MemoMarote: a working memory training game

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Abstract. Mate Marote is a flexible framework for large-scale educational interventions that include games developed, based on aspects from cognitive sciences as an effective way of learning. MemoMarote is a computer game designed for training working memory. The pilot study of this platform was an intervention in La Rioja province (Argentina). In this article we analyze the registered statistics of use of the unsupervised version of the game. We found that playing activity had a peak when recently installed, decreasing during the first year and observing an increase when starting school classes in 2013. Analyzing the usage statistics we observed that players have a poor performance, with more incorrect answers than correct ones. These results suggest that children did not read instructions or they were not understood, and so they played the game incorrectly. We plan the creation of an interactive tutorial to increase the understanding of the game.

Introduction

In the last 20 years, the world has suffered profound changes in digital inclusion into the society. Two decades ago news were read in printed newspaper, we had to go the library to read specialized books and mail was sent by writing in a piece of paper and going to the post office. Ten years ago, many things changed with the popularization of the Internet, such as email or newspapers and books in our PCs. Nowadays, a digital revolution is occuring: the massiffication of mobile devices and massive connectivity.

However, these breakthroughs have not penetrated deeply into educaction and research in educacional issues. One of the most remarkable innovations in education is the one-to-one model which consists in giving one computer per child. The first huge implementation of the one-to-one idea was One Laptop Per Child (OLPC)[5] which started in 2006. This program developed a netbook that costs around 100U$D specially designed for children, based on open-source initiatives which include Sugar[6]: a learning desktop specially built for children.

Sugar redefines how computers are used by proposing an environment for collaboration, reflection, and discovery directly integrated into the user interface. One of the main directives in Sugar is *you learn through doing, so if you want more learning you want more doing*[7].

OLPC has many implementations around the world. One of the most important is the Plan Ceibal, deployed in Uruguay. The Plan Ceibal[8] has more than half a millon netbooks given to all students of public primary and secondary school. The main 1-to-1 programs in Argentina are Joaquín V. González (running on all primary schools in La Rioja) and ConectarIgualdad[9] (running on all secondary schools of the country).

One of the most remarkable things of these implementations is that all students have the same digital platform. This fact represents a huge opportunity: a nation-wide educational study for research in education practices and cognitive psychology. This massive availablility of human force have been capitalized on human computation to solve open problems, such as Games With A Purpose [1–3]. We propose using this digital platform to study stereotyped patterns of human thought, together with real-time observation of the learning and teaching process.

Mate Marote is a project to train cognitive skills in children by using computer games [4]. Goldin and colleagues showed that children improve their performance in some subjects at school by playing to Mate Marote games. The games included in Mate Marote are: Avioncito (which mainly trains inhibitory control),

[5] http://laptop.org/
[6] http://sugarlabs.org/
[7] http://wiki.sugarlabs.org/go/What_is_Sugar%3F
[8] http://www.ceibal.edu.uy/
[9] http://www.conectarigualdad.gob.ar/

Casitas (oriented to planning tasks) and MemoMarote (focused on working memory).

In the original Mate Marote project the educational intervention was supervised by researchers that assisted to the participant schools as tutors of students. In 2012, Mate Marote was redesigned as an unsupervised on-line/off-line platform. This intervention consisted in installing the off-line Mate Marote application in the students personal netbooks in the La Rioja program[5]. Students were allowed to play spontaneously with supervision. The developed platform registers children behaviour while playing games and synchronizes it with Mate Marote server for further analysis.

In this work we present the analysis of usage data from MemoMarote, the game which mainly trains working memory. Working memory refers to the capacity to store and manipulate information for very brief periods of time [6]. This capacity is limited to a few items both in adults and children [7]. This ability is trained when playing MemoMarote, a game based on a non-spatial, pattern recognition working memory task, a paradigm that measures recognition memory for visual patterns, but not spatial locations [8, 9].

Materials and methods

Mate Marote is a flexible framework for large-scale educational interventions. The first case study, a province-wide intervention in La Rioja province (Argentina) consisted of three games that train basic cognitive abilities: inhibitory control, planning and working memory. MemoMarote is the game of project which mainly trains working memory. The game consists of solving a board where there are some cards and the player should do some actions to win.

The board is a grid of 4x6 cells where in each round some of the cells have a box which may contain a card. Each card consists of features, e.g. shape, color, number of stars, character. To win a round the player must click with the mouse each card once. Each time the player clicks a card, all of them dissappear and re-appear in a random box. The player must think a strategy to avoid clicking on a previous card.

