Brain Points: A Deeper Look at a Growth Mindset Incentive Structure for an Educational Game

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ABSTRACT
Student retention is a central challenge in systems for learning at scale. It has been argued that educational video games could improve student retention by providing engaging experiences and informing the design of other online learning environments. However, educational games are not uniformly effective. Our recent research shows that player retention can be increased by using a brain points incentive structure that rewards behaviors associated with growth mindset, or the belief that intelligence can grow. In this paper, we expand on our prior work by providing new insights into how growth mindset behaviors can be effectively promoted in the educational game *Refraction*. We present results from an online study of 25,000 children who were exposed to five different versions of the brain points intervention. We find that growth mindset animations cause a large number of players to quit, while brain points encourage persistence. Most importantly, we find that awarding brain points randomly is ineffective; the incentive structure is successful specifically because it rewards desirable growth mindset behaviors. These findings have important implications that can support the future generalization of the brain points intervention to new educational contexts.

Author Keywords
Educational games; growth mindset; incentive structures.

INTRODUCTION
One of the biggest challenges facing systems for learning at scale is student retention. Only a small percentage of students in Massive Open Online Courses (MOOCs) complete the courses they begin [10], and little is known about how to engage students in online learning environments. In contrast, video games are famous for their ability to motivate players to perform complex tasks over long periods of time. This has inspired a growing interest in leveraging games to engage students in educational settings [5, 22, 20]. Game incentive structures, the systems or rewards given to successful players, have attracted particular attention for their ability to motivate students [12]. As a result, there is great potential for educational games to provide engaging learning experiences at scale, and to inform the design of formal online learning experiences.

While educational games can motivate students, not all designs are equally effective. Our recent work shows that player persistence can be increased by modifying game incentives to reward behaviors associated with the growth mindset [24]. The growth mindset is the belief that intelligence can be increased over time through hard work and good strategies [21]. Psychology research shows that the growth mindset can be taught, and that growth mindset interventions can have a positive impact on students' motivation, reaction to failure, and academic achievement [2, 3, 6]. In our prior work, we encouraged growth mindset behaviors in the game *Refraction* using a novel "brain points" incentive structure that directly rewards students for their effort, use of strategy, and incremental progress [24]. While this research provides new insights into how persistence can be encouraged in online settings, the original study leaves a number of important questions unanswered.

In this paper, we expand on our previous work to gain a deeper understanding of the growth mindset intervention. The original intervention was composed of three central components: a growth mindset narrative, the brain points incentive structure, and a progress visualization. We study how each of these components contributes to the intervention's effects on student persistence, use of strategy, and reaction to challenge in the educational game *Refraction*. We developed four new versions of the intervention: one without a mindset narrative, one without brain points, one with brain points that are awarded randomly, and one without a progress visualization. Each version was created to explore a specific question about the intervention design. We present results from an online experiment with 25,000 students that compares each modified intervention to the original intervention design.

Our findings have a number of implications for the design of educational systems that aim to increase student retention by teaching the growth mindset. We found that fewer children persist when the growth mindset narrative is included because they quit during the game's introductory animation. This suggests that animations that interrupt gameplay are not effective at encouraging persistence. However, we found that the brain points incentive structure did increase persistence. More interestingly, we confirmed that rewarding players for their effort

L@S 2016, April 25-26, 2016, Edinburgh, Scotland Uk

DOI: http://dx.doi.org/10.1145/2876034.2876040

at random times is not effective; brain points are successful specifically because they reward productive struggle. This highlights the importance of developing intelligent behavioral metrics that can detect growth mindset behaviors when applying this approach to new learning environments. Finally, we found that visualizing player progress increases retention, suggesting that student data can be used as an effective motivator. We believe these findings make an important contribution that will help researchers generalize the brain points intervention to other online learning contexts in the future.

BACKGROUND

High rates of student attrition are common in online learning environments. In a meta-analysis of MOOC courses, Jordan found that completion rates range between 1% and 40%, with an average of 15% [10]. Researchers have cautioned against interpreting this high attrition rate as a failure of MOOCs because students begin courses with a diverse set of motivations, intentions, and circumstances that impact completion [14, 15, 27]. However, students who report that they are taking a course to earn a certificate still have low completion rates [15, 27], suggesting that there is room to improve.

While researchers have begun to explore methods of improving retention [7, 13, 16], we still have a limited understanding of how to motivate student to persist in online learning environments. However, we believe there is great potential for learning theory and educational games to inform the design of platforms for online learning. Psychologists have studied the relationship between motivation and academic achievement for decades, providing valuable insights that can inform the design of educational technologies. Game incentive structures have also been cited as a potentially valuable method of motivating students in a variety of learning environments [12].

In this section, we describe the theory behind the growth mindset and review related work on educational games. Then we provide an overview of our original work on incentivizing the growth mindset in games, and discuss the research questions left unanswered by our first study.

