Change Your Mind

Game Based AIS Can Reform Cognitive Behavior

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Abstract. Among the most challenging Learning Objectives are those that require the learner to unlearn behavior - especially behavior deeply rooted in ancient evolutionary selection [1]. One such challenge is the mitigation of cognitive bias. After observing that traditional linear training does not reliably deliver lasting improvement to such deeply held cognitive behavior [2], a group of researchers began to experiment with game-based learning.

Much of the success of the game experiments can be attributed to the efficacy of Adaptive Instruction Systems (AIS). The principles of AIS are usually applied consciously to the design of game-based learning. Even when they are not explicitly invoked, the nature of good game design is inherently one of adaptive instruction. This is most easily demonstrated with a case study of one of the games - *Enemy of Reason*.

Enemy of Reason has been shown to be a particularly efficacious tool for mitigating Cognitive Bias. A large scale and complex game, it employs a variety of mechanics rooted in game design, adaptive instructional design and in the literature of intelligence analysis.

Enemy of Reason is acutely relevant to the current moment. It treats cognitive bias not only as a natural phenomenon but as the result of an attack by an enemy determined to wage psychological warfare.

Keywords: Adaptive instruction system · Game based learning · Adaptive learning · Serious games · Intelligent tutoring system

1 Introduction

Game Based Learning is a form of Adaptive Instructional System in which the tropes and mechanics of entertainment games are employed to gracefully deliver the adaptive content. The format is familiar and engaging to learners of all ages. While only certain AIS systems are games, the case can be made that all games are adaptive learning systems. This is especially true of digital computer and videogames.

Games are used to present Adaptive Instructional Systems in a form that is readily acceptable. This is not because the game structure disguises the AIS. On the contrary, the game structure makes transparent the adaptive nature of the learning experience. Many salient features that facilitate adaptive learning (e.g.: continual assessment,

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branching, repetition, even simple learner modeling) [3] are familiar features of games, and in that context, players have come to trust their value.

Players expect certain adaptive learning features in a digital game and will employ them naturally. For example, a gameplayer expects and utilizes a tutorial level just as a textbook user expects a table of contents. Both are useful conventions of their respective learning media.

This report presents a case study of Game Based Learning and examines how it realizes the goals of adaptive learning using mechanisms derived both from game science and from advanced learning design theory.

1.1 Enemy of Reason

Enemy of Reason was developed under IARPA's SIRIUS program, by a diverse consortium of experts assembled and directed by Boeing's Senior Learning Scientist, Brandt Dargue. Enemy of Reason is a plot-driven mystery adventure game, in which several high-speed mini-games are embedded. It is an Intelligent Learning System in which the player is immersed for several hours of computationally mediated experiences. Every player enjoys a unique sequence of experiences as the game guides players of varying backgrounds and diverse learning capabilities past a common threshold of competence. Like most learning games, and many entertainment games, the Enemy of Reason can be best seen as a complex, interactive and media-rich Adaptive Learning System.

To elevate learners to a standard of mastery beyond that achieved by the control condition (a powerful but linear video lesson), the game employs several different pedagogic principles. Some of these are common to most media. Others are particular to game-based learning. These principles include

- Schema Graphs
- Concept Navigation
- Synthetic Mentor
- Spaced Learning
- Just In Time Instruction
- Germane Cognitive Load

In the following pages, we will examine each of these learning mechanisms to see how they advance learning and how they fit together to form a successful adaptive system.

2 Learning Objective

The Terminal Learning objective is a lasting behavior change which replaces the player's instinctual heuristic decision-making with rational analytic judgement. Specifically, the player will acquire behavior that helps identify and mitigate certain pernicious cognitive biases.

2.1 Salience

The Enemy of Reason emerged from a team of game designers and experienced members of the intelligence community. Behind its playful allegory, the game warns of a new and unseen existential threat to democratic civilizations. Developed before Brexit and the 2016 US elections, the game was a harbinger of a new species of warfare.

Nation shall not lift sword against nation. Nor will it will hurl nuclear bombs. Instead, to topple our society, a foe attacks the thought process of our citizens. Enemy of Reason boldly illustrates such an attack.

The game starts on a sunny September morning as the city-state of Capital City suffers a dramatic surprise attack. Explosions are heard and a dense red cloud rapidly engulfs the city (see Fig. 1). The scene evokes painful memories of urban destruction and panic grips the population (see Fig. 2).