Fig. 1 shows a screenshot of a round of MemoMarote that has 8 boxes (3 in the first row, 3 in in third, an 2 in the fourth), and 3 cards (the first one has a shape similar to a finger, the background is pink and has a character wearing a diving suit; the has a shape of a drop with green background and has a character; and the third one has a circled, the background is a beach landscape and has the same character as the second one).

In Table 1 all features available are listed with their possible values. Each card of a round is unique, with its assigned features values. Some feature-values may be shared, but there will be always a singular feature-value that makes the card unique.

At the beggining the player starts with round that have 6 boxes and only 3 cards, this is the easiest level. Each round has two possible results: win or lose. After winning 5 continuos rounds, the player changes to next level which includes more boxes and cards. Each time a player wins 5 continuous rounds he arrives to a *checkpoint*; however, if a player loses 3 times before getting to a checkpoint the game ends.

This game registers all the information about each round for later analysis. The format of this records can be seen in Listing 1.1.

The meaning of each line is detailed in the next list:

1. Add a box in position (523, 620)

⋮

3. Add a box in position (783, 230)
4. Add a card to a position with some features
5. Add a card to a position with some features
6. Add a card to a position with some features
7. Clicked card
8. Result of the click

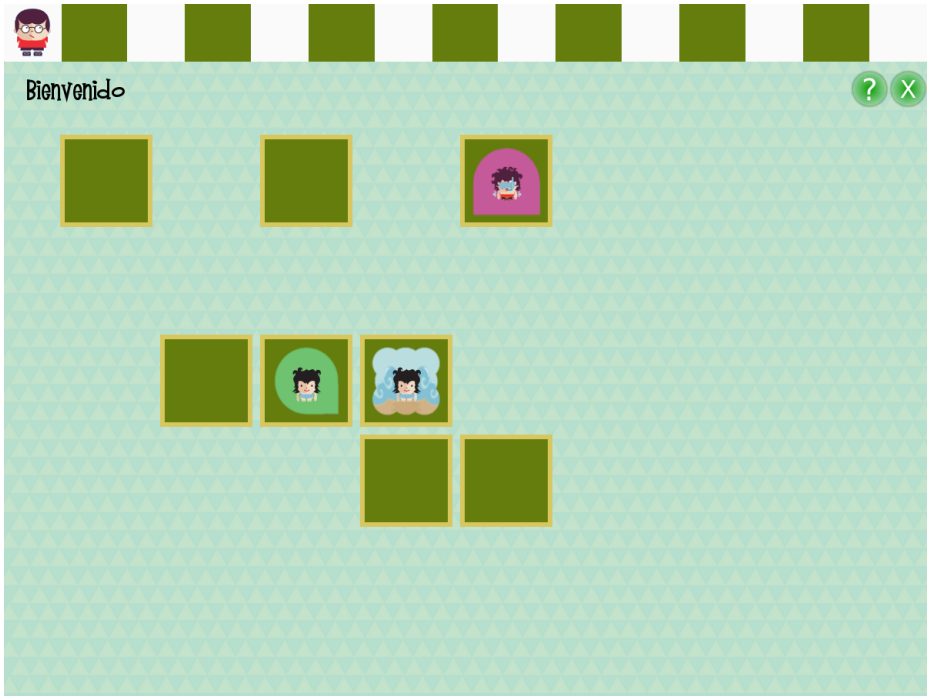

Fig. 1. Screenshot of MemoMarote

Feature	Value
Position	(X, Y) with, X∈[133, 263, 393, 523, 653, 783] Y∈[230, 360, 490, 620]
Shape	
Background	
Umbrella	
Stars	
Pail	
Character	

