# Improving motivation to play a brain training game with storyline

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***Abstract*—Intrinsic motivation can be improved with a storyline aimed at helping a main game character. In this study, a brain training game was created to teach the imagery mnemonic. The game provided a fun experience and the experimental group showed significantly higher intrinsic motivation to play the game. Participants performed a neurological test pre and post training, and the group helping the game's main character showed a significantly larger improvement on the 15 Word test.**

***Keywords*—Motivation, brain training game, mnemonics, students**

## I. Introduction

This study researches whether helping a game character can improve the intrinsic motivation to play a brain training game.

The loss of memory capabilities is a clear problem for people getting older [21] [11], but even younger people know examples of when they would have liked a better memory. Remembering the place of your keys, knowing your presentation by heart, or recalling the name of someone you just met are challenges everybody has experienced. To help with a decline in memory abilities when we get older, the learning of memory techniques (*mnemonics*) can help.

A mnemonic is a learning technique that enhances information retention. A basic technique for these mnemonics is visual imagery. The technique consists of mental images being formed, which are easier to remember than just words. It is advised to make the mental image as lively as possible and to use all senses to make the image memorable. It can be used to link words together, by creating a mental image connecting the words (figure 1). These techniques are usually taught in a classroom, but this can be boring and inconvenient. This may lead to amotivated students of the technique.

A game can provide a comfortable and exciting way to learn a new skill. A game for learning mnemonics was created and tested in this study. By adapting the storyline in the game, the influence of the story on intrinsic motivation was examined.

## II. Related work

### A. Cognitive decline

Although individual differences exist, our cognitive abilities decline from the age of 30 years old [38] [31]. This cognitive decline on many facets (memory, attention, executive functions etc.) makes every day life increasingly difficult [24]. At every age, human beings are able to counter the cognitive decline. This principle is called brain plasticity [4].

Usually the research with brain training (games) focuses on elderly people, or people with a brain deficit [19] [28] [3]. But since a human brain starts deteriorating around the age of 30, the damage to the brain has already been done by then. To really make an impact on someone's memory during their lifetime, it makes sense to start as early as can be to try to reduce the cognitive decline. This calls for research on younger subjects, as is done in this study.

Several methods to improve memory (or reduce the decline in capabilities) exist [18] [5] [1]. One of those ways is using brain training games. These games can provide impressive results on improving the cognitive decline [2] [7]. However, the research supporting the claims should be adopted with caution. These broad claims are sometimes supported by the brain training games themselves, and transfer of abilities learned in the games is usually lacking. Besides, these games might train memory by rote recall, but not *how* to use your memory. There are ways to improve your memory technique and train this.

### B. Mnemonics

Training people to use a different strategy (mnemonic) to memorize information can reduce the decline of memory capabilities. The meta-analytic study by Verhaegen et al [35] concluded that training gains were significantly larger in mnemonic training groups, over control and placebo groups.

Fig. 1: An example of the imagery technique. When a connection between the words *zebra* and *motor* needs to be remembered, the technique instructs to create a striking image between the two, like a zebra driving a motorcycle away from a chasing lion.

Training is needed to come up with connections between word couples (figure 1) quickly and effectively and to get used

to using the mnemonic for remembering information. These techniques are also used by memory champions [1], to achieve remarkable memory feats. Work Maguire et al [23] shows that people who have trained their mnemonic technique perform significantly better on several memory tests.

Several mnemonics use the imagery technique, which is based on the simple fact that human brains are better at remembering pictures than words. The Dual Coding Theory by Paivio [25] explains that the information, when using this technique, is stored twice in the brain (as a word and as an image), which makes the chance of recalling the information larger.

These mnemonics are usually taught to participants by an expert in a classroom setting. That means a classroom needs to be reserved, trainers need to be qualified and everyone needs to attend at a certain time. The techniques provide a way to improve memory, but keeping up the training after the experiment is tough, since this consumes a lot of effort, time and money. These techniques can be taught by software [14], but using normal software can be boring when it only gives instructions.

### C. Games

Games are a form of structured play with challenges, rules and interaction, where one can learn while playing. Games also have several features to help motivate and engage its users, like visual and audio features and rewards. With digital games, it is possible for a player to play a game at their preferred location and in their own time. If a game for memory training can be used, it can make training more comfortable, fun and exciting. Paras [26] made a comprehensive but clarifying overview of why games can improve learning procedures. He described the potential for well-designed games as follows: "The juncture of learning outcomes with well-designed game mechanics can result in learning experiences which are intrinsically motivating" . He also mentions the need for appropriate challenge, setting concrete goals, structuring control, and providing clear feedback, based on the flow theory of Csikszentmihalyip [13].

To the best of our knowledge, an experiment using a *game* to enhance the learning of mnemonic memory techniques has not been performed. Combining the worlds of gaming and classical memory training could lead to an exciting prospect of people playing fun games to get a better memory.

To be able to configure variables like the storyline, it was chosen not to use a standard brain training game, but to develop one. A more detailed description of the game can be found in appendix A.

### D. Motivation

As mentioned above, a game is a great way to keep people interested and enthusiastic. To have someone perform an activity, the most effective way is to have the person intrinsically motivated, since it leads to engagement and focus. As Chan and Ahern said in [10], "When people are intrinsically motivated to learn, they not only learn more, they also have a more positive experience". In self determination theory [29], the three basic psychological needs of a human being for intrinsic motivation are determined. These are competence, autonomy and relatedness. In a game, these features are represented as well. The competence (the feeling of mastering something) needs to be provided with challenge and feedback [9]. The player should be able to make crucial choices and develop tactics and techniques, since this gives the player the feeling of autonomy (the feeling of having influence on one's life). Relatedness is defined as the universal want to belong to and care for others [6]. This last feature is rarely investigated in games.

As the well-respected James Paul Gee wrote in 2003, in a book that provides important arguments for why games can behave as a learning tool: *"The more a player can manipulate a game character and make decisions that impact on the game character, the more the player invests in the character and the game at a deep level. This investment appears to be the deepest foundation of a player's motivation in sticking with and eventually mastering a game"* [17].