Theories of Intelligence

Extensive research in psychology shows that students' beliefs about intelligence can have a strong effect on their motivation, reaction to challenge or failure, and academic achievement [3, 6, 9]. Individuals who have a *fixed mindset* believe that they are born with a certain amount of intelligence, and that this is an unchangeable attribute. However, individuals who have a *growth mindset* believe that intelligence is malleable, and that it can be increased through hard work and good strategies [21]. These beliefs can impact both behavior and academic achievement; Blackwell et al. conducted a study that showed that holding a growth mindset predicted improving grades over the two years of middle school, while holding a fixed mindset predicted static or decreasing grades [3].

Fortunately, studies show that the growth mindset can be taught [21, 3, 2, 6, 11]. For example, growth mindset behaviors can be encouraged by changing the praise given to successful students. Multiple studies have shown that students who are praised for their ability after success ("you must be smart at these problems") react poorly to a subsequent failure, while students who are praised for their effort ("you must have worked hard at these problems") react favorably [11, 21]. The growth mindset can also be taught directly. Blackwell et al. taught middle-school students about the growth mindset through readings and discussions about the neural connections that form in the brain when it works hard. Before the intervention, students' math grades had been steadily decreasing, but after the workshop their grades improved significantly [3]. Aronson et al. report similar results in a study of an intervention for college students [2].

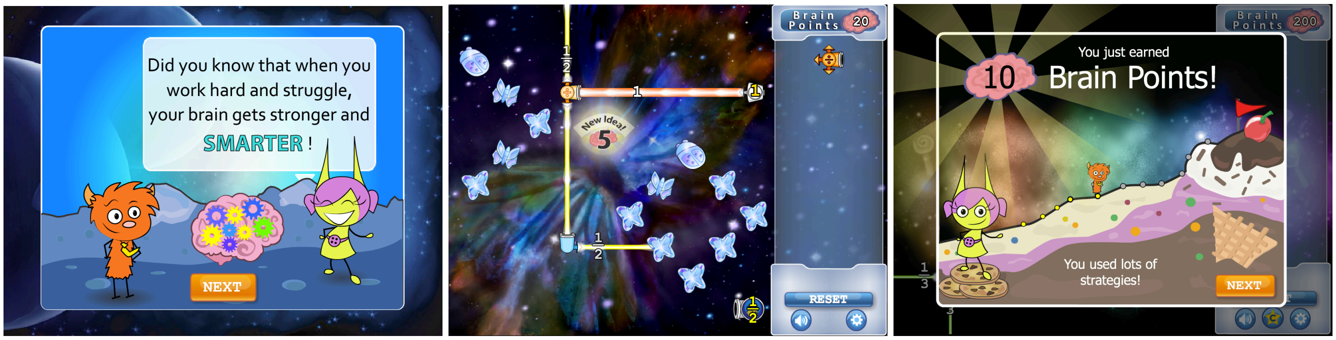
Growth mindset interventions have great potential to increase student motivation and performance at scale. As a result, recent efforts have explored methods of teaching the growth mindset online. Brainology, a for-purchase online program based on the Blackwell intervention, teaches students the scientific basis of the growth mindset through readings and interactive exercises [1]. Paunesku et al. studied the effectiveness of an online growth mindset intervention, delivered through two 45-minute sessions involving reading and writing exercises, and found student grades in core academic courses increased in comparison to a control [25]. However, little is know about how to teach the growth mindset through educational games.

Educational Games

Video games are increasingly recognized as a compelling platform that could be used to improve student motivation in educational settings [5, 22, 20]. Although empirical studies suggest that educational games can have mixed effects on learning outcomes [8, 18, 20], a number of clear successes highlight their potential as instructional tools. Mayo reviewed a variety of STEM game studies, and found that games can produce up to a 40% positive increase in learning outcomes [20]. Games have also been shown to increase student motivation [26] and time-on-task [18, 17]. Researchers note that successful educational games are typically designed around effective pedagogical practices [20, 22], highlighting the importance of grounding educational games in validated theory.

Researchers have explored methods of integrating learning theory into games to maximize student motivation, persistence, and learning [18, 4]. For example, Chase studied task framing in a genetics game, and found that students who are told their performance depends on both chance and skill persist longer after failure than those who are told their performance depends on skill alone [4]. Researchers have also studied methods of increasing persistence by adding game-like elements to formal learning environments [12]. Krause et al. found that student performance and retention improved when social gamification elements were added to a MOOC course [16]. This research suggests that games can be optimized for student motivation and persistence, and that incentive structures can be used to engage students outside of game environments. However, the relative impacts of varying game elements on student motivation are still not well understood.

[1] Brainology: http://www.mindsetworks.com/webnav/program.aspx



(a) (b) (c)

Figure 1. Screenshots of three central components of the brain points intervention for the educational game *Refraction*. Figure (a) shows a single panel from an introductory animation that teaches the growth mindset directly. Figure (b) shows brain points being earned during a game level. Figure (c) shows the brain points summary screen that displays a mountain that visualizes player progress.

The Brain Points Intervention

In recent work, we presented a new approach for promoting growth mindset behaviors in an educational game called *Refraction* [24]. This intervention is focused around a novel "brain points" incentive structure that directly rewards students for their effort, use of strategy, and incremental progress as they play. However, the intervention also includes a growth mindset narrative presented through an animated dialog, and a visualization of student progress that is displayed after each completed level. Screenshots of these three components of the intervention are shown in Figure 1.

