Brain Points: A Growth Mindset Incentive Structure Boosts Persistence in an Educational Game

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ABSTRACT
There is great interest in leveraging video games to improve student engagement and motivation. However, educational games are not uniformly effective, and little is known about how in-game rewards affect children's learning-related behavior. In this work, we argue that educational games can be improved by fundamentally changing their incentive structures to promote the growth mindset, or the belief that intelligence is malleable. We present "brain points," a system that encourages the development of growth mindset behaviors by directly incentivizing effort, use of strategy, and incremental progress. Through a study of 15,000 children, we show that the "brain points" system encourages more low-performing students to persist in the educational game *Refraction* when compared to a control, and increases overall time played, strategy use, and perseverance after challenge. We believe that this growth mindset incentive structure has great potential in many educational environments.

Author Keywords
Educational games; growth mindset; incentive structures.

ACM Classification Keywords
H.5.0 Information Interfaces and Presentation: General

INTRODUCTION
Video games are famous for their ability to engage players and motivate them to perform complex, time-consuming tasks. Most children today are exposed to games on a daily basis; 92% of children ages 2 to 17 play video games, for an average of 20 to 33 minutes per day [16]. As a result, there is a growing interest in leveraging games to address the problem of student motivation in educational environments [11, 25, 23]. Game incentive structures, or the systems of rewards that are given to successful players, have elicited particular attention for their potential to motivate students [18]. However, games have produced mixed learning outcomes in the classroom [14, 21, 23], and the effects of in-game praise and rewards on motivation and learning are not well understood.

CHI 2014, April 26 –May 01 2014, Toronto, ON, Canada

http://dx.doi.org/10.1145/2556288.2557157

A growing body of research in psychology suggests that feedback such as praise can have varying, and sometimes negative, effects [24, 13]. Praising a student's inherent ability has been shown to promote the fixed mindset, or the belief that intelligence is unchangeable, while praising a student's strategies or effort promotes the growth mindset, or the belief that intelligence is malleable [24, 13]. Studies have shown that children with a fixed mindset view mistakes, challenge, and effort as negative indicators of their intelligence, while children with growth mindset view effort as positive and challenges as opportunities to learn [9, 15]. More importantly, holding a fixed mindset predicts static or decreasing academic performance over time, while holding a growth mindset predicts academic improvement [3, 12].

Many laboratory and classroom studies have shown that children's mindsets can be changed through careful intervention [3, 24, 17]. Directly teaching students that intelligence is malleable was shown to improve classroom motivation and grades compared to a control group [3]. Even minimal interventions, such as praising children for their strategy or effort (e.g., "you must have worked really hard!") instead of their ability (e.g., "you must be smart at this!") as they solve problems produces a growth mindset, as well as higher motivation and task persistence [24, 17]. This research suggests that the praise and rewards given to students in educational games could impact their behavior, and even have negative consequences if rewards inadvertently support the fixed mindset.

In this work, we show that making a fundamental change to a game's incentive structure can positively impact children's behavior. We present "brain points," a system that rewards students for their effort, use of strategy, and incremental progress. Unlike previous mindset interventions, this incentive structure provides children with real-time feedback as they work to develop growth mindset behaviors. Through a study of 15,000 children, we show that persistence and use of strategy is encouraged in the educational game *Refraction* through the introduction of this unorthodox incentive structure. We believe this method of promoting the growth mindset has great potential in many educational environments.

BACKGROUND
Psychologists have been studying motivation and academic achievement for decades, and many of their discoveries have important implications for the designers of educational technologies. Messages and rewards that support the growth mindset could be used to significantly improve the impact

of such systems. In this section, we provide background on mindset research and discuss previous efforts to integrate growth mindset interventions into classrooms and educational tools. We also describe existing work on educational games, and suggest ways that the growth mindset could be used to improve their effectiveness.

Theories of Intelligence

Psychologist have shown that beliefs about the malleability of human attributes such as intelligence can have strong effects on motivation, reaction to challenge or failure, and academic achievement [3, 12, 15]. Individuals who hold a *fixed mindset* believe that they have a certain amount of intelligence, and that this is an unchangeable attribute. Studies have shown that people with a fixed mindset view challenging situations as "tests" of how much intelligence they have, and view effort and mistakes as indications of low ability [3, 15, 24]. On the other hand, individuals who hold a *growth mindset* believe that intelligence is malleable, and that people can increase their intelligence through hard work. They have been shown to value learning over performance, and view effort as a necessary part of the learning process [3, 15, 24]. These beliefs affect not only behavior but also academic achievement. In a longitudinal study of 373 seventh graders, Blackwell et al. 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].

A growing body of research shows that students' mindsets, and subsequently their behaviors and academic performance, can be changed through intervention [24, 3, 1, 12, 17]. One type of intervention involves changing the type of praise given to children when they are successful. In a now-famous 1998 study, Muller and Dweck showed that praise can have negative consequences when it supports the fixed mindset [24]. They gave fifth grade students a set of achievable problems and praised them for either their ability ("you must be smart at these problems") or their effort ("you must have worked hard at these problems"). Then they gave students very challenging problems on which they did poorly. Finally, they gave students another set of the original achievable problems. Students who received praise for their ability attributed their failure to lack of ability, and performed worse on the subsequent problem set, but students who received praise for their effort viewed the difficulty as a cue to try harder, and performed better on the subsequent problem set [24]. More recently, Gunderson et al. have confirmed the role of praise in mindsets, showing that the type of praise parents give to their young children at home predicts the child's mindset and desire for challenge five years later [13].

Another type of intervention involves teaching the growth mindset directly. Blackwell et al. taught a group of seventh grade students that intelligence is malleable during an eight-session workshop through readings and discussions about the neural connections that are formed in the brain when it works hard [3]. Before the intervention, students' math grades had been steadily decreasing (and this decline persisted for children in the control group), but after the intervention students grades improved significantly [3]. Aronson et al. also report the positive impact of a growth mindset intervention on the academic achievement of both African American and white college students [1]. The GPAs of both the African American and white students in the experimental condition were higher at the end of the academic quarter than those in the control condition [1].