This relatedness can be an intrinsic motivator by helping others. This is why the current research tries to improve intrinsic motivation by helping a game character with a manipulation of the storyline.

### E. Research questions

In this work, we tested a game to teach the imagery mnemonic on students. To investigate the influence of changing the storyline on intrinsic motivation, we will evaluate the following research question:

> RQ1: Do students get motivated more intrinsically to play a brain training game when they play to help the game's main character?

To assess the workings of changing the storyline on the results of a neuropsychological test, the following research question is evaluated:

> RQ2: Does students' memory improve more when they play a brain training game to help a game's main character?

## III. Methods

### A. Design

Using a between-subjects experimental design, it was determined whether changing the storyline of a brain training game can improve (1) the level of intrinsic motivation and (2) the scores on a neuropsychological test.

*1) The game:* Two groups of participants were formed and the storyline of the brain training game varied between the groups. In one variant the player helped the game's main character to find his parents and in the other variant the character helped the player to earn his elephant diploma. The game consisted mostly of remembering word couples and completing a puzzle. If the puzzle was completed, the goal regarding the concerned storyline was achieved by the player.

[1]Participants in the annual World Memory Championships remember - among other challenges - a shuffled deck of cards, a long string of 0's and 1's and fictual historical dates. See http://www.worldmemorychampionships.com/

Instructions on how to use the imagery mnemonic were given by the game's main character. The mnemonic helped the player to remember the word couples.

*2) The tests:* Motivation was measured using the Situational Motivation Scale (SIMS) [20]. A battery of 6 neuropsychological tests was used before and after training to determine improvements in memory.

### B. Participants

23 participants were recruited at Utrecht University. One participant was not included as participant for having dyslexia, since this would lead to an unfair disadvantage in the game. Three participants were excluded for not having played the game, due to a reported lack of time. The 19 remaining participants were all Dutch (ex-)students (age $22.00 \pm 1.76$ years (mean $\pm$ s.d.), 4 females) with a high number of years of education ($17.89 \pm 1.45$ years). No compensation was given to the participants.

### C. Evaluation

Motivation was measured using the SIMS [20]. This questionnaire uses the question "Why are you currently engaged in this activity?" to determine levels of different motivations. The participants were asked to rate the correspondence of their own feelings on a scale of 1-7 regarding potential answers like:"Because it is fun". 4 different types of motivation can be measured using 16 different answers.

To measure memory improvement, a battery of six neuropsychological tests was used before ($NPT_1$) and after ($NPT_2$) training. This battery consisted of WAIS IV digit span (Digit span) [36], RBMT story recall (Stories) [37], Trailmaking test (TMT) [27], the 15 word test (15WT) [30], Stroop test [32] and a custom made digital traditional memory game (Memory). All tests were performed in the native language of the participants (Dutch). The 15WT and Digit span, Stories and Memory were specifically selected to measure working memory capacity, episodic memory and spatio-visual memory respectively.

Personalia and self-reported memory skills were obtained using a questionnaire ($Q_1$) before $NPT_1$, which included questions like "Are you satisfied with your memory at the moment when you compare it to your peers?".

Another questionnaire ($Q_2$) was used after $NPT_2$ to evaluate the game itself and the memory techniques used by the participants during the game, $NPT_1$ and $NPT_2$.

Using in-game data like playing time, an indication of motivation was obtained as well, since a player who plays a lot is expected to be motivated more than one who plays less on average.

### D. Procedure

*1) Group assignment:* When a participant agreed to take part in the experiment, a link to a schedule was given, where they could claim a time slot to make $Q_1$ and $NPT_1$. The participants were alternately distributed into two groups on the basis of when they made $NPT_1$. The participants had no knowledge of the existence of the two groups.

*2) Experiment setup:* The pre test (which consists of $Q_1$ and $NPT_1$) and post test (which consisted of $NPT_2$ and $Q_2$) took place at Utrecht University, in a publicly available small room. The entire experiment took place from August until October of 2015.

Participants were asked to play the game for at least half an hour a week, for a three week period. The participants could play the game whenever or wherever they liked. They qualified for the post test if they played the game at least once in the three week period.

The post test consisted of the second neuropsychological test and a questionnaire ($NPT_2$ and $Q_2$). After $Q_2$, the participant finished the experiment. The three parts of the experiment (pre test, training and post test) are explained in more detail in the following sections.

### E. Pre test

The pre test consisted of a questionnaire (see appendix B-A) and a neuropsychological test.

The neuropsychological test comprised the six aforementioned subtests. The two tests with delay (Stories and 15 WT) did not overlap and had a delay of 10-15 minutes, depending on the speed of the participant on other tests. The order of the tests was as follows: Stories, Digit span, TMT, Stories recall, 15 WT, Stroop, Memory, 15 WT recall. The instructions and tests were read aloud in Dutch by the examiner and data (like number of words correct or time taken) was collected using a custom made program.

After the neuropsychological test, the game was sent to the participant for them to download. The participant was asked by the examiner to play the game for about half an hour a week for a three week period.

### F. Training

The game was called Memory Palace. This is a reference to an elaborate memory technique, but in the game it is the name of the puzzle that needs to be solved. The main character in the game was Maxime, a little elephant who guided the players through the game. Maxime gave advice and tried to motivate the player. For $NH$, Maxime told the player that he can earn his elephant diploma if he finishes the puzzle. $H$ were told that Maxime had lost his parents and needed his Memory Palace fixed, so he could remember were they were (figure 2a). During the game, when Maxime came on screen to tell the player about the progress in the game, he would say a line like "Well done! Thank you for helping me. I can almost remember where my parents are!' to $H$ and "Well done! Keep up the good work. you're halfway to your elephant diploma!" to $NH$. These lines helped the player remember the storyline. Maxime gave instructions about the imagery technique in a short tutorial. Each time the game was played, the instructions to use the technique were repeated at least once.

The participant needed to find word couples in a covered field (figure 2b. The words were obtained using an online word list generator [15], which allowed to use words with an imagery and concreteness rating of 5-7 out of 7 and a

meaningfullness of 5-10. This way, the imagery technique would be easier to apply (it is easier to imagine a *strawberry* than the word *opinion*). The words were all translated to Dutch. Word couples were connected through a colored line. Clicking with the mouse uncovered a small part of the field, showing the words underneath. The number of found words was shown on screen when the mouse was unclicked (figure 2b).