In our first paper, we evaluated the intervention through an online study of 15,000 students [24]. This experiment compared the growth mindset version of *Refraction* to a control version with a standard incentive structure that awarded points for each completed level. We found that children in the mindset condition played longer and completed more levels than those in the control, suggesting that the intervention encouraged persistence. These children also used more strategy, suggesting that they learned the behaviors rewarded by the brain points incentive structure. Finally, more struggling players persisted in the growth mindset condition, suggesting that the intervention improved children's reaction to challenge. These findings indicate that the brain points intervention encouraged students to adopt growth mindset behaviors during play. However, this study left a number of important questions unanswered.

It is not currently clear whether the mindset narrative, brain points incentive structure, or progress visualization had the strongest effect on player behavior. Since previous work shows that the growth mindset can be taught directly [3], it is possible that the narrative contributed the majority of the effect. Furthermore, the original study compared brain points awarded during gameplay to a control where points were awarded after each completed level. It is possible that children simply enjoy earning points while playing, and that rewarding growth mindset behaviors is unimportant. Finally, it is unclear whether the progress visualization contributes to the observed effects.

In this work, we explore these unanswered questions through a large-scale experiment that compares five alternate versions of the growth mindset intervention. Our goal is to expand on our prior work; the design of the original brain points intervention is not a contribution of this paper. Instead, we provide new insights about the design of the brain points intervention that improve our understanding of how to promote growth mindset behaviors through educational games. We believe our findings will prove instrumental for future efforts to generalize this approach to other learning contexts.

EXPERIMENT DESIGN

To tease apart the impact of the different components of the brain points intervention, we designed an experiment that compares five different versions of the educational game *Refraction*. The first version is a control that uses a lightly modified version of our original intervention [24]. The remaining four versions either remove or modify components of the intervention to address specific research questions. In our analysis, we compare each modified version to to the control version, which allows us to measure the added impact of each component of the design. We leave pairwise comparisons of the modified versions for future work. In this section, we provide an overview of *Refraction* and describe the control version of the game. Then we present our four research questions and the versions of *Refraction* that we use to address each question.

Refraction

Refraction is a Flash puzzle game that was created by game researchers and learning science experts at the Center for Game Science to teach faction concepts to elementary school students. The game was designed to support a conceptual understanding of fractions rooted in the concept of splitting [19]. To play, a child interacts with a grid that contains laser sources, target spaceships, and asteroids, as shown in Figure 2. The goal of the game is to satisfy target spaceships by avoiding asteroids and splitting the laser into the correct fractional amounts. The player uses pieces that change the laser direction or split the laser into two or three equal parts to achieve this goal. To win, the player must correctly satisfy all the target spaceships at the same time.

Refraction uses an adaptive level progression that allows players to advance through concepts at their own pace. The progression covers eleven fraction concepts, ranging from split-

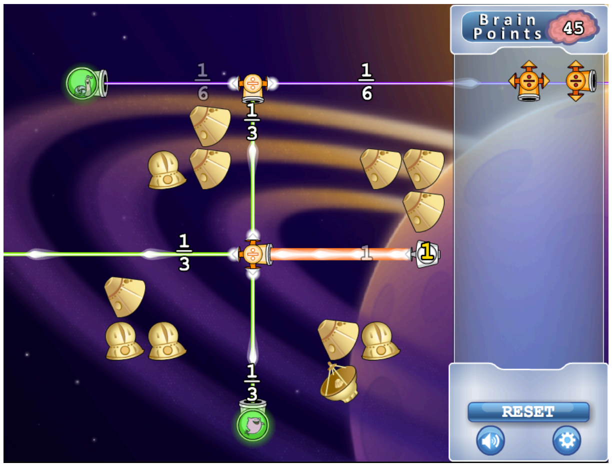


Figure 2. A level of Refraction. The pieces on the right are used to split lasers into fractional amounts and redirect them to satisfy the green target spaceships. All ships must be satisfied at the same time to win.

ting a laser into halves to splitting a laser to create both sixths and ninths. The game provides ten levels for each concept: one tutorial level with only required pieces, and nine puzzle levels that involve choosing between splitter pieces to produce the correct fractions. Each player begins with the tutorial level, and then continues to solve puzzle levels either two are solved under a mastery threshold or all nine puzzles are completed. To achieve mastery, the player must complete the level in 1.5 times the minimum required moves without making mathematical errors. The levels are always presented in the same order, so all children play the same first three levels, and some continue with additional puzzles until mastery is reached.

Control

To provide context for the four new versions of *Refraction* created for this study, we give a brief overview of the control version. For more detail on the intervention design see [24].

Narrative

The intervention includes a growth mindset narrative that is communicated through animations. A 25 second animation at the beginning of the game introduces the brain points incentive structure and teaches the growth mindset using language based on the Brainology curriculum and the Blackwell intervention [3]. This is followed by three additional animations, shown after the player completes the first three *Refraction* planets, which provide additional detail about the growth mindset. The animations are designed to directly teach the growth mindset and reinforce the value of strategy use and productive struggle.