The effects of these interventions on student motivation and academic achievement are impressive, and it would clearly be beneficial to integrate similar programs into educational technologies. Recently, efforts have been made to develop online materials that teach the growth mindset. 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 [4]. In ongoing work, Paunesku and colleagues are studying the impact of integrating a praise-based intervention into the online educational website Khan Academy [19] with initial success [29]. However, we are not aware of any work that integrates the growth mindset into the incentive structures of educational games.

Games as an Educational Platform

Video games are increasingly recognized as a compelling platform for instruction that could significantly improve student motivation in the classroom [11, 25, 23]. While empirical evidence supporting learning outcomes of educational games is mixed [14, 21, 23], there have been clear successes that highlight the potential of games as instructional tools. In a comparative review of STEM game studies, Mayo found that some games produce a 7 to 40% positive increase in learning outcomes [23]. Games have been shown to increase time-on-task, an important indicator for academic success [21, 20], and also increase student motivation [27]. Researchers have noted that successful educational games are those designed around effective pedagogical practices, perhaps explaining some of the mixed learning outcomes [23, 25]. These results indicate the importance of grounding educational games in valid pedagogical theory.

Many researchers have explored how to most effectively integrate learning theories into games, and leverage game features to maximize student motivation, persistence, and learning [21, 7]. For example, Chase studied how the framing of tasks in a genetics game affects student persistence and learning. She found that students who are told their performance is dependent on both chance and skill persist more after failure than those who are told their performance is dependent on skill alone [7]. However, the effects of game features on student motivation are still not well understood.

To our knowledge, no existing research has explored how to improve in-game motivation and persistence through growth mindset incentives and feedback. We believe that educational games provide a set of properties that make them particularly conducive to introducing and incentivizing growth mindset concepts. Game narratives provide a forum for directly teaching about brain growth, weaving messages that support the growth mindset throughout the game world. Constant interactive feedback provides a medium for showing students that their effort translates into progress [10, 23]. But most importantly, game incentive structures provide a way to support and reward behaviors consistent with the growth mindset, such as persistence and use of strategy.

Experimental Hypotheses

The goal of this research was to study the impact of incentivizing productive effort and teaching the growth mindset in an educational game. To explore this question, we developed two versions of *Refraction*, a game designed to teach fraction concepts to elementary school students. The experimental version teaches and rewards growth mindset behavior by leveraging the game's narrative and incentive structure, while the control version provides a neutral view of intelligence. We expected children who played the experimental version to exhibit behaviors consistent with the growth mindset.

Hypothesis 1: *Players in the experimental condition will be more persistent and more strategic than players in the control.*

While we expected all players to be affected by the growth mindset intervention, we thought that players who struggle with *Refraction* would be most strongly influenced by our incentive structure that rewards effort. We expected them to be more strongly motivated to persist in the game.

Hypothesis 2: *Struggling players will be most strongly motivated by the experimental intervention.*

In addition to observing general behavior, we wanted to explicitly study how children in the two conditions reacted to challenge and failure. Following a similar model to that used in the 1998 Muller and Dweck study of the effects of praise on children [24], we designed an unusually challenging level to test children's persistence and performance. We expected children who played the experimental version of *Refraction* to react well to challenge, struggle, and failure.

Hypothesis 3: *Players in the experimental condition will react better to challenge than players in the control.*

To evaluate these hypotheses, we released both versions of *Refraction* to BrainPOP, a popular educational website for elementary school students that provides a game portal [5]. We analyzed data from over 15,000 players to determine the effects of incentivizing effort and teaching the growth mindset.

EXPERIMENT DESIGN

To explore the effects of teaching and supporting the growth mindset in educational games, we created two versions of *Refraction*, a game designed by our research group. One version teaches the growth mindset directly through the game's narrative, feedback, and incentive structures, while the other provides a neutral mindset and the incentive structure commonly found in educational games. In this section, we describe the two versions of *Refraction* in detail and discuss the rationale behind our designs.

Refraction

This educational puzzle game was designed by game researchers and learning science experts at the Center for Game Science to teach fraction concepts to elementary school students. The game was designed to support a conceptual understanding of fractions rooted in the concept of splitting [22]. To play, a child must interact with a grid that contains laser sources, target spaceships, and asteroids, as shown in Figure 1. The goal of the game is to satisfy target spaceships by splitting the laser into the correct fractional amounts and avoiding asteroids. The player uses pieces that either 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* has been successful at attracting elementary school students, and has been played over 250,000 times on the educational website BrainPOP since its release in April 2012.