Table 1. Features used to build cards of MemoMarote

```
1  [2012-05-29 01.56.44] Add BOX (523, 620)
2  ...
3  [2012-05-29 01.56.44] Add BOX (783, 230)
4  [2012-05-29 01.56.44] Add CARD {pos: (523, 620), shape: 7, back: 4, props: [(1, Star, 2),]}
5  [2012-05-29 01.56.44] Add CARD {pos: (263, 620), shape: 2, back: 7, props: [(1, Star, 2),]}
6  [2012-05-29 01.56.44] Add CARD {pos: (523, 360), shape: 11, back: 2, props: [(1, Star, 8),]}
7  [2012-05-29 01.56.48] Card {pos: (263, 620), shape: 2, back: 7, props: [(1, Star, 2),]}
8  [2012-05-29 01.56.48] Card clicked OK
9  [2012-05-29 01.56.48] Move CARD from (523, 620) to (653, 360)
10 ...
11 [2012-05-29 01.56.48] Move CARD from (523, 360) to (653, 620)
12 ...
13 [2012-05-29 01.57.08] Card clicked OK
14 [2012-05-29 01.57.08] Game  WON
15 [2012-05-29 01.57.09] Status Correct: 1 - Wrong: 2 - Continuos correct: 1 - Checkpoint: 1
16 ...
17 [2012-05-29 01.57.22] Card {pos: (523, 360), shape: 6, back: 9, props: [(1, Star, 4),]}
18 [2012-05-29 01.57.22] Card  clicked WRONG
19 [2012-05-29 01.57.23] Status Correct: 1 - Wrong: 3 - Continuos correct: 0 - Checkpoint: 1
```

Listing 1.1. Summary of the record of a player behaviour playing MemoMarote

9. New position of the card

   ⋮

11. New position of the card

   ⋮

13. Result of the click
14. End of round, all card were clicked once successfully
15. New round

   ⋮

17. Clicked card
18. End of round. The card was clicked before
19. Status of the game

Results

In this work we analyze the registered data obtained from the usage statistics in La Rioja pilot study. The pilot study started on May 2012, and we use data received until March 2013.

In Fig. 2, we show how many rounds were received per month (blue line). As expected, we observe a peak on May 2012, when pilot study was launched. On the next running months activity decreases reaching the end of year (Jan/Feb 2013) with almost no activity. In march 2013, we observe again an increase of logging information.

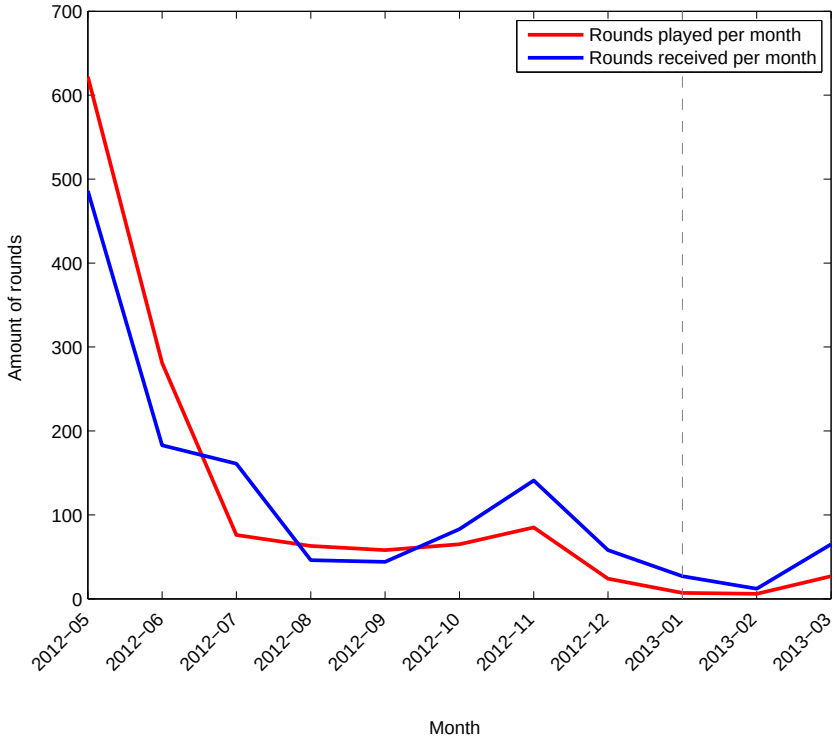

Fig. 2. The red line represents the amount of rounds played per month, and the blue one represents the amount of rounds received in the server per month

Mate Marote synchronizes usage statistics when computers have connection, thus the received results consisted of a package containing many logs that may include many days of records. Then, we discriminate logs by their date of play (instead of date of reception). In Fig. 2, the red plot shows the amount of round

played by month, shifted from the blue plot. This shift is consistent as received rounds (blue line) depend on connection and may take days or even weeks to synchronize.

