Combining Augmented Cognition and Gamification

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Abstract. The strategic goal of augmented cognition is to increase task performance capacity by using physiological sensor feedback to adjust or modify the activity for the user. Gamification has been shown to increase performance by using certain combinations of game elements. Both augmented cognition and gamification address increased task performance capacity. Gamification adds to augmented cognition by directly addressing the motivation of the user to remain engaged in the activity. This has also been referred to as flow, or the optimal experience. This paper describes an example of a gamified activity in which the physiological sensors of augmented cognition are used to foster the optimal experience desired in gamification. Also, discussed is how the strategic goals of augmented cognition and gamification overlap through the use of a gamified example that describes how the components of augmented cognition and elements of gamification can be used together to better achieve the goal of increased task performance capacity.

Keywords: augmented cognition, gamification, physiological sensors.

1 Introduction

The phenomenon of gamification has been gathering a great deal of interest among the various quadrants of society. It has been applied to a variety of areas, such as business[1], education[2], and health[3], and it has been included in the Gartner [1] hype cycle for emerging technologies in the last two years

There have been several attempts to define gamification. Deterding et al. [2] have defined it as “the use of game design elements in non-game contexts”. Werbach and Hunter [3] (p. 26) have elaborated on the definition to be “the use of game elements and game-design techniques in non-game contexts”. From these two definitions it becomes clear that gamification is not about building a fully fledge game, but rather about using parts of one. Deterding et al. [2] clarifies that these are “elements that are found in most (but not necessarily all) games, readily associated with games, and

[1] Foursquare - https://foursquare.com/
[2] Chore Wars -http://www.chorewars.com/
[3] Fitocracy - https://www.fitocracy.com/

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found to play a significant role in game play". Gamification leverages elements of games to promote users' motivation and to create engaging dynamics that can eventually influence and/or change the user's behavior.

Games are generally regarded as enjoyable and fun, but most interestingly, they have shown to motivate users to engage with them with unparalleled intensity and duration[2]. Moreover, research into human motivation demonstrates that people feel motivated by well-designed game features [3] (p. 10). It is this compelling nature of games that gamification researchers want to explore and capitalize in order to improve the effectiveness in other areas. This paper is particularly interested in how both augmented cognition and gamification can increase task performance capacity in education. Section 2 describes an example of a prototypical gamified activity and discusses how combining augmented cognition and gamification can support task performance capacity.

1.1 Background

Flow has been associated both with games and education. Flow, or the optimal experience, as described by Csikszentmihalyi refers to "a sense of that one's skills are adequate to cope with the challenges at hand in a goal directed, rule bound action system that provides clear clues as to how one is performing. Concentration is so intense that there is no attention left over to think about anything irrelevant or to worry about problems. Self-consciousness disappears, and the sense of time becomes distorted." [4] (p. 71).

The quality of an experience depends on an individual's level of challenge and skill when performing a given activity. Optimal experiences, i.e.: flow experiences, are likely to occur when both skills and challenges are high, when a person's skills are fully involved in overcoming a challenge that is just about manageable [5]. The repetition of flow moments will form a narrow flow channel (Fig. 1) within which the individual is in the desirable and enjoyable state of flow. Ideally, in order to excel and deeply engage in a given activity the individual's state should be located within this channel.

Falstein [6] studied the concept of Flow in fun and games to explain that game difficulty should vary in waves. Ikehara and Crosby [7] also recognized that in augmented cognition maintaining flow within an optimum cognitive load range would enhance learning. Ideally, if we were able to systematically adjust the level of challenge and skill a user faces we could hypothetically foster the efficacy of learning.

According to Csikszentmihalyi [4] (p. 71, 72), ". . . it is much more likely that flow will result either from a structured activity, or from an individual's ability to make flow occur, or both", but activities can also be designed to make optimal experiences easier to occur. It is easy to enter flow in games and these are actually exemplar flow activities. Important to that is the existence of clear goals and rules and of immediate feedback. Goals make it possible to act without thinking while rules direct energy in patterns that are enjoyable [4] (p. 76). Finally, immediate feedback makes the person aware of how well she is doing and enables the person to know whether she improved her position or not after each move.