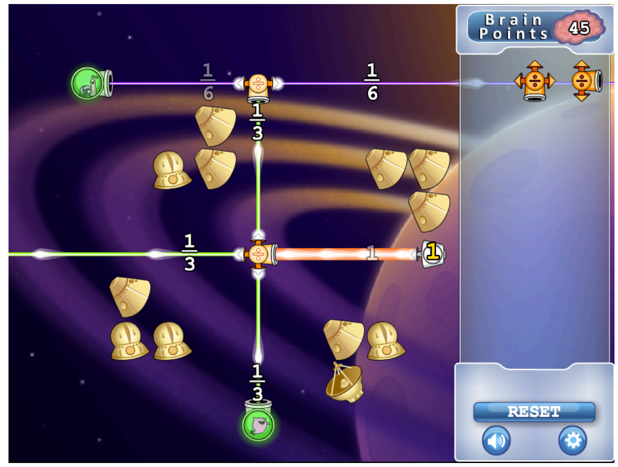


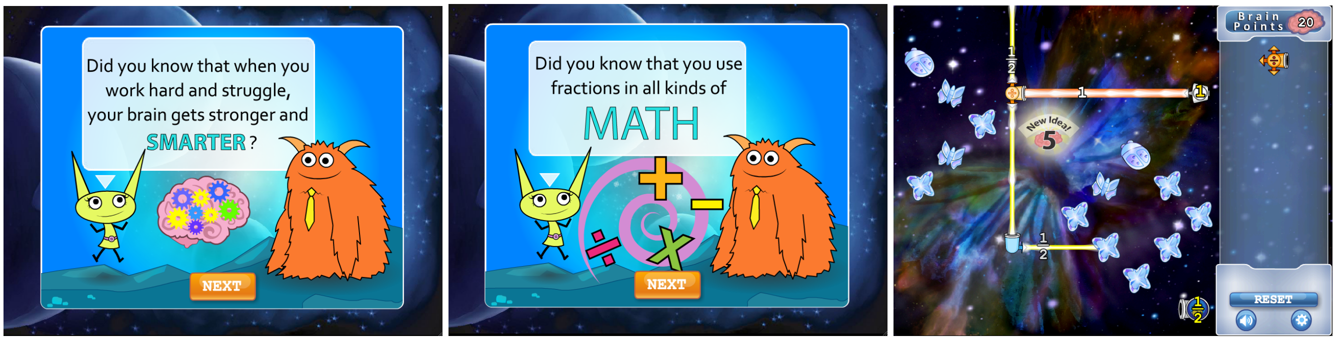
Figure 1. A level of Refraction. The pieces on the right are used to split lasers into fractional amounts and redirect them to satisfy the target spaceships. All ships must be satisfied at the same time to win.

Game Narrative

Both the experimental and control versions of *Refraction* are based on a central narrative. At the beginning of the game, players watch a 25 second introductory animation featuring Zuzu and Copper, characters who describe the game and its incentive structures. In the experimental version, we leverage this animation to teach players about the growth mindset directly, using language based on that used in the Brainology curriculum [4] and the Blackwell intervention [3]. In the control version, we present a neutral message about the importance of fractions. The text and art used in the animations are nearly identical, differing only in the messages they present to players. Screenshots are shown in Figure 2 and the full animation scripts are included in Table 1. We do not use audio in the animations because we cannot guarantee that players will have access to speakers or headphones. To accommodate different reading speeds, we added "Next" buttons that allow players to manually advance to the next part of the animation when they have finished reading.

Incentive Structures

Both versions of *Refraction* have point-based incentive structures designed to reward different types of behavior. For the experimental version, we designed a system of "brain points"



(a) (b) (c)

Figure 2. Figure (a) shows a screenshot of the introductory animation that teaches the growth mindset in the experimental version of Refraction. Figure (b) shows a corresponding screenshot in the control, which presents a neutral mindset about the importance of fractions. The animations use identical art and text wherever possible. Figure (c) shows the brain points interface in the experimental version. In this version players earn points for effort, use of strategy, and incremental progress as they work to solve levels, while in the control version players earn points each time they complete a level.

Experimental
Z: Hey Copper, guess what! *Z*: Did you know that when you work hard and struggle, your brain gets stronger and SMARTER? *C*: Whoa cool! *Z*: In this game, when you work out your brain and try new ideas, you'll get BRAIN POINTS! *C*: I want to get lots of brain points! Let's play, Zuzu!
Control
Z: Hey Copper, guess what! *Z*: Did you know that you use fractions in all kinds of MATH? *C*: Whoa cool! *Z*: In this game, when you make the fractions on the spaceships you'll get FRACTION POINTS! *C*: I want to get lots of fraction points! Let's play, Zuzu!

Table 1. The scripts for the introductory animations. The experimental animation teaches the growth mindset, while the control animation presents a neutral message about the importance of fractions. *Z* indicates Zuzu's line, and *C* indicates Copper's line.

that rewards children for their effort, use of strategy, and incremental progress. These types of behaviors support "learning" goals rather than "performance" goals, and rewarding similar behaviors with praise has been shown to promote the growth mindset [24, 13]. However, no existing growth mindset interventions have used point-based reward systems, so this is an entirely new method of teaching the growth mindset that is particularly well suited to the game context.

Children earn brain points while they are working to solve levels. We use a combination of four metrics that capture desirable strategic behaviors to determine when players should receive points. The *new hypothesis* metric captures each new idea the child tries. It triggers when the child makes two successive new moves with distinct pieces. The *board cleared* metric emphasizes stepping back to consider the puzzle from a fresh perspective. It triggers when there are at least two pieces on the laser, and the child returns all the pieces to the starting bin. The *math* metric captures incremental mathematical progress. It triggers when the child makes a target fraction for the first time. Finally, the *moves* metric captures effort. It triggers when the child makes ten distinct moves.

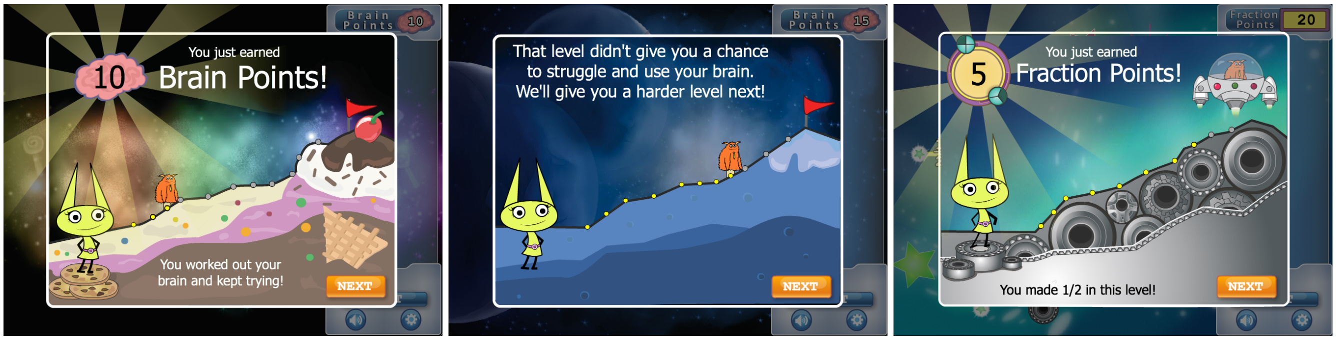
To earn brain points, the child must trigger two of these metrics. For example, a child might try a new hypothesis and then clear the board, earning five points. We require two metrics to be triggered because this makes the system more difficult to game, since the child cannot repeat his last sequence of moves to earn another point. Gaming the system is a problem in many educational domains [2], so we wanted to ensure that our point system rewarded desirable behaviors without being overly transparent. All metric data, such as the number of moves made so far, are cleared when the child earns a point so that subsequent points are earned from scratch.

