Demographic Differences in a Growth Mindset Incentive Structure for Educational Games

Eleanor O'Rourke
University of Washington
Computer Science
Seattle, WA
eorourke@cs.washington.edu

Yvonne Chen
University of Washington
Computer Science
Seattle, WA
evechen@cs.washington.edu

Kyla Haimovitz
Stanford University
Department of Psychology
Stanford, CA
kylah@stanford.edu

Carol S. Dweck
Stanford University
Department of Psychology
Stanford, CA
dweck@stanford.edu

Zoran Popović
University of Washington
Computer Science
Seattle, WA
zoran@cs.washington.edu

L@S 2015, Mar 14-18, 2015, Vancouver, BC, Canada
ACM 978-1-4503-3411-2/15/03.
http://dx.doi.org/10.1145/2724660.2728686

Abstract
Video games have great potential to motivate students in environments for learning at scale. However, little is known about how to design in-game incentive structures to maximize learning and engagement. In this work, we expand on our previous research that introduced a new "brain points" incentive structure designed to promote the growth mindset, or the belief that intelligence is malleable. We replicate our original findings, showing that brain points increase student persistence and use of strategy. We also explore how brain points impact students from different demographic groups. We find that brain points are less engaging for low-income students, and discuss methods of improving our design in the future.

Author Keywords
Educational games; growth mindset; incentive structures

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

Introduction
Video games are widely recognized for their ability to motivate players to perform complex tasks. As a result, there is a growing interest in using games to engage students in educational settings [5]. Student motivation is especially important in the context of learning at scale.

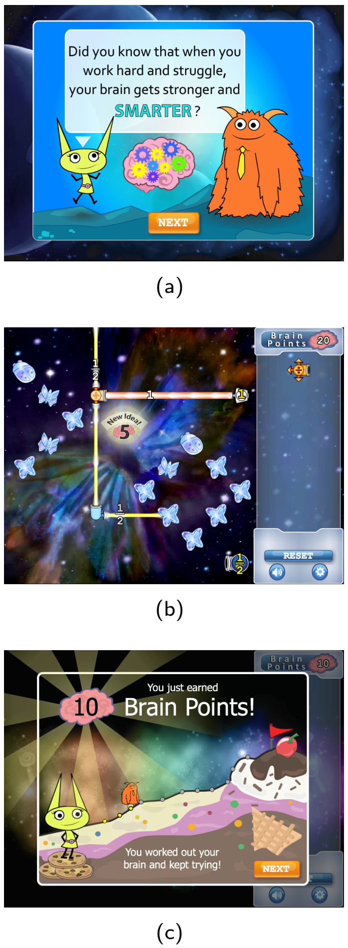

Figure 1: Screenshots of the brain points version of *Refraction*. Figure (a) shows the introductory animation, (b) shows brain points being earned, and (c) shows a brain points summary screen.

Studies show that the student-teacher relationship, and particularly the teacher's perceived physical and psychological closeness with students, can have a strong impact on motivation in the classroom [3]. In environments where there are thousands of students for every teacher, it is not possible to provide this type of interpersonal motivation. Educational games could be leveraged to help motivate students in these settings.

While educational games have potential, little is known about how to design in-game incentives to maximize learning and engagement. In previous work, we explored the impact of fundamentally changing game incentives to reward behaviors associated with the growth mindset [7]. Psychology research shows that praise can have varying effects on motivation [6]. Praising a student's inherent ability promotes the fixed mindset, or the belief that intelligence is unchangeable, while praising a student's strategies and effort promotes the growth mindset, or the belief that intelligence is malleable [6]. These mindsets can have a strong impact on students' motivation, reaction to failure, and academic achievement [2].

This research inspired us to explore whether rewarding behaviors associated with the growth mindset would increase student motivation and performance in an educational game. We created a "brain points" incentive structure for the game *Refraction* that rewards students for their effort, use of strategy, and incremental progress. Screenshots of the intervention are shown in Figure 1. In an online study of 15,000 students, we found that brain points produced higher student persistence and use of strategy compared to a standard incentive structure [7].

Encouraged by these results, we are continuing to study the impact of rewarding growth mindset behaviors in games. Our current work studies the effectiveness of the brain points version of *Refraction* in a new environment: the online schooling website K12.com. Our collaboration with K12 provides us with access to students who play for much longer than students on the casual website BrainPOP.com, where we conducted our initial study. Furthermore, K12 provides demographic data for their students. Growth mindset interventions have been shown to have a particularly strong effect on traditionally underperforming groups [1, 2], so we were interested in measuring whether our intervention has a similar effect.

Study Design

We conducted our study on the online schooling website K12.com. K12 is a for-profit company that provides curriculum content for online public schools as well as for home-schooled students. K12 was interested incorporating educational games into their curriculum, so we partnered with them to release the games developed by our research group, the Center for Game Science, through their website. Links to the game *Refraction*, designed to teach fraction concepts, were provided under an "additional activities" heading in 64 different locations within the K12 curriculum for third, fourth, and fifth grade math.