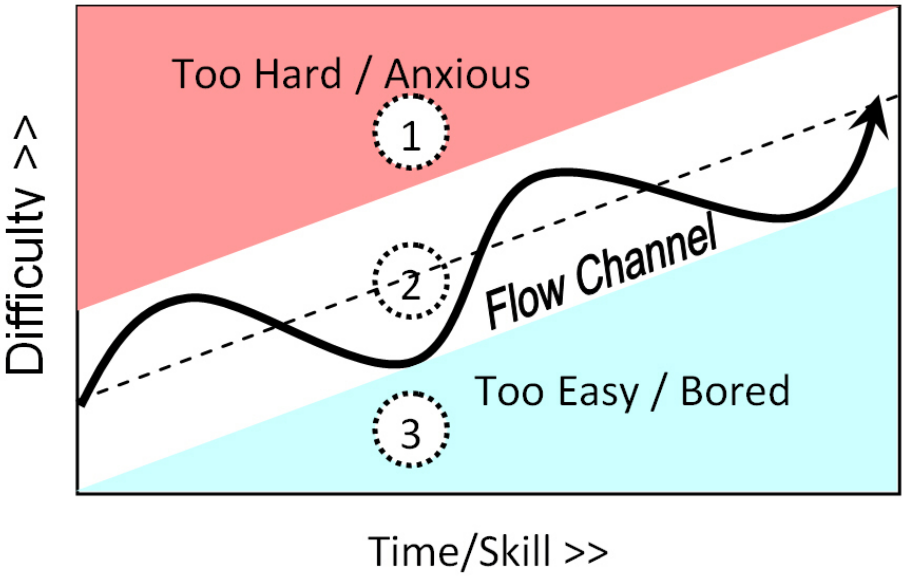

Fig. 1. The flow channel based on Csikszentmihalyi [4] (p. 74) and Falstein [6] depicting numbered example states

Due to the common complex combination of elements that are present in games it is difficult to exactly pinpoint the game elements and relationships between them that contribute to the optimal enjoyable experiences. Nonetheless, it is known that certain combinations of game elements enable flow to occur.

Researchers have tried to unfold those properties of games that make them so compelling. Jane McGonigal identified four game traits: goals, rules, feedback, and voluntary participation [8] (p. 21). Hunicke et al. [9] pulled out the components of games by formalizing them in the MDA framework that includes, mechanics, dynamics and aesthetics. Reeves and Read [10] identified the ten ingredients of great games: self representation with avatars, three-dimensional environments, narrative context, feedback, reputations, ranks, and levels, marketplaces and economies, competition under rules that are explicit and enforced, teams, parallel communication systems that can be easily configured, and time pressure. Werbach and Hunter [3] (p. 77-82) propose a pyramid of elements that from the top-down includes three levels of game elements: dynamics, mechanics and components (Table 1). These are used later in the description and discussion of how augmented cognition can be applied to a prototypical gamified activity to increase task performance.

Increasing task performance capacity is at the core of both gamification and augmented cognition. Augmented cognition "aims at evaluating in real-time the cognitive state of a user (e.g. EEG), and to design closed-loop systems to modulate information flow with respect to the user's cognitive capacity." [11] In order to increase the learning rate, the ability to do a task, or to maintain continued competent task performance,

Table 1. Werbach and Hunter Pyramid of Elements [3]

High Level - Dynamics	
H01	Constraints (that trigger meaningful choices)
H02	Emotions (what can make the experience richer and whatever motivates the people to play more)
H03	Narrative (what makes the gamified system coherent)
H04	Progression (what gives the player the sense that they are progressing towards the objective)
H05	Relationships(people interacting with each other (e.g., teams)
Mid-Level - Mechanics	
M01	Challenges (objective to reach)
M02	Chance (the luck involved)
M03	Competition (getting people to compete against each other)
M04	Cooperation (getting people to work together)
M05	Feedback (what enables the users to see how they are doing in real time and tends to drive them along to go further)
M06	Resource Acquisition (the things that the game gives you opportunity to get in the game in order to move it forward)
M07	Rewards (some benefits that you get for some achievement in the game)
M08	Transactions (buying and selling, or exchanging something with other players, or with what's called a non player character, with some automated character in the game)
M09	Turns (the opportunity or obligation to do something that comes successively to each of a number of people)
M10	Win States - The state which defines winning the game
Bottom Level - Components	
B01	Achievements (defined objectives)
B02	Avatars (visual representations of a player's character)
B03	Badges (visual representation of achievements)
B04	Boss fights (especially hard challenges and the culmination of a level)
B05	Collections (set of items or badges to accumulate)
B06	Combat (a defined battle, typically short-lived)
B07	Content unlocking (aspects available only when players reach objectives)
B08	Gifting (opportunities to share resources with others)
B09	Leaderboards (visual displays of player progression and achievements)
B10	Levels (predefined steps in player progression)
B11	Points (numerical representations of game progression)
B12	Quests (predefined challenges with objectives and rewards)
B13	Social Graphs (representation of players' social network within the game)
B14	Teams (defined groups of players working together for a common goal)
B15	Virtual goods (game assets with perceived or real-money value)

information is obtained from a variety of physiological sensors and used to adjust or modify a task. Elements of games have been used in augmented cognition to enhance task performance on an *ad hoc* basis [12]. The array of game elements that is used in gamification can be systematically leveraged to enhance augmented cognition systems.