Brain points are given to players in increments of five to make them more exciting. Each time the child triggers two metrics, she earns five points. When this happens, a small animated brain icon with a short message appears, as shown in Figure 2(c). The icon moves to the upper righthand corner of the screen, adding five to the total number of points shown in the brain points bar. The short 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.

For the control version of *Refraction*, we designed a system of "fraction points" that reward children for completing levels. We chose to incentivize advancement through the level progression because this is a commonly used metric of success in video games, as Schell notes in his popular game design book [28]. Players earn five fraction points every time they win a level, displayed on the summary screen described in the next section. The total number of fraction points earned so far are shown in the upper righthand corner of the screen.

Summary Screens

Each time a child completes a level of *Refraction*, a summary screen is displayed. This screen is designed to reinforce the game narrative and provide an opportunity for children to reflect on their success or progress. Identical art is used in the experimental and control versions, but different messages are given to support either the growth mindset or a neutral mindset. The summary screen has three components: a progress indicator, a points message, and a praise message. Screenshots of summary screens are shown in Figure 3.



(a) (b) (c)

Figure 3. Screenshots of the summary screens. Figure (a) shows the summary screen that is displayed when the child earns brain points in the experimental condition, and Figure (b) shows the screen that is displayed when the player does not earn brain points. Figure (c) shows the control condition summary screen that is displayed every time the player wins a level. In all cases, the mountain represents progress through the current *Refraction* planet. Copper physically climbs the mountain in the experimental summary screens to symbolize the player's effort. In the control summary screen, Copper waits in his spaceship at the top of the mountain. The player advances to a new planet each time she earns 50 points.

Metric	Growth Mindset Praise Messages
New Hypothesis	You worked hard and tried new ideas!
Board Cleared	You worked hard and got a fresh start!
Math	You worked hard and used your math brain!
Moves	You worked out your brain and kept trying!

Table 2. The four growth mindset praise messages displayed at the bottom of the summary screen in the experimental version of *Refraction*. The praise message shown on a given screen is selected based on the brain points message the child saw most frequently during the level.

The *Refraction* world has seven different planets, each with unique level art. In both conditions, children advance to a new planet each time they collect 50 points, an exciting reward that highlights their progress through the game. Since this advancement is based on points, children in the experimental condition move forward based on their effort and strategy use, while children in the control condition move forward based on their performance. Each summary screen shows a mountain with ten dots that indicate the player's progress through the planet. The player moves up one dot for every five points earned, and completed dots are shown in yellow. When the player reaches the top of the mountain, a reward animation shows the orange character Copper flying to the next planet.

In the experimental version, an animation shows Copper climbing the mountain every time the child earns brain points, as in Figure 3(a). This physical climbing metaphor was designed to symbolize the hard work required to earn brain points and support the growth mindset. In the control version, Copper waits at the top of the mountain in his spaceship while newly acquired dots are highlighted in yellow, as in Figure 3(c). This presents a more neutral message, showing progress without symbolizing effort.

At the top of the summary screen, a message tells the player how many points were earned. Since players in the experimental condition earn points based on their behavior, this number changes dynamically. If a player does not earn any brain points on a given level, a message apologizing for not giving the player an opportunity to struggle is displayed, as shown in Figure 3(b). This message is based on Dweck's suggested growth mindset response to situations that do not challenge children or provide them with an opportunity to learn [9]. Players in the control condition always earn exactly five fraction points for each level completed.

At the bottom of the summary screen, a message praising the child's work in this level is shown. In the experimental condition, one of four messages is chosen, depending on which of the four brain point messages the player saw most frequently during the level. The possible messages, which are based on messages used in Muller and Dweck's praise-based intervention [24], are shown in Table 2. In the control condition, a message summarizing the fractions the child made in this level is shown. If the child won a level with spaceships that required 1/6 and 1/9 laser power respectively, the message would read "You made 1/6 and 1/9 on that level!"

Adaptive Level Progression

In order to effectively incentivize effort in the experimental version of *Refraction*, it was important to design a level progression that would provide every player with an opportunity to struggle, irrespective of their incoming skill level. To address this requirement, we created an adaptive level progression that was used in both versions of the game. Our design is based on the mastery learning model used in many knowledge tracing systems, in which students must display mastery of a concept before advancing to the subsequent concept [8]. The adaptive progression covers eleven mathematical concepts typically included in *Refraction*, which are listed in Table 3. We designed ten levels for each concept: one tutorial level that introduces the concept without providing additional pieces, and nine puzzles in which the player must correctly choose between splitter pieces to create the correctly valued fractions.

All children play the eleven concepts in the order listed in Table 3, but they move through the concepts at different speeds depending on their skill level. Every child plays the tutorial level for a given concept, and is then given levels from that concept until she either wins two levels under a performance threshold, or completes all nine levels for the concept. To win a level below the performance threshold, the player must complete the level in less than 1.5 times the minimum number of moves required to beat the level without making any mathematical mistakes. Mistakes are defined as moves that split the laser to make fractional values that are not needed to solve the level. For example, if a child is working on a level with a 1/9 target spaceship, she should never split the laser to make 1/2 or 1/4.

