

“I’ll do it!”: Examining the Relationship Between Locus of Control and Math Game Retention for Preschoolers

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ABSTRACT

Acquiring simple arithmetic skills at the preschool level requires repetitive practices. One method for encouraging students to spend longer time practicing is by presenting the skills in an engaging game. As student retention on the game increases, the student will be more likely to acquire the practiced skill since she will have spent more time practicing. In this paper, we examine the relationship between internal locus of control and retention in game-based learning applications for young children using Todo Math, a mobile-based math learning application for children from Pre-K to 2nd grade. We examine 345,783 users’ log data to show that when children prefer “free” mode, which has high internal locus of control, their retention on Todo Math is higher than children who prefer “daily” mode, which has high external locus of control. We present three analyses that support our findings using survival analysis, post-hoc analysis, and t-test.

CCS CONCEPTS

• Applied computing~Interactive learning environments

KEYWORDS

Locus of control, Retention, Preschooler, Online math game

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1 INTRODUCTION

Acquiring simple arithmetic skills at the preschool level requires repetitive practices [5,7,10]. One method for encouraging students to spend longer time practicing such skills is by presenting the skills in an engaging format such as a game. As student retention on the game increases, the student will be more likely to acquire the practiced skill since she will have spent more time practicing. According to previous research, locus of control, which is an individual’s belief in his/her contribution to the success or failure of an event [8], is a key factor that can improve learners’ retention. The positive relationship between locus of control and retention has been studied in online learning environments at the undergraduate level [3,4,6], but not in game-based learning environments, nor at a younger age. In this paper, we examine the relationship between internal locus of control and retention in game-based learning applications for young children using Todo Math [9]. Todo Math is a mobile-based mathematics learning application for children mathematics learning, and has gained popularity for providing engaging math games for children from Pre-K to 2nd grade.

Existing literature on locus of control showed that an individual with high internal locus of control perceives that an event is related to his/her own behavior. On the other hand, an individual with external locus of control perceives that an event is not related to his/her own behavior but to external forces beyond his/her control such as luck, chance, fate or powerful others [8]. Studies examining locus of control indicate that students who have a high level of internal locus of control are more self-motivated and self-directed [1]. Therefore, the higher the learner’s internal locus of control, the lower the online

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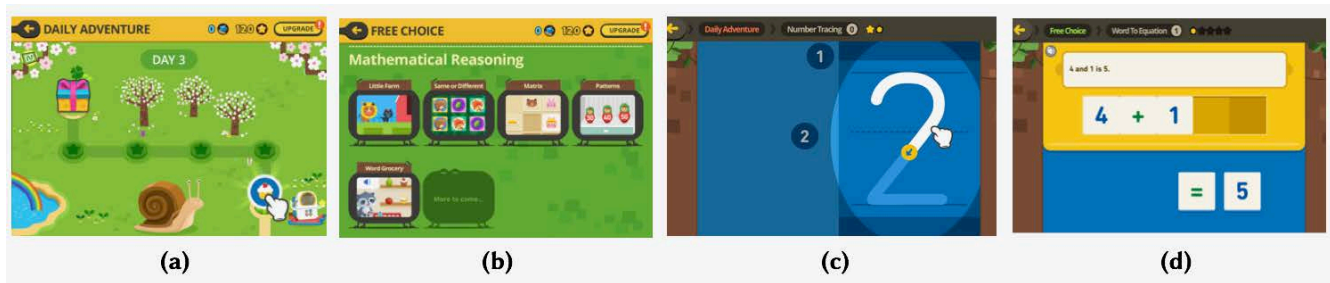


Figure 1. Todo Math: (a) daily adventure (Daily Mode), (b) free choice mode

learning dropout and higher learning achievement [3,4]. Similarly, we hypothesize that when young children use Todo Math to learn simple arithmetic skills, those with high of internal locus of control will have higher retention in the application. In Todo Math, the concept of locus of control can be translated into the two playing modes provided by the game. Namely, in the daily adventure mode, or “daily”, the external locus of control is high and internal locus of control is low since the system selects a game for the child to play. On the other hand, in the free choice mode, or “free”, the internal locus of control is high and external locus of control is low since this mode allows the learner to select a desired game based on learner’s preference.