Now, we set to study when children play MemoMarote and the performance obtained. In Fig. 3 we show the amount of played rounds per hour. Blue bars show wrong rounds and green bars show correct rounds. As observed, the rate of correct versus incorrect answers (overlaid solid red line) shows a very poor performance of this game. Almost every hour shows a performance rate below 1 (see reference dotted red line), indicating that there were more incorrect answers than correct ones.

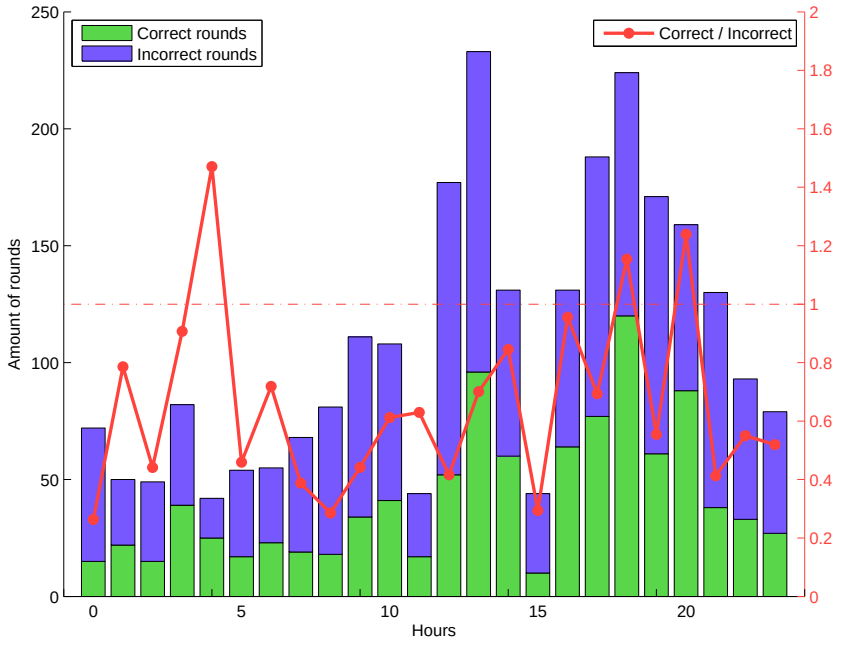

Fig. 3. The green bars shows the amount of winned rounds and the blue ones the lost rounds along the day. The red line indicate the rate of correct rounds versus the incorrect ones. The dotted red line is indicating that there is the same amount of correct rounds than incorrect.

Finally, we present the results of kids playing. In Fig. 4 we present the performance of children at the different levels. The game increases cards as players advance in levels (see methods for details). At each level, a correct play consists of the same clicks as the number of cards, i.e. at level 1 with 3 cards a correct round consists of 3 clicks, one on each card. Thus, we plot the success rate for each click at the different levels (solid lines, red: 3 cards, blue: 4 cards, green: 5 cards and yellow: 6 cards). Trivially, the first click is always correct as choosing any card is a correct answer, and thus successful rate is always 1. Then, for

example in the 3-cards rounds, the second click goes down to 0.7 indicating that almost one third of players choose wrong the second cards. Finally, the third click goes down 0.6.