2 Description of a Prototypical Gamified Activity

For children, learning fractions can be an increasingly challenging task as the numerator and denominator of the fraction increase in size. The strategic goal of teaching fractions is accomplished by getting children to repetitively practice fraction problems as the difficulty increases. A typical fraction exercise would consist of the set of fraction problems shown below.

$$\text{Is } \frac{1}{2} > \frac{1}{3}\ ?,\ \text{Is } \frac{2}{9} > \frac{1}{3}\ ?,\ \text{Is } \frac{4}{9} > \frac{1}{3}\ ?,\ \text{Is } \frac{11}{18} > \frac{1}{3}\ ?$$

To meet the strategic goal of the child learning fractions and the child's goal of participating in an engaging activity the fraction task can have game elements incorporated.

The Moving Targets Fractions (MTF) activity, described by Ikehara, Chin and Crosby [13] is a gamified version of the typical fraction activity shown above. The MTF task presents a fixed number of oval targets containing fractions on a computer screen. These fractions float across the screen from left to right (see Figure 2). The primary goal of the user is to maximize the score by selecting the fractions greater than 1/3 before they reach the right edge of the screen.

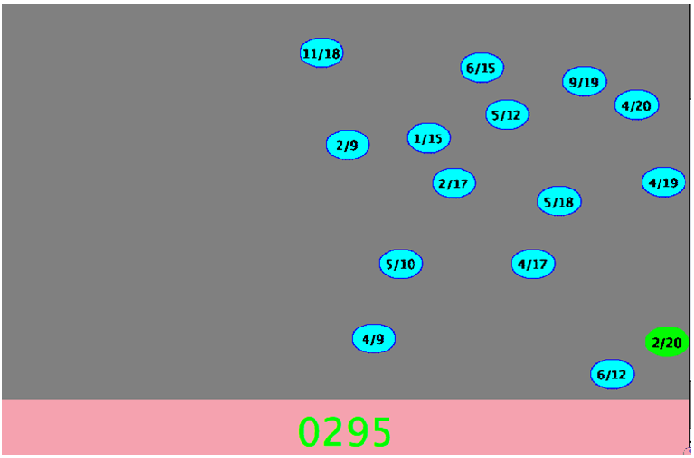

Fig. 1. Screen capture of the Moving Targets Fraction (MTF) task

There are several goals and subgoals in this activity, but interwoven into these are the elements of gamification used to motivate the user to achieve the strategic goals. Note that the game element code from Werback Gamification Pyramid of Elements follows element description. For example, high score (M07, B11) refers to high score being related to 'Points' from Werbach and Hunter Gamification Pyramid.

For the user to obtain the highest score (H02, H03, M01, M07, B11), the user must select all fractions greater than the critical value of 1/3 before they touch the right edge of the screen (H01). The goal of the user is to maximize the score (M01, M07), which is prominently displayed at the bottom of the screen (M05, B09), by achieving four subgoals before taking action.

- The first subgoal is to evaluate all fractions as they appear to determine if the fraction can be evaluated quickly or with difficulty (M01).
- The second subgoal is to evaluate each fraction's value, within the user's confidence level, to determine its relationship to a critical value (M01). Fractions greater than the critical value will increase the score when selected (B11). The difficulty of the comparison (i.e., cognitive load) is controlled by the fraction selected. For example, 1/2 is obviously greater than 1/3, but comparing 6/17 versus 1/3 requires much more cognitive effort. The user registers decisions by clicking with the mouse on those fraction targets greater than the critical value. Correctly selected fraction bubbles turn green. Incorrectly selected fraction bubbles turn red (M05). For even greater difficulty, the critical value can be changed from simple fractions like 1/3 to complex fractions such as 5/13 (M01).
- The third subgoal is to consider how the score is computed when selecting targets. The score is computed as 100 times the fractions that the user selects correctly above 1/3 (e.g., 3/4 * 100 = +75) and deducts 100 points for each incorrect selection. The negative scores for incorrect targets means the user cannot simply select everything on the screen to maximize the score (H01, M01).
- The fourth subgoal is to not let a fraction greater than the critical value touch the right edge. This fraction bubble will turn red. A deduction of 200 times the fraction value will occur if a fraction greater than the critical value touches the right side of the screen while a score of 200 point are added when the fraction is below the critical value. This motivates the subject to evaluate all fractions presented and not just the easily computed ones (H01, M01).