When the participant wanted to continue, the Memory Palace was shown (see figure 2c). In the Memory Palace of the game, 40 different items (e.g. pyramid, barbeque, narwhal) were placed in 10 different rooms. These items needed to be moved to its correct slot. All objects came with a cryptical description, which gave hints to its correct location. Items needed to be swapped with eachother to move them to a different slot. The variable *correct* (the number of correct items) was displayed in the Memory Palace. After the puzzle, the participant arrived in the test step (figure 2d. Here, the remembrance of the word couples was tested by showing one of the words of several word couples and the participant needed to type in the matching word. As a result, depending on the score (number of points) in the test, the *gamelevel* was increased or decreased. A higher gamelevel leaded to a higher number of words in the next round and a lower gamelevel to a lower number of words. Swaps to complete the puzzle were earned when certain amounts of total points was reached.

The goal of the game from the perspective of the player was to solve an intricate puzzle. By earning points for remembering word couples, *swaps* could be earned. These swaps were needed to solve the puzzle. If the puzzle was solved, the game was finished. Testing ensured that the game would provide at least 1.5 hours of playing time before the game was finished.

### G. Post test

The post test started with $NPT_2$. Digit span, Stroop and TMT were exactly the same test, while Stories, 15 WT and Memory had different versions. After the neuropsychological test was completed, $Q_2$ started, with questions to evaluate the game (e.g. “Did you like the game?” and “Did you get the feeling Maxime was helping you?”). At the end of the questionnaire, the SIMS was performed. It was explained that the activity that needed to be compared in the SIMS was playing the game. The test was done in English, to maintain the validity of the test. The full questionnaire is given in appendix B-B.

## IV. Experiments

To answer RQ1 from the introduction, the averaged summed score of the SIMS test for both groups was analysed to find differences in motivation. The following null hypothesis was tested statistically:

$H_{0a}$ = There is no difference in intrinsic motivation between group $H$ and group $NH$.

It was expected that because of the need for relatedness, $H$ will be motivated more intrinsically.

Regarding the improvement in memory, we will evaluate the following null hypothesis:

$H_{0b}$ = There is no difference in improvement in pre and post scores between group $H$ and group $NH$.

The results of $NPT_1$ were expected to be the same for both groups for all tests, since the participants were randomly assigned to a group and the participants came from the same young students population. The results of $NPT_2$ were hypothesized to be better than $NPT_1$ overall, because of retest effects. However, the results of $H$ were expected to improve more, since they are expected to be more motivated to play the game, and therefore learn the imagery technique better. If they use the technique in the second test, they should improve more. The results of the tests will be analysed qualitatively, for differences between $H$ and $NH$. The collected game data will be compared between $H$ and $NH$ as well, which are *gamelevel*, *correct* and average playtime. These variables are compared to get an indication of the motivation of the players. Two control questions of $Q_2$ asked if the players felt that the were helping Maxime or not. The storylines were anticipated to lead to clear differences in the answers to these questions between $H$ and $NH$.

## V. Results

### A. Motivation

To test $H_{0a}$, a two-tailed t-test assuming equal variances was performed on the summed scores for the questions about intrinsic motivations on the SIMS test. $H$ had a higher score for intrinsic motivation than $NH$ and the difference was significant ($p = 0.016$). Therefore, we can reject the null hypothesis $H_{0a}$ when we use $\alpha = 0.05$. The scores for the other types of motivation were also better (more motivated) for $H$ but showed no significant difference (figure 3).

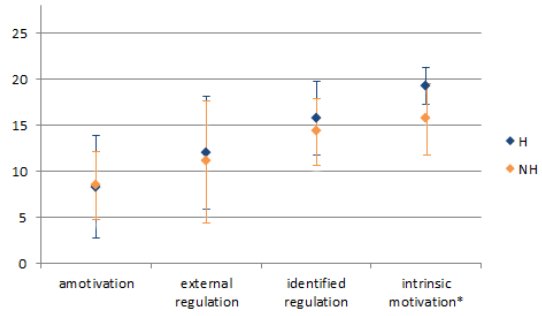
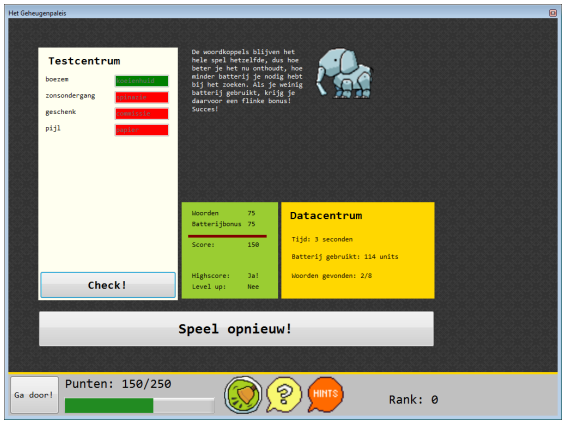



Fig. 3: Different motivations: Summed scores (maximum = 28) for each of the four types of motivation measured by the SIMS test, Error bars are standard deviations. A significant difference between $H$ and $NH$ was only found in intrinsic motivation ($p = 0.016$).


(a) The opening screen of the game, displaying the story by text.


(b) The player can search for word couples by clicking the grey area and needs to remember them as good as possible. Using the mouse less will earn a player more points


(c) A view of the Memory Palace. Descriptions of the items are shown in the top right corner. Any two items can swap positions. There are 10 different rooms and 40 items which can be browsed by the player. The puzzle is solved when all 40 items are on its correct position.




(d) The screen where the knowledge of the word couples is tested. Points are awarded for every word that is correct.

Fig. 2: Screenshots of the game. During the game, the progress is shown in the *statusbar* in the bottom of the screen. When the bar is filled, the player earns swaps to solve the puzzle.

### *B. Neuropsychological test*

The average time period between pre and post test was 28.6 $\pm$ 3.84 days (min 22.04 days, max 33.89 days) for each participant.