Every child will play between three and ten levels for each concept. The levels are given to all players in the same order, so every child plays the same first three levels for a concept, and some will continue on to play more levels. This means that many more children play the first three levels than play the ninth and tenth level.

Skipping Levels

For the growth mindset version of *Refraction*, we wanted players to think about their progress in terms of effort and strategy, symbolized by brain points, rather than in terms of the number of levels they have completed. As a result, we designed the summary screens and adaptive level progression in a way that minimizes the visibility of speed by making it difficult for children to compare the number of levels they have completed. One downside of this design is that it provides no way for players to back out of levels when they get stuck.

To address this issue and deter frustrated players from quitting the game, we added a "New Level" button that appears in each level after three minutes of play. Children are required to work on each level for at least three minutes, but then they are given an opportunity to move forward when they are stuck. To ensure that children notice the button, a tutorial message is displayed the first time it appears.

When a child clicks the "New Level" button, a summary screen is displayed. In the experimental version, if the child earns brain points before clicking the button, the standard summary screen shown in Figure 3(a) is displayed. If the child does not earn any brain points, the message "Work harder and use your brain on the next level to earn points!" is displayed in a screen similar to Figure 3(b). In the control version, children only earn points when they win levels, so the same summary screen with the message "Try again on a new level! To move up the mountain, save the spaceships!" is always shown. In all cases, the summary screen has a "Back" button that returns to the level and a "Next" button that advances to the next level in the current concept.

Challenge Levels

In addition to observing children's behavior as they interact with the standard game levels, we wanted to measure how they react to a particularly challenging level. In their 1998 study of praise, Muller and Dweck saw that failing to solve a very difficult problem affected children differently based on whether they received fixed or growth mindset praise [24]. We designed a similar test for *Refraction* players by giving them a "challenge level" 30 minutes after they started the game. This level had two 1/2 spaceships, and presented a tricky and unintuitive spatial problem. We used simple fractions because we could not guarantee that all players would have reached more complex concepts.

Order	Concept	Order	Concept
1	Halves	6	Halves and Fourths
2	Thirds	7	Thirds and Ninths
3	Fourths	8	Halves and Sixths
4	Ninths	9	Thirds and Sixths
5	Sixths	10	Fourths and Sixths
		11	Sixths and Ninths

Table 3. The fraction concepts covered in *Refracion*'s adaptive level progression. All children play the concepts in this order, but they advance through concepts at different speeds based on their performance.

Experimental	
Timing	*Message*
Tutorial	You won't earn points on this level, but it will let you challenge your brain and make it grow stronger!
Skip	You didn't master that challenge yet, but you can keep growing your brain by earning points on the next level!
Win	You beat the challenge! You really worked out your brain on that level.
Control	
Timing	*Message*
Tutorial	You won't earn points on this level, but it will let you show off your fraction skills!
Skip	You didn't beat that challenge, but you can use your fraction skills to earn points on the next level instead!
Win	You beat the challenge! You really used your fraction skills on that level.

Table 4. The three challenge level messages for each condition. The first message is shown during the challenge level tutorial, the second is shown when the level is skipped, and the third is shown when the level is won.

The challenge was framed as a special level separate from the standard game. We used an exciting animation to introduce the level, and designed a new background to accompany it. We wanted to measure whether any effects caused by the growth mindset intervention would transfer to levels where effort is not explicitly rewarded, so we did not give children points during the challenge level. We added a bright orange "New Level" button to the sidebar so that players could skip at any point. We also added a tutorial message highlighting the presence of the "New Level" button to make sure players knew it was available. The challenge level was identical in the two conditions except for the text displayed to children. There are three challenge-related messages: one shown at the beginning of the level, one shown when the child wins the level, and one shown when the child skips the level. These messages can be seen in Table 4.

METHOD

To gain an understanding of the effects of incentivizing productive effort and teaching the growth mindset in educational games, we studied how children play the experimental and control versions of *Refraction* on the popular educational website BrainPOP [5]. BrainPOP is best known for its curriculum resources, but it also provides an educational game portal designed for use in the classroom. The BrainPOP Educators community has over 210,000 members [6], and the website is used as a resource in around 20% of elementary schools in the United States (Traci Kampel, personal communication).

One benefit of using the BrainPOP game portal to study the impact of our growth mindset intervention is that it provides us with access to a large, diverse population of students, and allows us to quickly learn whether our intervention has promise in the classroom. However, one downside of this resource is that we know very little about the children who visit BrainPOP or the contexts in which they play. We cannot collect any demographic information, and while we know that the website is primarily used in schools, we cannot tell whether children are playing in the classroom, in a computer lab, or at an after-school program. We mitigate the effects of these uncontrolled variables by evenly distributing them between conditions through the use of randomization and large sample sizes. We are also unable to directly measuring learning through formal pre and post tests in this environment. Instead, we analyze how our intervention impacts observable in-game behaviors such as persistence, use of strategy, and reaction to challenge. These are key components of learning that capture how students react to our growth mindset system.

Our study has a single between-subjects factor *intervention* with two levels: experiment or control. To collect our data, we set up *Refraction* to randomly assign new players to either the experimental or control version of the game, and logged all interactions players made with the game or its interface. We only included new players who were not familiar with *Refraction* in our analysis, and only used data from a player's first session to control for issues with shared computers in schools. To track players, we stored their progress in the Flash cache, which allowed us to selectively include new players and exclude return sessions. One drawback of this method is that a player who clears the cache or changes computers will be treated as a new player by our system. While we cannot assess the seriousness of this risk, its effects will be evenly distributed across conditions. Furthermore, it is unlikely that children will clear the cache because this option is inconvenient to access and it deletes all saved game progress.