Fig. 1. Capital city under the Red Cloud.

But the Red Cloud rapidly dissipates, revealing a city apparently intact. The attack inflicts no physical damage on the city's infrastructure nor on the health of its terrified inhabitants. The nature of the weapon, if it was a weapon, is as mysterious as the identity of the attacker.

In this game, the player is Ian Solitaire, a Capital City intelligence agent, assigned to solve two mysteries. Who did this? What did they do? The Red Cloud damage is very subtle. Many affected citizens deny that the cloud contained any destructive agent at all. As Ian Solitaire, the player will discover that it did. But before they can understand what hit the city, players must learn the dangers of heuristic thinking.

By deploying the Red Cloud, the enemy unleashed a Cognitive Bias Virus. The virus amplifies dangerous heuristic thinking already present in the human host. These cognitive biases corrupt rational thought and unravel social trust.

Fig. 2. Within the Red Cloud, citizens panic.

Citizens afflicted by Confirmation Bias support their current opinion by avidly seeking consistent evidence. At the same time, they unconsciously distort and discount any contradictory observation. The biased citizen attempts to test a theory, but only reinforces it.

Someone suffering from Fundamental Attribution Error sees the behavior of other citizens as evidence of their character, most often evidence of their character flaws. They overlook the fact that most human behavior is actually driven by circumstance [4].

Those living with Bias Blind Spot have learned to recognize biases in other people, while incorrectly assuming this skill inoculates them against the same biases [5].

All these biases are hard to fully understand, difficult to detect and nearly impossible to mitigate. To save Capitol City, the player embarks on a hero's journey during which these challenges are mastered.

3 Common Features of GBL and AIS

3.1 Spaced Learning

In order to shape behavior (as opposed to transferring declarative knowledge), repetition is critical. Small bites of learning delivered at regular intervals ("trickle training") is most effective to develop new habits. Since it strove to build new habits of thinking, *Enemy of Reason* was designed as an episodic game, intended to be deployed as a series of brief scenarios encountered daily, or even weekly. Other Adaptive Instruction Systems also employ the advantages of spaced learning [6].

3.2 Schema Graphs

Learning objectives are structured into units of comprehension called schemas. Acquisition of each schema depends on the prior acquisition is predicate schemas. The entire hierarchy of dependencies is often represented as a Directed Acyclic Graph (DAG). This graph provides a map of all the learning required to successfully complete the unit's primary learning objective. Learner model tracking software and game scenario sequencing engines can use such a map to flexibly and meaningfully organize player experience [7].

3.3 Concept Navigation

In much Game-Based Learning, instructional topics are organized and distributed predictably across the gameplay topology. Gameplay topology can be geospatial or can refer to more abstract spaces such as narrative, puzzle space, or conversational. In a game the learner typically has some degree of agency to move among them, and to determine the instructional path.

There are several levels of adaptive learning designed into Enemy of Reason. Practical implementation varies: While the simplest strategies are fully realized throughout the game, implementation of some complex adaptive mechanics is more irregular.

In large part, this irregular implementation is a natural product of demands inherent in a narrative game of the 'adventure' genre. The playable nodes contain critical plot points and solution clues in addition to their cargo of learning content. Basic adaptive design might reorder the nodes to add or remove instructional scaffolding as needed. If not executed carefully. this adaptive tactic invites plot holes and missing clues that put the player at a great disadvantage or simply break the game. If the designers supply optional nodes that contain alternative learning (but similar plot elements) they invite a combinatorial explosion and a production nightmare that would break the budget.

3.4 Synthetic Mentor

One solution is to separate instruction from exposition at each node and deliver the latter even when the former is avoided. In *Enemy of Reason,* this is facilitated by the game design. Most instruction is delivered through Dr K - a character presented as an artificial anthropomorphic app embedded in the hand-held Think Machine. Dr K is herself an Intelligent Tutor. Her presence removes some of the burden of adaptive instruction from the gameplay graph.

A second limit to implementation of a simple adaptive strategy is predictability. The adaptive engine probes the player by offering a set of choices that assess the learner's state. These probes fit a pattern, and were they implemented strictly throughout the game, the pattern would be obvious to the player. Indeed, the design of an irregular decision space topology is one of the most difficult creative tasks in this type of project.

Just in Time Instruction

In classic pedagogy, instruction is followed by assessment. This assessment follows the instruction often at a considerable distance: at the end of a week of lessons, say, or at the midterm exam. By contrast, in game-based learning, as in AIS, instruction and assessment coincide. Finer analysis will show that while they may occur in the same few seconds of interaction, they are generally distinct phases.