*15 Word Test:* One outlier was omitted from the results, because of a Recall trial score (Post minus pre test score) larger than 3 SD's away from the mean.

To test $H_{0b}$, a two tailed t-test assuming equal variances was performed using the scores for improvement (post - pre scores). The results of the 15 Word Test (15 WT) show a significant increase in memory improvement for group $H$ ($p = 0.011$) on the Recall trial. Therefore we can reject the null hypothesis $H_{0b}$ when we use $\alpha = 0.05$. All participants in $H$ obtained maximum scores for the Recall trial in the post test. Results are shown in table I.

*Other neuropsychological tests:* The battery of neuropsychological tests included 5 other tests. When comparing pre and post test scores, group $H$ only performed worse on the Stories test, but improved on all others. Group $NH$ improved on all scores except the digit span forward test. When com-

TABLE I: Main results of the 15 Word Test (15 WT). Group $H$ improved their 15 WT scores on Trial 1 and recall more than group $NH$ even when the scores were initially higher. The improvement on the Recall trial showed significant results ($p = 0.011$). Remarkably, on the recall trial of the post test, all participants in $H$ got maximum scores. Other trials were omitted from the results, because especially in the post test, many participants obtained maximum scores. Scores displayed are mean number of words recalled, with the s.d. in brackets.

| | Trial 1 | | Recall | | Trial 1 | Recall |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Post - Pre | Post - Pre |
| $H$ | 9.13 (3.18) | 11.13 (2.30) | 13.13 (1.73) | 15.00 (0.00) | 2.00 (2.73) | 1.88 (1.73) |
| $NH$ | 7.30 (1.83) | 8.20 (2.70) | 12.20 (1.81) | 12.10 (2.33) | 0.90 (3.21) | -0.10 (1.60) |

paring $H$ and $NH$ scores, the results of $H$ were better than $NH$ on all tests, except for Stroop 3 and Memory. Both groups improved their scores on the tests of TMT, Stroop and Memory. These results can be found in table II.

### C. Game data

Other interesting data from the game were difference in total time spent in the game, which was slightly longer (about 16%, 132 vs 115 minutes) for $NH$. $H$ was slightly better at completing the puzzle, with 11% more pieces in its correct slot. In $NH$ 4 people completed the game (40 correct), and 2 in $H$. $H$ also achieved a much larger gamelevel (17.1 vs 11.7), which is an indicator of how well the words are remembered in the game (table III). It has to be mentioned that the standard deviations were very high.

TABLE III: Game data for the two different groups. Minutes are the number of minutes played, gamelevel is an indication of how well the words in the game were remembered and correct is the average number of items in its correct slot (out of 40), so it is an indication of how well the puzzle was made. The s.d. is shown in brackets.

| | minutes | | gamelevel | | correct | |
|---|---|---|---|---|---|---|
| $H$ | 114.75 | (63.07) | 17.13 | (15.65) | 20.25 | (13.91) |
| $NH$ | 132.36 | (84.03) | 11.73 | (11.65) | 18.18 | (17.57) |

### D. Questionnaires

*1) Use of imagery technique:* One of the goals of the game was to teach the imagery memory technique to the participants. In the questionnaire afterwards, all participants reported to have used the technique in the game, as was instructed. Sixteen out of nineteen participants used the technique during the 15 WT spontaniously, while no mentioning of the technique was made during testing (table IV). All participants except one did not use the imagery technique outside of the game in between tests. The participants mentioned several cases where they thought the technique from the game might be useful in the future, like studying, a presentation, learning languages or addresses. Nine out of 19 participants did not come up with concrete situations to use the technique, but only one participant thought it would not be helpful at all.

TABLE IV: Use of the imagery technique for the 15 WT increased drastically after playing the game. Figures displayed are people using the technique over total number of people in the group. The percentage is shown in brackets.

| | Pre | Post |
|---|---|---|
| $H$ | 3/8 (38%) | 8/8 (100%) |
| $NH$ | 2/11 (18%) | 8/11 (73%) |

When results of the 15 WT people who used the technique are compared to participants who do not use the technique, we find that people who used the technique once (i.e. only at the second test) improved more than people who did not use the imagery technique at all. Participants who were already familiar with imagery did not improve much, but had high scores already. Also, the 2 people who did not use the technique were from group $NH$.

*2) Helping:* The post training questionnaire ($Q_2$) also asked about how the participants felt about helping and being helped by Maxime. $H$ did feel like it was helping Maxime moderately more, and a significant result (at $\alpha = 0.05$) was found when a t-test assuming equal variances was performed ($p = 0.03$). $NH$ felt like it was being helped by Maxime a bit more than $H$ (no significance found ($p = 0.16$)). Results can be found in table V.

*3) Game evaluation:* The post training questionnaire asked participants if they liked the game and how much sympathy they had for Maxime - the game's main character. These were rated on a scale from 1 to 7. The modus and median were both 5 for the game's rating and 6 for Maxime's sympathy (table VI).

## VI. Discussion

This research showed that it is possible to obtain higher intrinsic motivation scores by using a storyline to one where players need to help the game's main character ($H$), compared to one where the players only help themselves ($NH$). Significant differences were found in intrinsic motivation scores, in favour of $H$. When the neuropsychological test results of before and after training were compared, a significantly larger

TABLE II: Mean scores of all neuropsychological tests except 15 WT. A higher score means a better score on Digit span and Stories, while on TMT, Stroop and Memory, lower scores are better. Memory was a 6x6 traditional memory game on the computer, where the quality is the average number of clicks on all cards that were not clicked once. The s.d. is shown in brackets.