Another challenge of studying student behavior online is that average play times are typically small. Previous research conducted on BrainPOP shows that children play *Refraction* for about three minutes on average [26]. We expected our brain points system to influence student behavior even during this short period of play because previous studies have shown that very minimal interventions, such as praising children for their effort or strategies, can improve motivation and persistence [24, 17]. However, we filtered our data to ensure that all students included in our analysis had an opportunity to be influenced by our growth mindset intervention. The first growth mindset message presented to students is the introductory animation, so for both conditions we only included those who watched the entire introductory animation and made at least one move in the game. We also conducted our analysis with a stricter filtering criterion that only included students who completed the first four levels of the game. After four levels, 99% of players in the experimental condition have received brain points and seen the summary screen. Both analyses showed the same patterns of significance and led to the same conclusions, so we chose to present results for the looser filtering method that included more students in the analysis.

After filtering, our data set contained 15,491 players, with 7,807 players in the experimental condition and 7,684 in the control condition. These data were collected between September 3 and September 13, 2013. *Refraction* was featured on the front page of BrainPOP's game portal between September 3 and September 5, allowing us to attract large numbers of students. Since the data sets for the two conditions had different numbers of players, we randomly selected 7,500 players from each condition to include in our analysis.

DATA ANALYSIS AND RESULTS

We study the effects of our growth mindset intervention on children's behavior by analyzing a number of outcome measures, each of which is described in detail below. Before performing this 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. We therefore use non-parametric statistical methods: 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 Growth Mindset Intervention Increases Persistence

We expected children who played the experimental version of *Refraction* to be more persistent than those who played the control version. To evaluate this hypothesis, we analyzed two outcome measures: the amount of time children spent playing the game, and the number of unique levels they played. Since BrainPOP offers many other games that teach fraction concepts, we expected children to quit *Refraction* when they became bored or frustrated. As a result, these measures capture how long children are willing to persist before choosing to leave the game.

We calculate active time by counting the number of seconds each child played *Refraction*, excluding menu navigation and idle periods with more than thirty seconds between actions. Our analysis showed that *intervention* has a significant effect on active time played, with children in the experimental condition playing a median of 118 seconds, compared to 89 for the control condition (Z=-8.61, $p<0.0001$, r=0.07). A graph of the active time for both conditions is shown in Figure 4.

We calculate the number of unique levels each child played by counting levels with at least one game action. Since *Refraction* has an adaptive level progression, each child plays a different set of levels based on their incoming skill. However, since children are randomly assigned to either the experimental or control condition, we expect skill to be evenly distributed across conditions. Our analysis showed that *intervention* has a significant effect on levels played (Z=-9.04, $p<0.0001$, r=0.07). Children in the experimental condition played more levels, a mean of 6.7 levels compared to 5.5 for those in the control. The median was 2 in both conditions.

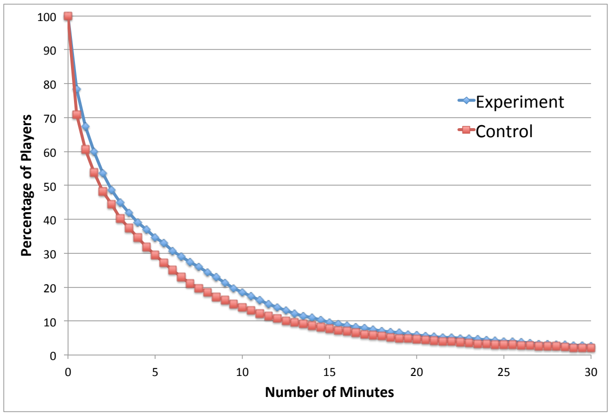


Figure 4. A graph showing the percentage of players in each condition who are still playing after a given number of active minutes. Children in the experimental brain points condition play significantly longer.

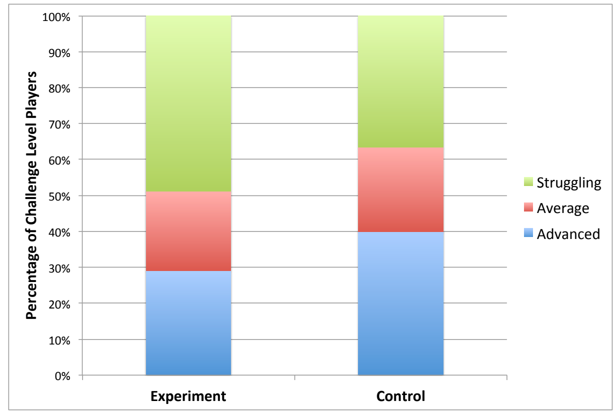


Figure 5. A graph showing the performance level distribution of players who persist for thirty minutes and reach the challenge level. The brain points version of *Refraction* is better at retaining struggling players.

These results suggest that children who play the growth mindset version of *Refraction* are more persistent than those who play the control version. They stay in the game significantly longer and play significantly more levels. However, both of these effects are very small. Given the BrainPOP environment, where the majority of children play for less than three minutes, this is not surprising. Therefore, the fact that we observe a 33% increase in median time played is encouraging, despite the small effect size.

The Intervention Promotes Growth Mindset Behavior

We expected children who played the experimental version of *Refraction* to display behaviors consistent with the growth mindset more frequently than those who played the control version. To evaluate this hypothesis, we analyzed an outcome measure that combines the four metrics used to award brain points to children in the experimental version. Recall from the Experiment Design section that we used a *new hypothesis* metric, an *empty board* metric, a *math* metric, and a *moves* metric to decide when to give brain points. In both versions of *Refraction*, we log an event every time one of the four metrics is triggered. We combine these four metrics to measure how frequently children exhibit the behaviors incentivized by the brain points system.