The subgoals can take on different priorities depending on task variables such as the difficulty of evaluating the fraction, the value of the fraction, how close the fraction is to the right side of the screen and the number of fractions presented (H01, M01). The priorities of the subgoals can also be affected by user factors such as arousal, stress and motivation (H02).

With augmented cognition, incorporating physiological sensors to adjust or modify game elements it is possible to keep the user in the optimum flow channel is possible by identifying two general classes of easily modifiable game elements: challenges and rewards. Modifiable challenges of the game includes: win states, time pressure, chance, transactions, content unlocking and quests. Rewards includes: leaderboards, reputations, ranks, levels, resource acquisition, badges, collections, points and virtual goods. Both challenges and rewards can be modified based on physiological sensor to keep the user in the flow channel. See Table 2 for a list of physiological sensors, physiological measures and secondary measures than can be used to direct the modification of game elements.

Table 2. Sensors, physiological measures and secondary measures

Sensors	Physiological Measures	Secondary Measures
Eye Position Tracker	Gaze Position, Fixation Number, Fixation Duration, Repeat Fixations, Search Patterns	Difficulty, Attention, Stress, Relaxation Problem Solving, Successful Learner, Higher Level of Reading Skill [14], [15]
	Pupil Size, Blink Rate, Blink Duratio	Fatigue, Difficulty, Strong Emotion, Interest, Mental Activity - Effort, Familiar Recall, Positive / Negative Attitudes, Information Processing Speed [14]
Mouse Pressure	Pressures Applied to the Mouse Case and Buttons.	Stress, Certainty of Response, Cognitive Load [16], [17]
Skin Conductivity	Tonic and Phasic Changes	Arousal [14]
Temperature	Finger, Wrist and Ambient Temperature	Negative Affect (Decrease), Relaxation (Increase) [14]
Relative Blood Flow	Heart Rate and Beat to Beat Heart Flow Change	Stress, Emotion Intensity [14]

Three examples below describe the 'task state', 'physiological sensors used', 'user state detected by the sensors' and 'element of the game modified' (see Table 3). Refer to Figure 1 for where these three examples are located in relation to the flow channel.

Table 3. Examples of physiological sensor directed modification of game elements

	Task State	Physiological Sensors Used	User State Detected by the Sensors	Element of the Game Modified
	Fractions are too difficult	Relative blood flow - heart rate above normal	Sensors indicate a persistent high level of arousal, the person is above the flow channel boundary	Reduce challenge by reducing the time pressure by slowing the flow of fractions or by reducing the level of difficulty of the fraction
	Fraction difficulty is appropriate	Skin conductivity-normal	Indicate a normal level of arousal, the person is within the flow boundary	No change
	Fractions are too simple	Eye Tracking - Blink duration longer than normal	Indicate a persistent low level of arousal, the person is below the flow channel boundary	Challenge modification is to increase the time pressure or increase the level of difficulty to move the user to an increased skill level

As shown in the example above, information from the physiological sensors can be used to modify game elements in the activity. This allows the achievement of the strategic goal of teaching fractions, while maintaining the positive attitude of the individual to continue performing the activity. Concurrent modification of challenges and rewards can be used to maintain or move a user higher in the flow channel. For example, increasing the time pressure (i.e., Challenge) while increasing the rank (i.e., Reward) could be used to move a user to a higher level of skill or challenge.

3 Conclusion

There is an alignment of the strategic goals of augmented cognition and gamification. This paper describes an example of an activity in which gamification elements are found in augmented cognition activities to increase task performance capacity. The Moving Targets Fractions task provides an example where game elements are identified and the potential of modifying game elements based on physiological sensors is described. Established are the relationships between the physiological sensors of augmented cognition and elements of gamification and how using sensor information to direct the modification of game elements can lead to achieving the strategic goal of increase task performance capacity while motivating the individual to achieve a high level of competence.

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