| | $H$ pre | | $H$ post | | $NH$ pre | | $NH$ post | |
|---|---|---|---|---|---|---|---|---|
| Digit span forward (correct) | 11.25 | (1.04) | 12.00 | (1.31) | 10.18 | (1.25) | 10.09 | (1.7) |
| Digit span forward (span) | 6.13 | (0.83) | 6.50 | (0.53) | 5.64 | (0.92) | 5.45 | (1.04) |
| Digit span backward (correct) | 10.13 | (2.64) | 11.88 | (1.46) | 9.73 | (1.85) | 10.91 | (1.58) |
| Digit span backward (span) | 5.88 | (1.55) | 6.63 | (0.74) | 5.45 | (0.93) | 5.91 | (0.94) |
| Trailmaking A (s) | 16.75 | (4.27) | 13.75 | (2.25) | 17.09 | (4.21) | 15.55 | (4.5) |
| Trailmaking B (s) | 35.63 | (10.64) | 31.25 | (7.89) | 46.18 | (14.06) | 39.18 | (13.17) |
| RBMT Stories 1 (points) | 13.06 | (3.11) | 10.56 | (2.95) | 8.00 | (3.44) | 9.55 | (3.52) |
| RBMT Stories 1 Recall | 13.00 | (4.05) | 9.38 | (3.1) | 7.32 | (3.94) | 8.27 | (3.89) |
| RBMT Stories 2 | 13.13 | (3.73) | 12.56 | (2.5) | 8.36 | (3.24) | 10.55 | (4.04) |
| RBMT Stories 2 Recall | 12.44 | (3.84) | 9.94 | (4.42) | 7.45 | (3.52) | 8.73 | (3.6) |
| Stroop 1 (s) | 38.86 | (5.81) | 36.14 | (5.76) | 39.55 | (9.23) | 37.36 | (7.41) |
| Stroop 2 (s) | 47.86 | (11.39) | 44.00 | (9.11) | 49.27 | (10.46) | 45.45 | (9.23) |
| Stroop 3 (s) | 71.71 | (19.73) | 63.43 | (14.64) | 69.91 | (13.41) | 57.64 | (23.53) |
| Memory (clicks) | 70.50 | (6.48) | 68.25 | (7.05) | 68.73 | (6.47) | 66.18 | (9.73) |
| Memory (quality) | 2.36 | (0.22) | 2.25 | (0.19) | 2.26 | (0.14) | 2.23 | (0.23) |

TABLE V: Responses to the questions in $Q_2$ "Did you get the feeling you helped Maxime?" and "Did get the feeling Maxime helped you?", for "You help" and "Maxime help", respectively. Figures displayed are number of responses and the percentage of the total number of responses is shown in brackets.

| | You help | | | | Maxime helps | | | |
|---|---|---|---|---|---|---|---|---|
| | $H$ | | $NH$ | | $H$ | | $NH$ | |
| (no, absolutely not) 1 | 1 | (12.5) | 5 | (45.45) | 1 | (9.09) | 0 | (0) |
| 2 | 2 | (25) | 1 | (9.09) | 2 | (18.18) | 1 | (9.09) |
| 3 | 1 | (12.5) | 4 | (36.36) | 2 | (18.18) | 3 | (27.27) |
| 4 | 0 | (0) | 0 | (0) | 1 | (9.09) | 2 | (18.18) |
| 5 | 3 | (37.5) | 1 | (9.09) | 0 | (0) | 4 | (36.36) |
| 6 | 1 | (12.5) | 0 | (0) | 2 | (18.18) | 0 | (0) |
| (yes, absolutely) 7 | 0 | (0) | 0 | (0) | 0 | (0) | 1 | (9.09) |
| mean (s.d.) | 3.6 (1.8) | | 2.2 (1.3) | | 2.1 (4.2) | | 4.2 | (1.4) |

TABLE VI: Displays answers to the questions "Did you like the game?" and "Did you think Maxime was sympathetic?", for Game rating and Maxime's rating, respectively.

| | Game rating n (%) | | Maxime's rating n (%) | |
|---|---|---|---|---|
| (no, absolutely not) 1 | 0 | (0) | 0 | (0) |
| 2 | 2 | (10.5) | 0 | (0) |
| 3 | 2 | (10.5) | 2 | (10.5) |
| 4 | 1 | (5.3) | 4 | (21.1) |
| 5 | 8 | (42.1) | 2 | (10.5) |
| 6 | 5 | (26.3) | 8 | (42.1) |
| (yes, absolutely) 7 | 1 | (5.3) | 3 | (15.8) |

increase in Recall trial test scores for the 15 WT for $H$ was discovered as well. This research also displayed that it is possible to develop a game that both gets a good rating from the players and trains people to use imagery mnemonics, which leads to higher scores on a memory test.

### A. Motivation

To repeat RQ1: *Do students get motivated more intrinsically to play a brain training game when they play to help the game's main character?*

It was expected that the group helping the game character ($H$) would be motivated more intrinsically to play the game, since helping would enhance the *relatedness*, something which is an essential social need accompanied by competence and autonomy. These factors can, when attended to in a proper way, increase the intrinsic motivation [29]. Helping the game's main character would increase the intrinsic motivation to play the game, because of this increased relatedness (a more intricate relationship) to the character, thereby satisfying the need to belong [6]. This seems to have been the case, regarding the results from the SIMS test. The results on this test show that $H$ were self-reportedly more intrinsically motivated than $NH$.

The paper on the SIMS test [20] shows that the SIMS is composed of internally consistent factors. It is a reliable way to collect self-reported motivation figures. Even though the participants were acquainted with the examiner, it is still reasonable to expect that $H$ and $NH$ were equally honest about their motivations, since all participants were acquainted. Therefore, these factors did not explain the difference between $H$ and $NH$ in intrinsic motivation scores.

From the $NPT_1$ (i.e. 15 WT, Stories, Digit recall) and the game data (gamelevel), we see indications that $H$ has a better verbal memory than $NH$. This may lead to the suspicion that $H$ is more intrinsically motivated, because they are more competent at the game. $H$ also rated their own memory higher when compared to their peers ($5.75 \pm 1.28$ and $4.82 \pm 1.99$, for $H$ and $NH$ respectively on a scale of 1-7).

At the same time, it was expected that the more intrinsically motivated students would play the game more, but $H$ did not play the game longer on average. However, this can be explained by the simple fact that the SIMS measures motivation *during* gameplay. Also, the game may not have been on the top of the priority list of the students. All participants received an additional e-mail, which some participants needed

as a reminder to get playing. This e-mail was sent from the fictive e-mailaccount of Maxime and asked the participant if everything was working properly.

Although there was a difference as expected in responses to the questions in the post test regarding helping, the results were less pronounced than hypothesized. It might have helped subconciously, but it was predicted that the differences between $H$ and $NH$ would have been larger on those questions.