Incentive Structure

The "brain points" incentive structure was designed to reward players for their effort, use of strategy, and incremental progress. Players earn brain points as they work to solve levels. We designed four metrics that capture desirable growth mindset behaviors in the game. The *new hypothesis* metric triggers when a player makes two new moves in a row. The *empty board* metric triggers when at least two pieces are on the board and the player returns all pieces to the starting bin. The *math* metric triggers when the player makes a target fraction for the first time. Finally, the *moves* metric triggers when the player makes ten distinct moves. These metrics capture desirable learning strategies and productive persistence in *Refraction*.

To make the system more difficult to game, a player must trigger two of these metrics to earn points. For example, a player will earn points if she first clears the board and then tries a new hypothesis. This allows the system to reward desirable behaviors without being overly transparent. Brain points are awarded to players in increments of five. When points are earned, a small animated brain icon with a short message is displayed, as shown in Figure 1(b). The message reflects the last metric the child triggered. The messages associated with the four metrics are "New Idea" for the *new hypothesis* metric, "Fresh Start" for the *board cleared* metric, "Math Effort" for the *math* metric, and "Working Hard" for the *moves* metric.

Progress Visualization

The *Refraction* world has seven different planets, and players advance to a new planet every time they collect 50 points. After each level, a summary screen showing the player's progress through the current planet is displayed, as shown in Figure 1(c). This visualization shows a mountain with ten dots. The player climbs one dot for every five points earned, symbolizing the player's hard work. At the top of the summary screen, a message highlights the number of points earned during the previous level. At the bottom, a message praises the player's work, reinforcing the growth mindset narrative and highlighting the connection between using growth mindset learning strategies and solving levels.

RQ1: Does the growth mindset narrative matter?

The first question we wanted to explore was whether the growth mindset narrative presented through the sequence of four animations have a strong impact on player behavior. We hypothesized that the narrative would make an important contribution, increasing persistence and improving players' reaction to challenge. To answer this question, we created a version of *Refraction* that did not include the four animations. After loading this version of the game, players are immediately dropped into the first level, without any introduction to the growth mindset or the brain points incentive structure. Players receive points just as they would in the control version, and they see the progress visualization after each level.

RQ2: Do brain points matter?

Next we wanted to explore whether brain points impact the effectiveness of the intervention. We hypothesized that points would contribute to encouraging growth mindset behaviors. However, since many effective mindset interventions focus exclusively on textual narratives [3], it is possible that brain points have no impact on student persistence, strategy use, and reaction to challenge. To explore this question, we created a new version of the intervention that included the growth mindset animations but no points.

In this version, players begin by watching a modified version of the introductory animation that teaches the growth mindset but does not mention the brain points incentive structure. After the animation, children play the game exactly as they would in the control condition, except that that no points are earned

Figure 3. A screenshot of the neutral dialog box displayed after each level in the version of *Refraction* that does not include brain points.

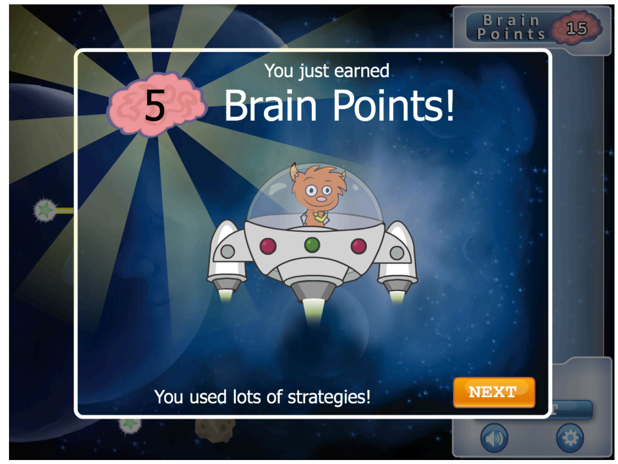


Figure 4. A screenshot of the summary screen without the mountain visualization that displays player progress through the current *Refraction* planet. We display a neutral animation of a spaceship in this summary screen instead.

during gameplay. Since the progress visualization displayed after each level is centered around earning points, we removed the summary screen in this version. Instead, we display a neutral dialog box, shown in Figure 3. While players do not earn points in this version, we silently calculate the number of brain points each player would have earned. We use this point count to determine when to advance players to the next *Refraction* planet, so that players advance at the same rate that they would have in the control condition.

RQ3: Do brain points need to reward specific behaviors?

We were also interested in studying whether brain points are more effective when they reward specific behaviors. We hypothesized that rewarding growth mindset behaviors would contribute to the effect. However, it is possible that players simply enjoy earning points during gameplay, and that rewarding growth mindset behaviors is unimportant. To explore this question, we developed a version of the game that awarded points randomly, rather than in response to strategic behavior.

In this version, players view the same growth mindset narrative and progress visualization as in the control condition. Players still earn points during gameplay, but we do not use the combined strategy metric to determine when to award points. Instead, we set a timer to award points after a certain number of seconds. When the random points timer finishes, we wait until the player makes a move, and then award brain points. We chose this approach to make the points seem less random, since earning points when you have not made any move feels unnatural. When players earn random points, the "Working Hard" message is displayed to insinuate that the points are rewarding effort. The "Working Hard" message is always displayed on the summary screen in this version.