To combine the metrics, we summed the number of times each metric was triggered during play. Since children in the experimental condition play for significantly longer, they have more opportunities to trigger these metrics. To control for the amount of time played, we divided our combined metric by the number of minutes of active time played. This produced the average number of metric triggers per minute, our strategy outcome measure. Our analysis showed that *intervention* had a significant effect on this combined measure. Children in the experimental condition triggered an average of 2.49 metrics per minute, compared to 2.18 triggers per minute for the control (Z=-8.18, $p<0.0001$, r=0.07).

These results show that children who play the growth mindset version of *Refraction* learn to use the strategies incentivized by the brain points system. While the size of this effect is small, it is encouraging to see that such a short intervention can change the way children approach a problem, teaching them to exhibit growth mindset behaviors.

The Intervention Makes More Struggling Children Persist

We expected the experimental version of *Refraction* to encourage more struggling children to persist because effort was incentivized rather than speed or performance. To evaluate this hypothesis, we grouped players into three performance levels by measuring how quickly they mastered the first two concepts in the adaptive level progression. For each of the 483 players who mastered both concepts, we calculated the number of levels needed to complete the concepts. The minimum number of levels to master the concepts is six, and the maximum is twenty. To determine our grouping criteria, we ordered players by the number of levels they needed to master the concepts, and divided them into three equal groups. We consider children who complete the concepts in seven or fewer levels to be advanced, eight to ten levels to be average, and more than ten levels to be struggling.

To determine which types of players are encouraged to persist in each version of the game, we analyzed the performance level distribution of children who completed the first two concepts and reached the challenge puzzle that appears after thirty minutes of play. We found that *intervention* had a significant effect on performance level after thirty minutes (χ^2=8.00, $p<0.05$, V=0.13). As shown in Figure 5, 49% of children in the experimental version were labeled as struggling, 29% were advanced, and 22% were average, compared to 37% struggling, 40% advanced, and 23% average for the control. This suggests that our growth mindset intervention encourages more low performing students to persist for extended periods of time in *Refraction*.

The Intervention May Improve Reaction to Challenge

We expected children who played the experimental version of the game to react more favorably to an especially challenging level than children who played the control version. To evaluate this hypothesis, we analyzed children's behavior in the "Challenge Level" given to players thirty minutes into the game. Very few children play *Refraction* for long enough to reach the challenge level, so our analysis only includes 281 players from the experimental condition and 248 from the control condition.

First, we analyzed the time played and combined strategy outcome measures used previously. We found no significant effect of *intervention* on amount of active time played (Z=-0.81, *n.s*) or the number of strategy metrics fired per minute (Z=0.69, *n.s*). We also looked at whether children win the challenge level, skip by clicking the "New Level" button, or quit the game entirely. We did find a significant effect of *intervention* on win rate, most likely due to the uneven performance distribution at this point in the game. Children in the control condition won 18% of the time, compared to 11% for the experimental condition (χ^2=4.79, $p<0.05$, V=0.1).There were no significant differences in the skip rate (χ^2=2.0, *n.s.*) or the quit rate (χ^2=0.08, *n.s.*).

Finally, we studied how children were impacted by struggle by measuring how long children continued playing *Refraction* after the challenge level. We calculated the amount of active time children spent playing after this level, and while there was no significant effect, the results trend in the hypothesized direction of children in the experimental condition playing longer (Z=-1.71, p=0.088, r=0.07). They played for a median of 381 seconds after the challenge level, compared to 258 for children in the control condition, despite the fact that the remaining group of students in the experimental condition had a larger percentage of low performers.

We had hoped to see the increased persistence and use of strategy observed in the standard *Refraction* levels transfer to the challenge level, where effort was not explicitly rewarded through brain points. While it is possible that children in the experimental condition were less motivated to persist because they did not earn brain points on this level, it is also possible that we saw no effects due to the population of players included in this analysis. Children who play *Refraction* for more than thirty minutes on BrainPOP are unusual; they may be more persistent than average, and could already be inclined towards the growth mindset. Future research will need to explore this question in more depth in a environment where we can assess and control for children's incoming mindsets.

Despite the overall lack of difference in children's behavior during the challenge level, we measured a promising trend showing that children in the experimental condition may play longer after experiencing struggle and failure than children in the control condition. This trend suggests that even among the unusual group of children who play *Refraction* for over thirty minutes, our brain points intervention may affect how long they are willing to persist. This is especially encouraging because a larger percentage of the children who persisted until the challenge level in the experimental condition struggled with the game. However, this trend is not significant and will need to be confirmed through future research.

CONCLUSION

In this work, we show that making a fundamental change to an educational game's incentive structure can positively impact children's behavior. We present a new method of promoting the growth mindset through the "brain points" incentive structure. This system shows children how to practice and achieve growth mindset behaviors, in addition to teaching them the theory behind this mindset. The results from our preliminary study on BrainPOP are encouraging. Children were only exposed to our intervention for a short period of time, three minutes on average, and yet we were able to capture the effects it had on their behavior. Children in the experimental condition played longer and completed more levels than those in the control condition. They also learned to use the strategies incentivized by the brain points system, exhibiting strategic behavior more often than children in the control condition. Finally, an analysis of the children who played for thirty minutes showed that those in the experimental condition may persist longer after struggling with a challenging level than those in the control condition.

While the initial results are promising, this study has a number of limitations that we hope to address in future work. We know little about the children who play games on BrainPOP or the contexts in which they play, information which could help us better understand their behavior. Furthermore, children play for a very limited amount of time. While previous studies have shown that minimal interventions, such as praising students' hard work and strategies, can increase motivation and task persistence [24, 17], it would be valuable to understand how our system affects student behavior during longer play sessions. Finally, we could not directly measure how the intervention impacted student learning with formal pre- and post-tests in this work due to the nature of our online study. We plan to expand our understanding of the brain points intervention in future work by studying its effects in a fully controlled classroom environment.