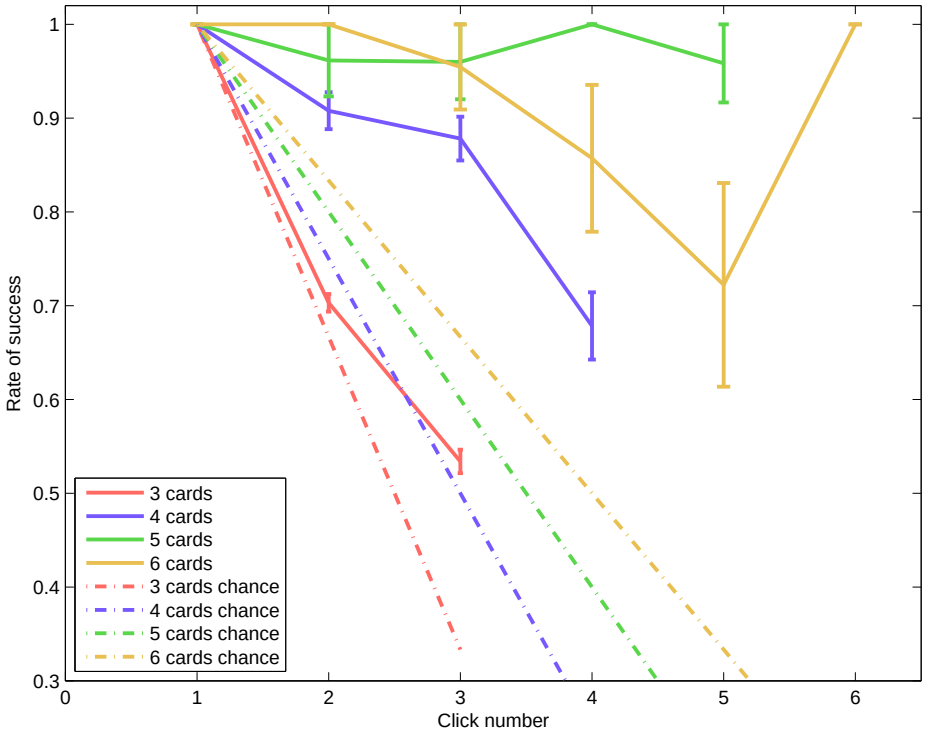

Fig. 4. The X axis represents the number of click in a round, and the Y axis the rate of success. In solid lines the behaviour of children playing MemoMarote is shown for the differet leves played: in red: 3 cards level; blue: 4 cards level; green: 5 cards level, yellow: 6 cards level. In dotted lines the rate of success of an automated agent that plays randomly is shown with the same colors as before (red: 3 cards; blue: 4 cards; green: 5 cards, yellow: 6 cards).

We decided to compare players behaviour to a simulated agent that plays randomly, i.e. at each round it chooses the cards randomly. For instance in the 3-cards level, the first choice is always correct, then the probability of choosing a correct card is 2/3 and in the last turn, the probability is 1/3. We plot this random agent (see dotted lines in Fig. 4) for each level, red: 3 cards, blue: 4 cards, green: 5 cards and yellow: 6 cards. Comparing players with random agents, we observe that in all levels children play better than random agents.

Discussion and Conclusion

One-to-one models open a door to a new world of research and education interventions. Mate Marote proposes a unified digital platform to study stereotyped patterns of human thought by playing games in educational contexts. In this work we present the results of a game which mainly trains working memory (MemoMarote) included in the pilot intervention at La Rioja province.

We analyzed the recevied logs during the year 2012 (and beginning of 2013). We observed a difference between the date when children play and the date when the results of playing are received. In La Rioja there is not complete coverage of Internet access, and so connectivity is not available everywhere. This fact causes computers to send information when Internet connection is detected and this might not be in real-time. We confirmed this situation by the shift between received logs and date of playing included in these records.

In previous work, we demonstrated that new computers are registered every day [5]. This fact suggests that many other computers could have been used but – due to the untrustful connection – their registered data was never sent to the server, until connection is available.

Based on the registered data, we analyzed how children play MemoMarote. We found that players show a poor performance in most hours of the day reported by a extremely low successful rate, with more incorrect answers than correct ones. Performance with greater correct answers than incorrect ones were only obtained in three cases: 4, 18 and 20 hour.

These results suggest that children do not play the game correctly. We compared the success rate with an automated agent playing randomly. We observed that children playing 3-cards level had the worst performance, indicated by closeness to random agent results. We theorize that many of the children do not understand the rules of this game, so they never pass the first level showed by the worst results in it. This pilot study was done in children between 6 and 8 years old which do not know how to read fluidly and they are anxious to start playing without following the instructions. In the cases where the children learned the rules and passed to the next levels, we found that performance is much better than random agents.

Finally, we conclude that instructions were not clearly displayed. We plan to create a mandatory interactive tutorial that would increase the number of players that learn and apply the game rules correctly.

Acknowledgements

This research was supported by UBA, CONICET, ANPCyT, CEMIC, IBM Scalable Data Analytics Innovation Awards and Human Frontiers Program. Mariano Sigman is sponsored by the James McDonnell Foundation.

Authors thank Walter Flores (Minister of Education, La Rioja, Argentina) and Rita Taquías (J. V. González Program director) for their collaboration during the pilot deployment, Varinia Telleria for the design of characters and drawings used in the games, Martín Elias Costa who has greatly contributed to the development of this work and Cecilia Calero and Antonio Battro for fruitful discussions and useful comments on the manuscript.

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