To ensure that random points are awarded at the same rate as brain points, we randomly select each wait time from the distribution of times between brain points in the data set collected for the original experiment [24]. However, as we discuss in detail in the analysis section, random points are awarded significantly more often than brain points. This is because we award random points using this time distribution during all levels the game. In the control condition, it is more difficult to earn brain points during the four tutorial levels at the beginning of the game because these levels do not include fractions.

RQ4: Does the progress visualization matter?

Finally, we wanted to study whether the progress visualizations displayed on the summary screens contribute to the effects measured in the original study. We hypothesized that the visualization would contribute to engagement, since it provides a clear indication of player progress through the game. However, it is possible that the visualization and mountain metaphor are too abstract to have a strong impact on children. To study this question, we created a version of the intervention that showed a summary screen without the mountain visualization. The summary still displays the points earned during the previous level and the growth mindset message. However, the mountain is replaced by an animated image of a spaceship, as shown in Figure 4.

METHOD

To address our research questions, we studied how children played the five versions of *Refraction* on the educational website BrainPOP [2]. BrainPOP is a popular resource in the United States, where it is used in around 20% of elementary schools (Traci Kampel, personal communication). The website provides extensive curriculum materials for teachers, and also includes an educational game portal designed for use in the classroom. This is the same website that was used to conduct the original brain points study reported in [24].

BrainPOP is a valuable resource for studying the impact of educational game interventions because it provides researchers with access to a large, diverse population of students. However, as is common with online platforms, we know very little about the students who visit BrainPOP. While the website is primarily used in schools, we have no information about the contexts in which students play. We use random assignment

[2]BrainPOP: http://www.brainpop.com/

(a) (b) (c)

Figure 5. We designed a "challenge level" to observe how children react in the face of a particularly difficult puzzle. Figure (a) shows the message displayed when the player earns the challenge level. Figure (b) shows the introductory message displayed when the player starts the challenge level. Figure (c) shows the challenge level interface. The player can skip the challenge at any point by clicking the "New Level" button. For the no points condition, all textual references to points are removed from these dialog boxes.

and large sample sizes to mitigate the effects of any uncontrolled variables. We are also unable to administer pre- and post-tests to formally measure learning. Instead, we measure how our interventions impact observable in-game behaviors.

Behavioral Metrics

We use a variety of metrics to capture behaviors associated with the growth mindset, which we describe in detail below. As children play *Refraction*, we log all interactions with the game or its interface to capture behavior so that we can calculate these metrics for our analysis.

Persistence

To capture student persistence, we use two outcome measures: the amount of time children spend playing the game, and the number of levels they play. We calculate the amount of active time played by counting the number of seconds children spend interacting with the game, excluding menu navigation and idle periods with more than thirty sections between actions. We calculate the number of levels played by counting levels with at least one game action. Since *Refraction* uses an adaptive level progression, each child plays a different set of levels based on their incoming skill. However, we expect incoming skill to be evenly distributed across conditions because we assign players randomly.

Growth Mindset Behavior

We also wanted to measure whether students exhibit the growth mindset behaviors rewarded by brain points. To capture these behaviors, we use an outcome measure that combines the four metrics used to award brain points in the control version of *Refraction*. As mentioned in the Experiment Design section, we use the *new hypothesis*, *empty board*, *math*, and *moves* metrics to determine when to award points. In all five versions of *Refraction*, we log an event every time one of these metrics is triggered. We sum the number of times each of the four metrics is triggered during play to calculate overall strategy use. Then to control for amount of time played, we divide this combined metric by the number of minutes of active time. This produces a final outcome measure that captures the average number of metrics triggered per minute during play.

Reaction to Challenge

In addition to observing behavior during standard game levels, we wanted to measure how children are impacted by a particularly challenging level. Previous studies show that children react differently to failure on a challenging problem when they receive fixed and growth mindset praise [21]. We use a similar test in *Refraction* by giving players access to a "challenge level" when they earn sixty points. This level presents a unintuitive spatial problem that is tricky for adults to solve. The challenge is framed as a special reward given to players for their progress in the game. Screenshots of the challenge level and associated messages are shown in Figure 5.

Players are given the option of either playing the challenge level immediately or skipping the level. Players can return to the challenge at any point during gameplay by clicking the "C" button on the game's sidebar. This allows persistent children to attempt the challenge multiple times. We wanted to measure whether effects produced by the growth mindset intervention would transfer to levels where effort is not explicitly rewarded, so no points were given during the challenge level. Players could exit the challenge at any point by clicking the "New Level" button on the game sidebar. The challenge-related text is identical in all versions of the game except the "no points" version, in which references to points are removed.

