation.

vi. Facilitator Support

The rulebook dedicated a "note to facilitators" section that contextualises the educational purpose of the game and clarifies its intended learning outcomes. This supports instructors in framing gameplay as a structured learning activity rather than purely recreational play.

However, guidance remains relatively brief. Expanded teaching notes, or suggested strategies could further support classroom implementation, particularly for mixed ability groups.

References

1. IžikevičE.M. (2010). *Dynamical systems in neuroscience : the geometry of excitability and bursting.* Cambridge, Ma ; London: The Mit Press.
2. Pan, S., Hafez, B., Iskandar, A. and Ming, Z. (2024). Integrating constructivist principles in an adaptive hybrid learning system for developing social entrepreneurship education among college students. *Learning and Motivation*, 87, pp.102023–102023.
3. Siphukhanyo, L. and Olawale, B.E. (2024). Chronicling the Experiences of Life Sciences Teachers and Learners on the Usage of Enquiry-Based Learning in Enhancing Learners' Academic Performance. *Journal of Culture and Values in Education*, [online] 7(1), pp.19–36.