All in all, it seems that $H$ was indeed intrinsically more motivated during gameplay, but this may have had other reasons than just the fact that $H$ was helping Maxime in the game.

### B. Memory

To repeat RQ2: *Does students' memory improve more when they play a brain training game to help a game's main character?*

Regarding the neuropsychological tests, the results of the 15 WT were expected to show the largest improvement, since it resembles the game the most. Indeed, both groups improved on the scores of all trials. Even though $H$ had higher initial scores on both Trial 1 and the Recall trial, they still improved more, to an even higher score than $NH$. On the other tests, $H$ obtained higher scores as well, except for the Memory game.

However, it goes too far to say that the students memory improved more. First of all, it has to be said that memory is a much wider concept than remembering lists of words. Although it can be indicative of a good, bad or damaged memory, it is clearly not the same. To claim someone's memory has improved would need more affirmation than performing better at remembering words.

Also, the participants' self reported improvement did not differ much between $H$ and $NH$ ($4.75 \pm 0.71$ and $4.45 \pm 0.52$ for $H$ and $NH$, respectively on a scale of 1-7), and the above mentioned fact about memory being broader than performing well in an NPT was noted by several participants.

The memories of the participants probably have not improved. However, the improvement on the tests were evident and even remarkable.

There was no control group to check for retest effects on the 15 WT without training, but earlier research shows no evidence of this occuring when participants have one month between the different tests [12].

The participants were not all tested under the same conditions. Much effort has been made to make it as easy as possible for the participants, which lead to a different pre and post location for the test in some cases. A person may not be as sharp as the next day. However, most cases (17/19) made the two NPT's under roughly the same conditions. The Digit recall, Stroop and Trailmaking test all used the same exact test twice. Here, a retest effect might be expected more easily. But Memory, Stories and 15 WT all had different content in the second NPT, so the difference in pre and post test may be explained by accident, acquaintance with the procedure (retest effects), or the fact that the participant used another method to do the test.

It could very well be that the game teaches the imagery mnemonic well and that the imagery mnemonic works well when remembering lists of words. This would then lead to higher scores on the 15 WT. The fact that all participants used the technique in the game and that 16 out of 19 participants used the technique the second time the 15 WT was tested, is evidence of this theory. Participants regularly mentioned the fact that it had helped them and that it worked on the 15 WT.

Obviously, if the technique only works on the 15 WT it would be of little use. The participants did not all come up with situations where the technique would be convenient. A shopping list (which was mentioned) is easier written down than remembered. Giving a presentation or learning a language seems more appropriate. The technique can also be handy when remembering names with faces, but no participant mentioned this.

This leads to the conclusion that with regard to RQ2, it is not possible to state that the memory has improved more. Some retest effects are observed in different tests of the NPT, which seems to have played a role, but the improvements on the 15 WT cannot be ignored. The fact that the technique was used and reportedly helped the participants leads to believe that using the imagery technique can work for students to remember information.

### C. Limitations

*1) Participants:* The group of participants was small, so that raises the question whether they are representative of the students population. To ascertain the sample as representative for the young, highly educated adult population, results of the Stroop test and 15 WT were compared with normative scores. In both cases, the group is compared to 25 year old (this is slightly older), highly educated Dutch speaking people. When the Stroop test is taken as a reference, we see that for the pre test, the group of participants got scores between 20th and 50th, between 50th and 80th and between 50th and 80th percentile rank for the tests Stroop I, II and III, respectively [34]. The different scores for $H$ and $NH$ do not lead to different percentile ranks.

For the more interesting 15 WT, the scores for the pre test Recall trial lead to percentile ranks of 50th to 80th for both $H$ and $NH$ [33].

Without a control group, it seems essential that $H$ and $NH$ are performing at the same level in the initial test, to really measure the influence of the different games on the neuropsychological tests. In trial 1 of the 15 WT in the pre test, $H$ clearly outperformed $NH$. The results of the pre test of the 15 WT and overall results on the 15 WT lead to believe that $H$ has more verbal intellect than $NH$. This is confirmed by the results of the Stories test, in which $H$ got higher average scores on all tests, both pre and post. Also, on the Digit recall test, $H$ scores consistently higher. Results for the Trailmaking Test were better for $H$ as well, while the game of Memory was slightly worse. To state that the general intelligence of $H$ would require additional testing.

This confirms the sample is a smart group of participants, representative of young, intelligent adults.

Another motivation is that all participants were acquainted with the examiner. This may have lead to a more positive rating

for the game (4.79 out of 7) and could have influenced other factors as well, like wanting to do better on the post test.

*2) Neuropsychological tests:* The biggest problem of the 15 WT is probably that individuals in both groups reached ceiling scores on several trials. This seems to be a limitation of the 15 WT with highly educated students. It would be interesting to see how these results would end up if it was the 30 WT, but that does not exist. If it would be created using different versions of the 15 WT and sticking them together, it would not be a validated test.

In Trial 2-4, if a ceiling score was reached in an earlier trial, this trial and further trials were deemed unnecessary. Therefore, only Trial 1 and the Recall Trial were used in analysis. However, this did mean that some participants got less trials and got to hear the words less often. Although it does not seem to be like the case, this might have influenced results.

The Memory test was thought to provide a great opportunity to use the technique as well, since it contained couples of concrete items, but pictures were used and not words (figure 4). Here, only one out of 19 participants reported to have tried the technique in the post test. Apparently, the participants did not try to make the connection between the images themselves and the locations into a combined image.

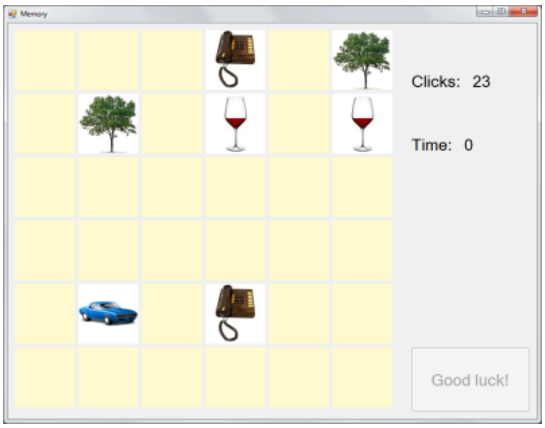



Fig. 4: The Memory game played in the neuropsychological test. Participants were told that the time was not registered and the goal was to make as few errors as possible in this classical memory game.