We capture player behavior in relation to the challenge level using four different metrics. For all of these analyses, we only include children who play the game long enough to earn the challenge level. First, we calculate the number of times each player attempts the challenge level. Next, we calculate whether each player wins the challenge level. Since the level is very difficult, and players can skip the level at any time, we expect only a small percentage of children to win. We capture persistence by calculating the amount of active time each player spent on the challenge level. Finally, we calculate the average number of growth mindset behaviors per minute using the combined measure described above. These measures provide us with a robust picture of how children in each condition react to a particularly challenging level.

Condition	Active Time Played			# Levels Played			Growth Mindset Behavior Per Minute		
Control	2.54 min	$N = 10,000$	$p < 0.0001$	4 levels	$N = 10,000$	$p < 0.0001$	2.40	$N = 10,000$	$p < 0.0001$
No Narrative	3.01 min	$Z = -5.05$	$r = 0.05$	4 levels	$Z = 4.74$	$r = 0.05$	2.61	$Z = 7.08$	$r = 0.07$
Control	2.54 min	$N = 10,000$	$p < 0.0001$	4 levels	$N = 10,000$	*n.s.*	2.40	$N = 10,000$	$p < 0.0001$
No Points	2.21 min	$Z = -4.89$	$r = 0.05$	4 levels	$Z = -1.49$		2.71	$Z = 8.47$	$r = 0.09$
Control	2.54 min	$N = 10,000$	$p < 0.01$	4 levels	$N = 10,000$	$p < 0.0001$	2.40	$N = 10,000$	$p < 0.0001$
Random Points	2.19 min	$Z = -2.66$	$r = 0.03$	3 levels	$Z = -5.62$	$r = 0.06$	2.02	$Z = -7.22$	$r = 0.07$
Control	2.54 min	$N = 10,000$	$p < 0.0001$	4 levels	$N = 10,000$	$p < 0.005$	2.40	$N = 10,000$	*n.s.*
No Progress Viz	2.26 min	$Z = -3.80$	$r = 0.04$	3 levels	$Z = -2.89$	$r = 0.03$	2.46	$Z = 0.63$	

Table 1. Results from the statistical tests analyzing children's behavior while playing *Refraction*. We report the amount of active time children spend playing the game, the number of levels attempted, and the average number of growth mindset behaviors they exhibit per minute during the game. In each column, the median values are reported to the left of each cell.

Condition	# Challenge Attempts			Challenge Win Rate			Active Time Played			Growth Mindset Behavior Per Minute		
Control	1 attempt	$N = 1,580$	*n.s.*	7.69%	$N = 1,580$	*n.s.*	2.08 min	$N = 1,580$	*n.s.*	0.99	$N = 1,580$	*n.s.*
No Narrative	1 attempt	$Z = 0.05$		5.75%	$\chi^2 = 2.38$		2.06 min	$Z = 1.12$		0.87	$Z = 1.52$	
Control	1 attempt	$N = 1,309$	$p < 0.05$	7.69%	$N = 1,309$	$p < 0.05$	2.08 min	$N = 1,309$	$p < 0.05$	0.99	$N = 1,309$	$p < 0.05$
No Points	1 attempt	$Z = 2.07$	$r = 0.06$	11.19%	$\chi^2 = 4.67$	$v = 0.06$	2.48 min	$Z = 1.99$	$r = 0.06$	1.10	$Z = 2.47$	$r = 0.07$
Control	1 attempt	$N = 1,326$	$p < 0.01$	7.69%	$N = 1,326$	*n.s.*	2.08 min	$N = 1,326$	$p < 0.05$	0.99	$N = 1,326$	$p < 0.005$
Random Points	1 attempt	$Z = -2.78$	$r = 0.08$	7.69%	$\chi^2 = 0.00$		1.86 min	$Z = -2.50$	$r = 0.07$	0.73	$Z = -2.87$	$r = 0.08$
Control	1 attempt	$N = 1,325$	*n.s.*	7.69%	$N = 1,325$	*n.s.*	2.08 min	$N = 1,325$	*n.s.*	0.99	$N = 1,325$	*n.s.*
No Progress Viz	1 attempt	$Z = 1.51$		9.55%	$\chi^2 = 1.14$		2.33 min	$Z = 1.06$		1.06	$Z = 1.37$	

Table 2. Results from the statistical tests analyzing children's behavior while interacting with *Refraction*'s challenge level. Players earn a challenge level after collecting 60 points, giving us an opportunity to observe how they react to a difficult puzzle. We report the number of times children attempt the challenge level, their win rate, the amount of active time they spend working on the challenge, and the average number of growth mindset behaviors they exhibit per minute during the level. In each column, the median values are reported to the left of each cell.

Data Collection

To collect our data, we modified *Refraction* to randomly assign BrainPOP players to one of the five versions of the game. We only include new players in our analysis, and only use data from a player's first game session to control for issues with shared computers in school. We track players by storing information in the Flash cache, which allows us to exclude returning players. One disadvantage of this approach is that a player who clears the cache or switches computers will be treated as a new player in our experiment. However, this effect is distributed evenly across conditions due to randomization.

We collected data on BrainPOP between September 3 and October 28, 2015. *Refraction* was featured on the front page of the BrainPOP game portal once per week during this period, allowing us to attract large numbers of students. Our data set contained a total of 26,662 players. We randomly selected 5,000 players from each condition to include in our analysis.