In the rest of the paper, we present how we examined learners’ log data from Todo Math to see if there a positive correlation between retention and internal locus of control in children’s mathematics learning. Section 2 provides an overview of the data source and describes measurements associated with retention. In section 3, the results of analysis are discussed. Finally, section 4 gives overall conclusions and implication of this paper.

2 DATA SOURCE AND MEASUREMENTS

2.1 Data Source

The data used in the analysis is the learners’ log data for the Todo Math system. Todo Math is a mobile-based learning application that contains basic mathematical concepts for children from Pre-K to 2nd grade. They learn math by touching screen to play graphic-supported games as shown in Figure 1. For example, they can click on a moving figure to count numbers from 1 to 10 and follow a finger-shaped icon to write numbers from 1 to 20 (Fig 1c). They can also sort blocks with numbers and mathematical symbols to complete simple numeric sentences (Fig 1d), or add and subtract numbers between 0 and 20 by dragging game characters on the screen. There is a suite of multi-level games with over 500 stages in Todo Math.

The two main playing modes of Todo Math are daily adventure mode, or “daily”, and free choice mode, or “free” (Fig 1). More specifically, in “daily”, the system controls the type of learning contents and presents one game at a time for a learner. The learner solves mathematical problems in the form of game like an everyday workbook. After finishing one game set for a

workbook day, the learner can move to the next workbook day on the map if she wants to play additional games. On the other hand, in “free”, the system allows the learner to freely select the game they want to play. The free mode provides approximately 40 mathematical games with more than 500 levels combined according to learners’ proficiency. Note that, in either mode, user can consecutively play as many games as he chooses to play. The only difference is whether the system (“daily”) or the user (“free”) selects/ controls the type of a game to play.

For this analysis, we used samples of Todo Math’s log data that was collected during the period from July 8, 2016 to August 31, 2017. The data analyzed includes activity logs for 366,041 users. We defined “part”, as the unit of analysis as shown in Figure 2. If a user did not use Todo Math for longer than 4 weeks, we regarded the data after 4 weeks to be a different “part” since the return to the game could be due to external motivation such as advertisement about the game, or start of a school year. A total of 596,812 parts were obtained from our data. Of these parts, we excluded parts that are longer than two standard deviations away from the average of part length since such long usages are outliers, which fall under the long-tail of distribution of part length. After the exclusion, a total of 563,610 parts of 345,783 users remained. We also defined “session”, to be continuous user activity events less than 10 minutes apart. If a user did not use Todo Math for longer than 10 minutes, and came back to use after that, a new session start was marked. Figure 2 shows that the third session which occurred within Part 2 contains 7 problems which was started by a student user. Once a problem is started by a user, he can either correctly solve the problem, or quit and exit Todo Math since the application does not allow a user to proceed to a next problem until he correctly solves the current problem.

In the following subsections, we explain three groups of measurements used for our analysis; mode, retention/ retention groups, and variables that can be related to locus of control during game play.

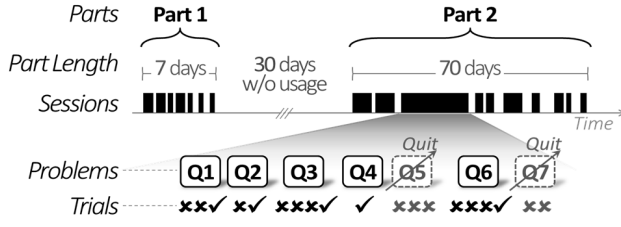


Figure 2: Unit of analysis

2.2 Measurement

2.2.1 Mode. A typical user plays in both free and daily modes. However, in our data, majority of users do not play both types of modes equally, but rather have a dominant mode of play in either free or daily. To determine each part’s dominant mode of play, we used the following formula and labeled each part as “free”, or “daily”. We excluded parts in which users have played both types of modes in equal amounts, which were approximately 2% of parts. Of the labeled parts, 38% of parts were labeled as “daily”, and 62% of parts were labeled as “free”.