*3) Mnemonics:* Apparently, the game teaches the imagery mnemonic in such a way, that it is applicable in the 15 WT. In other neuropsychological tests, not so much. Despite the fact that some participants tried to use the technique in the Digit recall test and the stories test, they reported it was usually more of a hindrance than a help. Although the mnemonic is versatile, it is not automatically applicable for the students for other practices, so further instructions might be needed for other use.

The game only taught the imagery mnemonic, while many different mnemonic memory strategies exist. A lot of these techniques are quite advanced and require much practice. For this experiment, it was deemed more appropriate to learn a basic imagery strategy. A more advanced technique like loci [8] would require more time and effort from the participants. Also the game that needed to be made would be more intricate.

### D. The game

The use of a game to teach the imagery mnemonic is - to the best of my knowledge - unprecedented. Using a game to improve memory techniques is a superior way to teaching it in a classroom. There is no personal contact with a mnemonic expert, but this does not need to be a disadvantage. The techniques are quite easy to explain, the only thing that needs training is the discipline to use it. A game can easily provide this motivation. A game gives freedom to the player, who can play whenever and wherever he or she wants. It is also cheaper, since there is no need to hire a teacher and a classroom. The player only needs a computer to play the game on, but in 2016, this seems to be common for people of any age when they live independently.

In the current game, the appropriate challenge is provided by a system that increases (or decreases) the number of words that need to be remembered, when the scores were good (or bad) in the last two tests. The concrete goals are completing the puzzle, which is divided into smaller goals, since the points collected by remembering the word couples earned swaps to finish the puzzle. Structured control was implemented by using a clear screen order, which gave structure to the game.

The current game could easily be expanded to teach other memory techniques. For instance, it could be interesting to have the player remember names and faces in the game, using the imagery mnemonic. The link to memorizing names and faces of real people would be a lot clearer, improving the practicality of the technique.

### E. Future research

Helping a little elephant back to his parents is obviously only one way of helping the games main character. The sympathy for Maxime appealed to the students and they were able and willing to help. Different characters and stories need to be tested to see if we can generalize to a theory that helping can indeed improve intrinsic motivation. It would also be interesting to see if we can take the mnemonics a step further. We can introduce more instructions on how and when to use the technique in daily life and see if that improves the rate of usage in the daily routine of students, which includes a lot of remembering. It remains to be seen whether this game - or *any* game - can motivate other types of people as well. For instance elderly, where the quality of memory usually has declined, can be introduced in a fun way to the mnemonic strategy. More memory research with elderly is needed [22], and even for elderly, a game can improve the quality and fun of the training.

### F. Conclusion

This research showed that it is possible to obtain higher intrinsic motivation scores when the storyline is changed to

one where players need to help the game's main character. Whether the correlation was a causality remains to be seen. Memories of the participants may not have improved, but they learnt a mnemonic technique which can help and they did it while playing a game that was entertaining to them. This is a big difference from the sometimes tedious and even boring classroom sessions to teach mnemonics.

This research also showed that differences in intrinsic motivation can be measured and that this might be because of the helping of the game's main character. It also showed that it is possible to develop a game that both entertains and trains people to use imagery mnemonics, which in turn seems to improve their memory a little bit.

## APPENDIX A
## THE BRAIN TRAINING GAME

The game was designed to make it more enjoyable than learning the imagery technique in a classroom session. The player is immediately acquainted with the game's main character, Maxime.

Maxime is a little elephant, since elephants are well known for having a good memory. The sympathetic and young look of Maxime were expected to have participant help Maxime more easily.

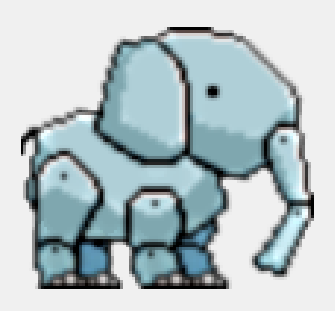


Fig. 5: Maxime, small elephant who is the game's main character.

The storyline is introduced using a startup screen, where the player needs to state their name and is asked if they want to help Maxime. This was done to have the player make a concious decision to help Maxime.

### A. *Game flow*

The main activities in the game consisted of searching and remembering word pairs, after which the Memory Palace was shown, and following that the test was held. This order was always the same. The puzzle provided a mental challenge to distract the player from remembering the word couples. The puzzle consisted of 40 items that needed to be *swapped* into the right place. Swaps could be earned by memorizing the words correctly. When a player had no swaps, he could obviously skip the puzzle. To prevent people from saving swaps and clicking through the puzzle, the maximum of saved swaps was 10. To prevent people from gaining points from just the battery bonus (clicking through the search screen), the points were only awarded when at least one word couple was remembered correctly.

### B. *Tutorial*

A quick tutorial helped the player through the first game flow of the game. In the first search screen (figure 2b), the words zebra and motor are hidden. When they are found, an instruction page is shown, explaining the imagery technique (figure 6). To explain the technique, a large amount of text is needed. While this can be a bit boring for the player, it is essential that the technique is learned. Other ways to explain the technique, like audio or video, would have taken too much time to produce. The players all used the technique in the game, so it seems an adequate way to explain the imagery technique to the players.


Fig. 6: The window shown when zebra and motor are found, explaining the imagery technique.

When the player arrives in the puzzle screen (the actual Memory Palace), Maxime explains how the puzzle works. The player is familiarized with swapping items in the tutorial, by swapping Maximes father to the "first place" (figure 7).


Fig. 7: The puzzle tutorial. In three steps, Maxime guides the player to swapping his father to the right place.

In the test screen (figure 2d) Maxime explains how the testscreen works and tells the player to use as little battery as possible in the search and remember screen.