Our K12 study has an identical design to the BrainPOP study described in [7]. It has a single between-subjects factor *intervention* with two levels: experiment or control. The experimental version of the game included an introductory animation that describes the growth mindset, and used the brain points incentive structure that rewards effort, use of strategy, and incremental progress. The control version included an introductory animation that presents a neutral message, and used a "level points" incentive structure that awards points for each completed level. We chose this incentive structure for the control because progress is commonly rewarded in games.

Cond.	Time (minutes)	Strategy (per minute)
Brain	14.7	2.9
Control	10.8	2.7

Table 1: The median time played and strategies used for students in the experimental (brain points) condition and the control (level points) condition.

Gender	Time (minutes)	Strategy (per minute)
M	19.3	3.0
F	12.5	2.8

Table 2: The median time played and strategies used for students of different genders.

Grade	Time (minutes)	Strategy (per minute)
3rd	24.3	2.7
4th	19.1	2.8
5th	16.1	3.0
6th	9.5	3.1

Table 3: The median time played and strategies used for students of different grades.

Free Lunch	Time (minutes)	Strategy (per minute)
Yes	12.8	2.7
No	19.1	3.0

Table 4: The median time played and strategies used for students of who were and were not eligible for free/reduced lunch.

Preliminary Results

We collected data from 7,940 students in between October 2013 and August 2014 (3,924 students in the experimental condition and 4,016 in the control). We report an analysis of two outcome measures. The first captures student persistence by measuring the amount of time played. The second captures use of strategies that are associated with the growth mindset by combining the four metrics used to award brain points, described in detail in [7]. We use non-parametric statistics in this analysis because our data is non-normally distributed.

First, we analyzed our data to determine the impact of the *intervention* factor. We found that students in the experimental condition were significantly more persistent (Z=6.81, p<0.0001) and exhibited significantly more growth mindset behaviors (Z=4.93, p<0.0001) than students in the control condition. Median values are given in Table 1. These results confirm the findings from our original study, showing that the brain points intervention promotes students' persistence and use of strategy.

Next, we analyzed the impact of student demographics. For this analysis, we only included students who reported demographic information to K12, a total of 2,024 players in the experimental condition and 2,064 in the control. We studied three demographic factors: *gender*, *grade*, and *free/reduced lunch status*. We were particularly interested in measuring interactions between the *intervention* factor and each demographic factor, so we performed a factorial analysis. Since our data was non-normally distributed, we applied the Aligned Rank Transform [4] procedure, which aligns and ranks non-parametric data so that a standard ANOVA model can be used to perform a factorial analysis. We used the ARTool program developed by Wobbrock et al. to align and rank our data [8].

The *gender* factor has two levels: male and female. We found that male students played for significantly longer than female students (F(1,4084)=42.74, p<0.0001), and that male students used significantly more growth mindset strategies than female students (F(1,4084)=56.41, p<0.0001). The median values for each metric by gender are given in Table 2. However, the *intervention*gender* interaction did not have a significant effect on either metric, showing that the brain points intervention was equally effective for students of both genders.

The *grade* factor has four levels: 3rd, 4th, 5th, and 6th grade. We found that younger students played for significantly longer (F(1,4084)=63.61, p<0.0001), but that older students used significantly more growth mindset strategies (F(1,4084)=37.9, p<0.0001). The median values are given in Table 3. While *intervention*grade* did not have a significant effect on either outcome measure, the results for the time played measure trend towards younger students being more positively impacted by the brain points intervention than older students (F(1,4084)=2.44, p=0.06). This suggests that the intervention may be more motivating for younger students.

The *free/reduced lunch status* factor has two levels: eligible for free and/or reduced lunch, and not eligible. Lower income students in the United States are eligible for free or reduced school lunch, and as a result lunch status is often used as a proxy measure for socioeconomic status. For this analysis, we grouped all students who were eligible for free and/or reduced lunch and compared them to those who were not eligible. We excluded students with an unknown lunch status. We found that eligible students play for significantly less time (F(1,3226)=43.70, p<0.0001) and use significantly fewer growth mindset strategies (F(1,3226)=59.47, p<0.0001) than students who are not eligible. The median values are given in Table 4. More importantly, while the *intervention*lunch status* interaction did not have an effect on strategy use, it did have a statistically significant effect on time played ($F(1,3226)=4.67$, $p=0.03$). The brain points intervention was more effective at engaging students of higher income and encouraging them to play for long periods of time.

Discussion

Our preliminary results replicate the findings from our first study [7], showing that our growth mindset intervention has a positive impact on student persistence and strategy use. However, we also found that it does not benefit all students equally. The intervention may be more engaging for younger students, and is less engaging for lower income students. While we hoped that brain points would have a stronger effect on female students, as has been measured for other growth mindset interventions [2], we found that it has the same effect on students of both genders.

These results may say more about *Refraction* than about the brain points incentive structure. The game itself may be less appealing to girls and lower income students, and the cartoony style of the game characters may be more engaging for younger students. However, it is also possible that the effects are caused in part by the design of the intervention. The growth mindset messages used in the game are all presented through text in the user interface, which might be less engaging for students who are weak readers. We are currently exploring whether presenting growth mindset messages using an audio voiceover improves the effectiveness of the intervention for lower income students. We are also working on integrating brain points into other educational games to determine whether these effects are primarily driven by the design of *Refraction* or the design of the brain points intervention.

Acknowledgements

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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