DATA ANALYSIS AND RESULTS

We study the effects of our modified versions of the growth mindset intervention by comparing each to the control version of the intervention. We chose not to compare the four experimental versions to each other because this would result in a large number of pairwise comparisons. As a result, we are not able to formally reason about the relative impacts of the four versions. However, this analysis allows us to effectively explore our four research questions, which focus on understanding the added impact of each aspect of the intervention design. We leave comparative analyses of the four modified intervention designs for future work.

Before performing our analysis, we evaluated the Kolmogorov-Smirnov test to assess the normality of our data, and found that it was statistically significant for all of our outcome measures. As a result, we chose to use non-parametric statistical methods. We use a Wilcoxon rank sums test and an r measure of effect size for continuous variables, and a Chi-square statistic and a Cramer's V measure of effect size for nominal variables. We report effect sizes in addition to p-values to show the magnitude of the differences between our populations, since we are likely to find many significant differences due to our large sample sizes. For both tests, effect sizes with values less than 0.1 are considered *very small*, 0.1 are *small*, 0.3 are *moderate*, and 0.5 or greater are *large*. The results of our statistical analyses are reported in Tables 1 and 2. We describe these results and their implications in the following sections.

Growth Mindset Animations Provide No Added Benefit

We expected the growth mindset narrative presented through animations to encourage persistence and strategic behavior. However, our analysis showed the opposite effect. Children in the no narrative condition played significantly longer, a median of 3.01 minutes compared to 2.54 minutes for the control. They also completed significantly more levels; the median was 4 levels for both conditions, but children in the no narrative condition completed a mean of 8.08 levels compared to a mean of 7.65 levels for the control. Finally, players who did not see the animations were more strategic, exhibiting a median of 2.61 growth mindset behaviors per minute compared to 2.40 per minute for those in the control.

These results surprised us. Previous research shows that interventions that teach the growth mindset directly can be effective [2, 3]. On the other hand, this is the first intervention to attempt to teach the growth mindset through in-game animations, and games research has shown that players dislike tutorials that interrupt gameplay [1]. This made us wonder if a large percentage of players quit during the introductory animation itself, leading to lower overall persistence. To explore this question, we performed a follow-up analysis that only included players in both conditions who completed the first level of the game.

This analysis tells a different story. A larger number of children complete the first level in the no narrative condition, 3,536 players compared to 3,278 players in the control. However, we found no significant difference in the amount of time played ($Z = 1.32$, $N = 6,814$, *n.s.*), with medians of 6.09 minutes for the no narrative condition and 6.38 minutes for the control. There was also no significant difference in the number of levels completed ($Z = -0.14$, $N = 6,814$, *n.s.*), with medians of 8 levels for both conditions. Finally, we found no significant difference in the number of growth mindset behaviors observed per minute ($Z = 0.57$, $N = 6,814$, *n.s.*), with medians of 2.95 for the no narrative condition and 2.93 for the control.

This analysis suggests that the growth mindset animation dissuades some children from playing the game, reducing overall engagement. However, the animations do not have a negative impact on children's persistence or growth mindset behavior. This interpretation is further reinforced by our analysis of children's behavior during the challenge level. As reported in Table 2, there were no significant differences between these two conditions for any of our challenge level measures.

There are a number of possible explanations for this result. It may be that children do not like watching animations during gameplay, and that those who persist through the animation do not pay attention to its content. We display growth mindset messages throughout the game, on the summary screens at the end of each level and on the brain points themselves. It is therefore possible that reinforcing the growth mindset narrative through animations is not necessary. We will need to confirm this hypothesis through further studies, however our findings indicate that growth mindset animations are not necessary to effectively promote desirable behaviors in *Refraction*.

Brain Points Increase Player Retention

We expected the control version of *Refraction* with the brain points incentive structure to be more effective at encouraging growth mindset behaviors than the version without points. Our analysis confirms that children in the no points condition play for less time, a median of 2.21 minutes compared to 2.54 minutes for the control. However, there is no significant difference in the number of levels completed. More surprisingly, players in the no points condition exhibit significantly more growth mindset behaviors during gameplay, a median of 2.71 per minute compared to 2.40 per minute for the control.

A smaller number of children persist until the challenge level in the no points condition, 581 compared to 728 in the control. However, our analysis of challenge level behavior shows that players in the no points condition are more persistent and strategic. They attempted the challenge level significantly more times; the median number of attempts was 1 for both conditions, but players in the no points condition tried the challenge slightly more often, a mean of 1.06 times compared to 1 time for players in the control. Players in the no points condition spent more time on the challenge, used more growth mindset strategies, and won the challenge more often.

There are a number of possible interpretations of these results. It may be that the no points version of *Refraction* is more effective at encouraging use of strategy and persistence in the face of challenge. However, our analysis also shows that children in the no points condition completed the same number of levels as those in the control condition in less time. It is therefore more likely that the players who choose to persist in the no points version are more skilled at *Refraction*. In a recent study of player demographics on the homeschooling website K12.com, we found that older players exhibit more growth mindset behavior per minute than younger players [23]. Since older players are typically more skilled at the game, this suggests that the combined growth mindset behavior metric may be correlated with incoming ability.