$$M_i = \operatorname{argmax}(N_i^F, N_i^D) \quad (1)$$

$$\begin{cases} M_i: \text{dominant mode of play in part } i \\ N_i^F: \text{number of free mode execution in part } i \\ N_i^D: \text{number of daily mode execution in part } i \end{cases}$$

The choice of mode reflects the type of learners’ locus of control. Specifically, in free choice mode, a learner can determine the contents and type of game which impacts learning. Therefore, the learner’s internal locus of control increases in free choice mode. On the other hand, in daily mode, the system decides the learning content and game type, which indicates high external locus of control.

2.2.2 Retention and retention group. A learner’s retention, or the amount that a learner continues using Todo Math, can be measured in terms of time or games played. These two types of retention are defined as follows 1) Retention_partLength: the amount of days spent on playing the game for learner, 2) Retention_problemSolved: the number of problems solved without quitting in the middle. Specifically, we use figure 2 to illustrate how the two types of retention are calculated. Using the definition of retention_partLength, since a learners’ retention is the number of days from when the learner first played a game in Todo Math to when the learner last played a game within a part, the retention of part 1 is 7 days, and the retention of part 2 is 70 days. Using the definition of retention_problemSolved, since a learner’s retention is number of problems that a learner solved within a part, the retention of part 2 is 5 games which were solved without quitting, if there were no other problems solved in other sessions within part 2. Note that within Todo Math, a learner cannot “undo” the action of solving a problem, the number of problems solved in a part is

a monotonically increasing function, which can act as a function for learner’s retention.

In addition to learner’s retention, we wanted to examine if there’s a difference of percentage of main execution mode between users with short retention and long retention length. Since our data showed that the proportion of users who quit after playing only one game is approximately 25%, we used quartiles of Retention_partLength to group users into four retention groups. Thus, each user is assigned into one of the following groups: Min-Q1, Q1-Q2, Q2-Q3, and Q3-Max group.

2.2.3 Variables relating to locus of control during game play. A learner’s dominant mode of play approximates locus of control in terms of “starting” a game. To measure how locus of control is demonstrated during game play, we measured number of problems that a user actively starts or quits within a session; 1) problemStartPerSession: ratio of the number of problems started to the number of sessions in a part 2) problemQuitPerSession: ratio of the number of problems abandoned to the number of sessions in a part. For instance, Part 2 in figure 2 has 10 sessions, 7 started problems, and 2 quitted problems. Hence, problemStartPerSession is 0.7 (7 started, 10 sessions) and problemQuitPerSession is 0.2 (2 quitted, 10 sessions).

3 RESULTS AND DISCUSSION

3.1 Comparison of retention in daily and free modes using survival analysis

To examine the difference between daily and free modes on retention, we used Survival Analysis [2]. In Survival Analysis, we can determine the survival function by estimating a period of retention. We estimated two types of retention in terms of time and games played using Kaplan-Meier estimators. After determining the survival functions, chi-square test of survival functions was conducted. As a result, we found the retention of free choice mode learner to be higher than that of daily mode learners for both retention_partLength and retention_solved ($p < 0.01$ each). The results imply that internal locus of control has a positive correlation with learner’s retention. However, since survival analysis yields estimated retention length, we conducted another type of retention analysis using existing data with post-hoc method in the next section.

Table 1: Comparison of the survival function average of the free and daily mode learners, * $p < 0.001$

Estimated retention	Mode	Estimated Mean	Chi-square
partLength* (days)	Free	36.266	9305.871
	Daily	26.028	
problemSolved* (problems)	Free	613.212	5251.211
	Daily	431.153	

3.2 Distribution of users for four retention groups using post-hoc analysis

To examine if there's a difference of main execution modes between the four retention groups according to their retention length, we used post-hoc analysis after using chi-squared test.