In a well-designed game, assessment begins immediately (and never ends). It is integrated into the nature of gameplay. The player is offered a challenge that assumes mastery of the learning material. If the player fails the challenge, remedial instruction is given to cure the deficiency before the challenge is (in some form) repeated. The remediation can range from crude repetition, to material selected from a matrix of alternatives, based on the state variables that track user experience, demonstrated competencies, and successful learning modalities. Meanwhile players who demonstrate working competency move forward in the game unaware of the instruction they avoid [8].

A more complex design allows more nuanced adaptive features. At almost every node in the gameplay topology, the player has several action choices. Often, for pragmatic purposes, the designer has attached the same path forward to multiple choices, either directly or after the player experiences inconsequential activity. This is the case, for instance, in the previously discussed case, where the game challenge is used to determine whether the learner has mastered a particular skill. The player's action either immediately leads out further into the game narrative or it engages the player in needed instruction first.

Instead, the more complex design, like most sophisticated adaptive tutors, seeks to classify the player's deficiencies so these can be addressed. At higher levels of Enemy of Reason, for example, the player is learning to avoid a cognitive phenomenon called Bias Blind Spot. This is the unfortunate heuristic that prevents those experts sensitized to the appearance of a cognitive bias in other people's reasoning from recognizing this same bias in their own.

In one level of Enemy of Reason, the player plays as Consuela, a veteran of guerilla warfare who returns to her mountain cadre seeking information leading to the perpetrator of the Red Cloud attack (see Fig. 3). The player must guide her as she interviews her former comrades, assembling clues from these often very unreliable informants. Some guerillas may deceive Consuela, but far more often they report what they think. Unfortunately, the fighters do not think very clearly, and the player is expected to detect the cognitive biases that distort the reports Consuela receives. However, at another level, Consuela's behavior might be driven by the player's own cognitive bias. Fundamental Attribution Error, for example, can cause the player to assume malevolent intent in the actions of characters that were driven by simple situational constraints.

The game presents choices designed to assess the player's specific skills. Struggling players, directing the Consuela avatar, fail to employ the bias detection skills introduced much earlier in the game. Choosing an option that reveals this failure, they navigate into game sequences designed for remedial instruction. A better player might correctly detect and mitigate bias in her informant but fail to realize that she herself is distorting the informant's answer to conform to her own biases. The game will drive this player into material designed to sensitize her to the problem of Bias Blind Spot.

Fig. 3. Consuela interrogates guerillas to locate Stilo

Some players will identify both the guerilla's bias and their own. These players will be expedited forward in the game.

In one scene, a love-struck young female fighter misinterprets the cadre leader's ordinary remarks as sly declarations of affection. Consuela must disregard this bias since logic based on that interpretation will lead her away from the leader's true location. Consuela must also fight her own bias to consider the leader malevolent. When the female fighter cites, as a sign of affection, the black eye given to her by the leader, Consuela recoils. She is ready to consider it evidence of abuse. However, dispassionate investigation will reveal that the black eye resulted from neither abuse nor affection. It was an accidental slip during a martial arts exercise. Each player investigates as much as seems necessary before deciding what the black eye represents and chooses action to be pursued on this decision. This action reveals the player's competencies and selects the next learning experience.

More subtle adaptive design exploits features of the game environment. For example, the learning game design generally serves two distinct objectives. First, the player must master the game's extrinsic learning content. In our case, the player must master certain skills that mitigate several cognitive biases.

3.5 Germane Cognitive Load

At the same time, the same player, in the same game must solve intrinsic game challenges. In Enemy of Reason, the player must identify and capture the perpetrator of a Red Cloud attack on Capital City from a broad array of enemies and rivals within the City and among her foreign adversaries.

The fact that the game offers challenges in both its intrinsic puzzles and its extrinsic training should warn designers that they might overload the player. Proponents of classic Cognitive Load Theory will be especially cautious, since this appears to be the

sort of extraneous load that the Theory abhors. More game-friendly learning theorists admit the possibility that well-engineered game challenges may serve instead as germane cognitive load. By shouldering germane load, a learner acquires schemas which expedite further progress toward the core objectives.