Further research is needed to understand the full implications of these results. It is clear from this analysis that brain points encourage a larger number of players to persist for long periods of time in *Refraction*. While it is likely that players who persist in the no points condition exhibit more strategic behaviors because they have a high level of incoming ability, it is not possible to confirm this hypothesis through our current study.

Rewarding Players Randomly is Not Effective

We expected that rewarding players with brain points randomly, instead of in response to growth mindset behaviors, would be less effective. Our analysis confirms this hypothesis. Players who received points randomly played for significantly less time, a median of 2.19 minutes compared to 2.54 for the control. They also played significantly fewer levels, a median of 3 compared to 4 for the control. Finally, they exhibited significantly less growth mindset behavior, a median of 2.02 per minute compared to 2.40 per minute for the control.

Fewer players persist until the challenge level in the random points condition, a total of 598 compared to 728 in the control. Those that did make it to the challenge level played fewer times; while the mean was 1 attempt for both conditions, those in the no points condition made a mean of 0.92 attempts, compared to 1 attempt for those in the control. Children in the random points condition spent less time working on the challenge level, used less strategy, and were less likely to win.

To confirm that brain points are not awarded more frequently than random points, we compared the number of points earned per minute in each condition. Recall that points are awarded in increments of five in both versions. We found that players in the random points condition received points significantly more often ($Z = 31.72$, $N = 10,000$, $p < 0.0001$, $r = 0.3$), a median of 5.31 points per minute compared to 2.39 per minute for the control. However, this difference is driven by a difference in earned points on the tutorial levels. Brain points are challenging to earn during the tutorial levels, but random points are awarded at the same rate on all levels.

These results suggest that randomly praising students for their effort is not effective. While it is possible that random points are less engaging because they are given out more frequently, this would not explain the differences in observed growth mindset behaviors and students' reaction to challenge during gameplay. As a result, it appears that the brain points incentive structure is successful specifically because it rewards students for their productive struggle and use of strategy. This finding has important implications. In order to effectively integrate this intervention into a new context, it will be necessary to develop new behavioral metrics that accurately capture growth mindset behaviors to determine when to award points.

The Progress Visualization Increases Player Retention

We hypothesized that the summary screen progress visualization would contribute to player engagement. Our analysis confirmed this hypothesis. We found that players with no visualization played for significantly less time, a median of 2.26 minutes compared to 2.54 minutes for the control. They also completed significantly fewer levels, a median of 3 levels compared to 4 levels for the control. However, the progress visualization had no impact on growth mindset behaviors. There was no significant difference in the growth mindset behavior per minute, nor in any of the challenge level measures.

This finding suggests that showing players their progress, where progress measures growth mindset behavior rather than number of levels completed, increases player retention. This suggests that children may be motivated by seeing their progress and anticipating the reward of moving on to the next *Refraction* planet. The progress visualization is therefore a worthwhile addition to the growth mindset intervention.

CONCLUSION

In this work, we provide new insights into the design of a brain points incentive structure to promote the growth mindset in an educational game. We follow up on our previous research on brain points [24], exploring questions left unanswered by the original study. In particular, we explore the impact of the growth mindset narrative, brain points incentive structure, and summary screen progress visualizations on player persistence, use of strategy, and reaction to challenge. We find that narrative animations provide no added benefit to the intervention, and cause many players to quit before trying the first game level. However, we find that the progress visualizations and the brain points incentive structure both increase player persistence. Most importantly, we find that brain points are effective specifically because they reward desirable growth mindset behaviors. A similar incentive structure that rewards players at random intervals fails to encourage strategy use and persistence in the face of challenge.

While these results provide a deeper understanding of the design brain points intervention, a number of questions remain unanswered. We found that growth mindset animations had no positive impact on player behavior, however we cannot confirm why these animations were disengaging. It is possible that players never enjoy watching animations in casual games, however it's also possible that the cartoony style of the animations was unappealing to older students. We also found that players who did not receive brain points were more strategic and persistent in the face of challenge than players who did. This may be because more skillful players choose to persist in the no points version of the game, but we cannot confirm this hypothesis with the current data. Further research is needed to explore these open questions.

Despite these limitations, our findings make an important contribution to our understanding of growth mindset interventions for educational games. We believe the brain points incentive structure could be generalized to other educational games, and could even be used to gamify more formal learning environments. Online interventions that teach the growth mindset have been shown to be effective [25], and it is possible that growth mindset theory could be adopted into systems for learning at scale to improve student retention. We hope to explore this important research area in the future.

ACKNOWLEDGMENTS

We thank creators of *Refraction* for making this work possible. In particular, we would like to recognize Barbara Krug and Marianne Lee who created the incredible art and animations for this study. We also thank Allisyn Levy of BrainPOP for promoting *Refraction*. This work was supported by the Office of Naval Research grant N00014-12-C-0158, the Bill and Melinda Gates Foundation grant OPP1031488, the Hewlett Foundation grant 2012-8161, Adobe, and Microsoft.

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