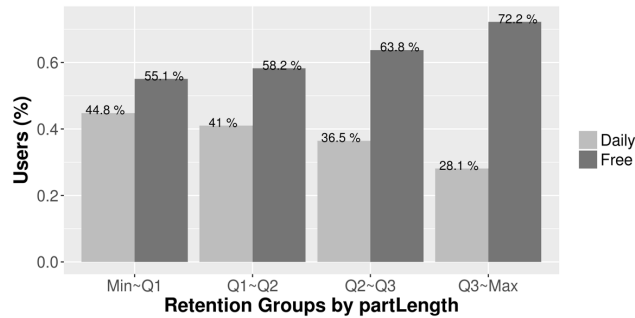


Figure 3: Proportion of main execution modes for each retention groups

The statistical analysis shows that the percentage of main execution modes differ, from 55.1% of free users in the lowest quantile retention group to 72.2% of free users in the highest quantile retention group.

In fact, as shown in Figure 3, the proportion of free users steadily increase from lowest to highest quartile. A test of homogeneity using chi-squared test showed that the four groups are not homogeneous ($\chi^2_3 = 9786.6, p < 0.001$). A post-hoc analysis between adjacent groups showed that a group with longer retention length has statistically more users in the free group, compared to users in the shorter retention length group; Min~Q1 < Q1~Q2 ($\chi^2_1 = 403.26, p < 0.001$), Q1~Q2 < Q2~Q3 ($\chi^2_1 = 652.28, p < 0.001$), Q2~Q3 < Q3~Max ($\chi^2_1 = 2646.3, p < 0.001$).

The difference in distribution in each of the four retention groups are in line with survival analysis results, indicating that learners in the higher retention group tend to prefer their main execution mode to be free, which has high internal locus of control, rather than daily, which has high external locus of control. Although the survival and post-hoc analysis provide support for a positive relationship between retention length and the level of learner's internal locus of control, we were curious about whether the game playing patterns differ between free and daily group. Thus, in the next section, we present analysis of game playing patterns that are indicative of learners' level of internal locus of control.

3.3 Examining game playing patterns in daily and free modes using t-test

To examine the game playing patterns in daily and free groups, we conducted t-tests to inspect the difference between features measuring problem start and quit. As the numbers in Table 2 show, students in the daily group started more problems. However, the frequency for quitting the game is higher in the

free group. These pieces of evidence suggest that during game play, level of internal locus of choice in the free groups is higher compared to daily group.

Table 2: Comparison of game play variables, * $p < 0.001$

Variables	Mode	Mean	t
problemStart	Free	40.36	-36.36
PerSession*	Daily	43.99	
problemQuit	Free	2.11	260.64
PerSession*	Daily	0.79	

4 CONCLUSIONS

In this paper, we examined the relationship between internal locus of control and retention in game-based learning application for young children using Todo Math, a mobile-based mathematics learning application for children from Pre-K to 2nd grade. We examine 345,783 users' log data to show that when children prefer "free" mode, which has high internal locus of control, their retention on Todo Math is higher than children who prefer "daily" mode, which has high external locus of control. Specifically, the survival analysis result showed that the retention period of survival function is longer for children who prefer free mode as their dominant mode of play, compared to those who prefer daily mode. The positive correlation is also supported by post-hoc analysis which divided users into four retention groups according to their retention length. Although in the lowest quartile retention group, the percentage of users who are in free group is 55.1%, this percentage steadily increases to be 72.2% in the highest quartile retention group. Furthermore, examining the variables calculated from users' game play log unveiled that frequency for quitting the game are higher for children in free compared to daily group. This suggests that children in free group not only tend to select the game to begin, but they also actively leave the game at their own will, which is another indication of high internal locus of control.

Our study has limitations in that we did not consider how a user's behavior changes over time. Additional analysis which considers change of mode or game play patterns over time may yield more interesting stories on retention. Secondly, we could not infer causal relationship from our data since we analyzed existing log data rather than conducting an experimental study.

Despite such limitations, the current study is meaningful in that the positive relationship between external locus of control and retention was found in young children's data as found in existing research with older students. For our future work, we plan to conduct an experimental study to examine causal relationship between locus of control and retention on young children.

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