In Enemy of Reason, the game design indulges frequent excursions from the narrow instructional path. Each of these is designed to be germane cognitive load and delivers a constructive schema to the player. For example, the player, seeking the perpetrator of the Red Cloud attack on Capital City might seek evidence that implicates Beloved Leader, the dynastic autocrat who rules an isolated and militarized neighboring country. Beloved Leader brutalizes his starving and enslaved population but rallies their support by loudly threatening Capitol City with annihilation.

In chasing this rather obvious suspect, the player is cautioned to avoid confirmation bias. Nevertheless, many players surrender to heuristic thinking and pursue more and more evidence to confirm their suspicions. Among the evidence that they amass are secret videos belonging to Beloved Leader's Intelligence Analyst Training division.

Each of these items is a prized token for winning the game level. But the player can also view them. One video is an awkwardly translated Kunqu (Chinese Opera) performance that glorifies deductive reasoning, an important prerequisite skill for those seeking to overcome confirmation bias. (The singers, of course, credit the Beloved Leader with discovery of deductive reasoning.)

Another displays the progress of a traditional Asian children's game with slate and tiles (see Fig. 4). The game, in fact, perfectly illustrates the Analysis of Competing Hypotheses (ACH), an intellectual tool for defeating confirmation bias, developed by Richard Heuer at the CIA's Sherman Kent School for Intelligence Analysis and a critical learning objective treated elsewhere in the game.

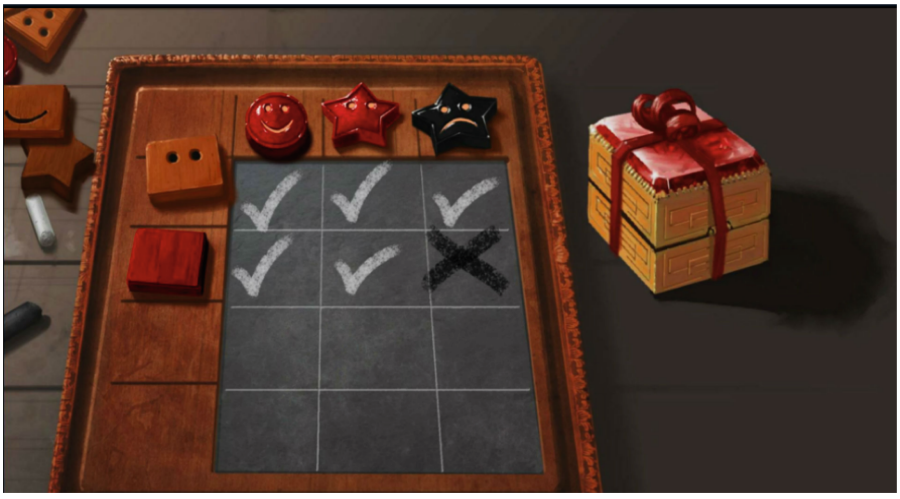

Fig. 4. Slate and tiles game to illustrate the Analysis of Competing Hypotheses (ACH).

To win, the player identifies the secret boxed token using the fewest moves. By choosing wooden clue tiles, the player works to disconfirm all but one of the three alternative solutions in the top row.

Both the Chinese opera and the children's game are, of course, completely fictional, invented to reinforce important schemas that support the core learning objectives.

4 Conclusion

Game Based Learning employs purpose-built digital games ("serious games") to help players overcome real-world learning challenges. These games employ many sophisticated pedagogic features, many of which are immediately recognizable to the student of Adaptive Instructional Systems (AIS). While it is tempting to suggest these games generally include some form of AIS, it is more useful to declare that the games themselves comprise a particular class of Adaptive Instructional System.

A Venn diagram of the intersection of the pedagogic feature set of advanced GBL with that of state-of-the-art non-game AIS would be dominated by their common overlap. Nevertheless, the two disciplines have developed areas of special development.

Practitioners of Game Based Learning would do well to follow the mainstream AIS literature. Work being advanced in learner modeling, data-driven artificial intelligence and advanced sensors can be used to upgrade serious game engines. In general, the game designer is better equipped to offer the learner attractive, meaningful choices than to determine which choices the learner currently needs.

Conversely proponents of non-game Intelligent Tutoring Systems and traditional Adaptive Instructional Systems would profit from a study of the work done in Game based Learning. Rich media assets are an obvious advantage of games, but these are not the most important. Games achieve learning by leveraging player agency and by exercising constructive failure. These, more than the media assets, are attributes that can find their way into traditional Adaptive Instructional Systems.

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