Despite these limitations, our preliminary results suggest that growth mindset feedback has the potential to increase persistence and performance in educational games. We believe that the brain points incentive structure could be generalized and integrated into many game environments, and even adopted in other contexts to incentivize effort, strategic thinking, and persistence. Our brain points system was designed to reward the micro behaviors that are indicative of productive struggle in *Refraction*. This design could be applied to another application through the development of a context-specific metric for detecting effort and use of strategy. This metric could be used to provide real-time rewards that encourage growth mindset behavior in the new application. We hope that this method of promoting the growth mindset by directly rewarding desired behaviors can be adopted in many settings, and we plan to explore this possibility in future work.

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.

REFERENCES

1. Aronson, J., Fried, C. B., and Good, C. Reducing the Effects of Stereotype Threat on African American College Students by Shaping Theories of Intelligence. *Journal of Experimental Social Psychology 38* (2002), 113–125.
2. Baker, R., Walonoski, J., Heffernan, N., Roll, I., Corbett, A., and Koedinger, K. R. Why students engage in “gaming the system” behavior in interactive learning environments. *Journal of Interactive Learning Research 19*, 2 (2008), 185–224.
3. Blackwell, L. S., Trzesniewski, K. H., and Dweck, C. S. Implicit Theories of Intelligence Predict Achievement Across an Adolescent Transition: A Longitudinal Study and an Intervention. *Child Development 78*, 1 (2007), 246–263.
4. Brainology. http://www.mindsetworks.com/webnav/program.aspx.
5. BrainPOP. http://www.brainpop.com/.
6. BrainPOP Educators. http://www.brainpop.com/educators/home//.
7. Chase, C. The interplay of chance and skill: Exploiting a common game mechanic to enhance learning and persistence. In *Proceedings of the 2012 International Conference of the Learning Sciences* (2012).
8. Corbett, A. T., and Anderson, J. R. Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction 4*, 4 (1995), 253–278.
9. Dweck, C. S. *Mindset: The new psychology of success*. New York: Random House, 2006.
10. Gee, J., and Shaffer, D. Looking where the light is bad: Video games and the future of assessment. (Epistemic Games Group Working Paper No. 2010-02), Madison: University of Wisconsin-Madison (2010).
11. Gee, J. P. *What Video Games Have to Teach Us About Learning and Literacy*. St. Martin’s Press, 2008.
12. Good, C., Aronson, J., and Inzlicht, M. Improving adolescents standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology 24* (2003), 645–662.
13. Gunderson, E. A., Gripshover, S. J., Romero, C., and Dweck, C. S. Parent Praise to 1- to 3-Year-Olds Predicts Children’s Motivational Frameworks 5 Years Later. *Child Development 84*, 5 (2013), 1526–1541.
14. Harpstead, E., Myers, B. A., and Aleven, V. In search of learning: facilitating data analysis in educational games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI ’13, ACM (New York, NY, USA, 2013), 79–88.
15. Heyman, G. D., and Dweck, C. S. Children’s Thinking about Traits: Implications for Judgments of the Self and Others. *Child Development 64*, 2 (1998), 391–403.
16. Kaiser Family Foundation. Key Facts: Children and Video Games, 2002. http://kaiserfamilyfoundation.files.wordpress.com/2013/04/5959.pdf.
17. Kamins, M. L., and Dweck, C. S. Person versus process praise and criticism: Implications for contingent self-worth and coping. *Developmental Psychology 35*, 3 (1999), 835–847.
18. Kapp, K. M. *The gamification of learning and instruction: game-based methods and strategies for training and education*. San Francisco, CA: Pfeiffer, 2012.
19. Khan Academy. http://www.khanacademy.org/.
20. Lee, J., Luchini, K., Michael, B., Norris, C., and Soloway, E. More than just fun and games: assessing the value of educational video games in the classroom. In *CHI ’04 Extended Abstracts on Human Factors in Computing Systems*, CHI EA ’04, ACM (New York, NY, USA, 2004), 1375–1378.
21. Linehan, C., Kirman, B., Lawson, S., and Chan, G. Practical, appropriate, empirically-validated guidelines for designing educational games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI ’11, ACM (New York, NY, USA, 2011), 1979–1988.
22. Martin, T., Smith, C. P., Andersen, E., Liu, Y.-E., and Popović, Z. Refraction time: Making split decisions in an online fraction game. In *American Educational Research Association Annual Meeting*, AERA (2012).
23. Mayo, M. J. Video Games: A Route to Large-Scale STEM Education? *Science 323* (2009), 79–82.
24. Mueller, C. M., and Dweck, C. S. Praise for Intelligence Can Undermine Children’s Motivation and Performance. *Journal of Personality and Social Psychology 75*, 1 (1998), 33–52.
25. O’Neil, H. F., Wainess, R., and Baker, E. L. Classification of learning outcomes: evidence from the computer games literature. *The Curriculum Journal 16*, 4 (2005), 455–474.
26. O’Rourke, E., Butler, E., Liu, Y., Ballwebber, C., and Popović, Z. The effects of age on player behavior in educational games. In *Foundations of Digital Games*, FDG ’13 (2013).
27. Ricci, K. E., Salas, E., and Cannon-Bowers, J. A. Do computer-based games facilitate knowledge acquisition and retention? *Military Psychology 8*, 4 (1996), 295–307.
28. Schell, J. *The Art of Game Design: A Book of Lenses*. Morgan Kaufmann Publishers, Burlington, MA, 2008, p.120.
29. Yeager, D. S., Paunesku, D., Walton, G. M., and Dweck, C. S. *How Can We Instill Productive Mindsets at Scale? A Review of the Evidence and an Initial R&D Agenda*. A White Paper prepared for the White House meeting on Excellence in Education: The Importance of Academic Mindsets, 2013.