### C. Items

The items in the memory palace were chosen in such a way, that there was a large diversity in the categories of the items (buildings, animals, tools etc.). This made it easier to differentiate between the items. The cryptical descriptions for the items referred for instance to locations ("The blimp feels at home in the top left corner"), other items ("the cemetery is next to the happiest item in the Memory Palace"), or different rooms ("this alarm clock looks way too old for the room it should be in"). The descriptions were made by the examiner and, probably because of the subjective nature, were experienced as vague by most participants. The sprites originate from the game Scribblenauts [2]. The fun, simple, but clear sprites created an appropriate look for the game. This sprite collection provided a lot of different objects, which made it easier to select the 40 different items for the puzzle.

### D. Feedback

The progressbar (in the bottom left corner) shows how many points are needed to fill the bar. When it is filled, the player gets 3 swaps for the puzzle. This is then displayed in a pop-up message. A screen with the progress of the puzzle is shown automatically to the player when 1, 5, 10, 20 and 40 items are correct in the puzzle. When the player presses the orange Hints-button in the button, the same screen is shown, with the progress of the puzzle and some extra hints, like "In one room, all names of the objects start with the same letter".

### E. Game characteristics

The model described by Garris et al [16] was used to design the game. In the paper, fantasy, rules & goals, sensory stimuli, challenge, mystery and control are mentioned as categories that can describe game characteristics. In the current game, these dimensions are respected in the following ways.

*1) Fantasy:* Fantasy is defined as mental images of physical or social situations that do not exist. The Memory palace, the small world of Maxime, gives the player a place where things are clearly different from the real world. The weird combinations of items and the non-realistic sprites entices the player into thinking they are in another world. When using the imagery mnemonic to remember the word couples, the players had to use their fantasy as well to come up with unusual combinations of objects.

*2) Rules & Goals:* The rules are clearly described by Maxime in the tutorial. The goals for the player are clear as well. The progressbar for points is always visible, and this remains an obvious goal for the player. Solving the puzzle is a greater goal and the progress of solving the puzzle is shown frequently or on demand.

[2]The sprites (images) of the game were downloaded from the website http://www.spriters-resource.com/ds/scribblenauts/

*3) Sensory stimuli:* The sprites provide some happy looking images, which were obviously from another world. Unfortunately, there was no sound in the game, because of a lack of time. There were no dynamic graphics either, which would be an improvement. Since students usually return to practice activities that include dynamic graphics [16].

*4) Challenge:* The main challenge was remembering the word couples. This was made easier or harder (distributing more or less words in the field), according to the test results. This way, the player was always challenged on a level he could handle. The puzzle provided another challenge and actually got progressively easier when more items were in the right spot.

*5) Mystery:* The search and find game was designed to enable the player's curiosity take a flight. When a player found one word, he has to find the other word it is connected with. When the two words are found, it is up to the player to create a striking image, connecting the two. Learning the imagery mnemonic also stimulated the players' desire for knowledge.

*6) Control:* Control refers to the exercise of authority or the ability to regulate, direct, or command something. In this game, the player was free to progress to the next step in the game flow at any time, increasing the players feeling of control. Having some distraction between the remembering and recall was deemed necessary, but the player can still develop their own tactics on when they save swaps or use them right away.

## APPENDIX B
## QUESTIONNAIRES

### A. Pre

The questionnaire $Q_1$ was used to obtain personalia and initial data about the memory of the participants. It was performed orally and administered in Google forms.

*Question (answer possibility)*

- Name (open)
- Age (open)
- Gender (male/female)
- E-mail address (open)
- How many years of education did you receive? (open)
- Do you have physical disablities that might hinder the playing of a computer game? (yes/no)
- Do you have dyslexia? (yes/no)
- Are you happy with your memory if you compare it to your peers? (scale 1-7)
- How many hours a week do you spend behind the computer? (open)
- How many hours a week do you spend playing computer games? (open)
- I am aware of the fact that I am participating voluntarily to this experiment. I can quit at any time, for whatever reason. My results will be anonimised and shown to me if I ask for it. For the experiment a neuropsychological test will be performed and I should play the game half an hour a week, for a three week period. (check button)

### B. Post

The questionnaire $Q_2$ was used to obtain a review of the game and the technique taught. It was performed orally and administered in Google forms. On the scale of 1-7, 1 is "absolutely not" and 7 is "yes, absolutely".

*Question (answer possibility)*

- Name
- Did you like the game? (scale 1-7)
- What did you like about the game? (open)
- What did you dislike about the game? (open)
- What would you change about the game if you could? (open)
- Do you think Maxime the little elephant is sympathetic? (scale 1-7)
- Did you get the feeling you helped Maxime? (scale 1-7)
- Did you get the feeling Maxime helped you? (scale 1-7)
- What gender do you think Maxime is (male/female/sexless/did not think about it)
- Do you think you can train your memory? (yes/no)
- Did you notice a connection between the game and the neuropsychological tests? (checkboxes for the different tests)
- Did you use the imagery technique in the game? (yes/no)
- Did you use the imagery technique during the NPT's? If yes, at what test? (checkboxes for pre and post tests)
- Did you use the technique outside of the game? If yes, with what? (open)
- Do you think you will use the technique in the future outside of the game? If yes, with what? (open)
- Are you happy with your memory if you compare it to your peers? (scale 1-7)
- Do you have the feeling your memory got better? (scale 1-7 ("no, it got worse" to "yes, it got better"))

After these questions, the SIMS test was performed, in English.

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## REFERENCES

[1] Maaike Angevaren, Geert Aufdemkampe, HJ Verhaar, A Aleman, and Luc Vanhees. Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. *Cochrane Database Syst Rev*, 3(3), 2008.

[2] Joaquin A Anguera, Jacqueline Boccanfuso, James L Rintoul, Omar Al-Hashimi, Farhoud Faraji, Jacqueline Janowich, Eric Kong, Yudy Larraburo, Christine Rolle, E Johnston, et al. Video game training enhances cognitive control in older adults. *Nature*, 501(7465):97–101, 2013.

[3] Karlene Ball, Daniel B Berch, Karin F Helmers, Jared B Jobe, Mary D Leveck, Michael Marsiske, John N Morris, George W Rebok, David M Smith, Sharon L Tennstedt, et al. Effects of cognitive training interventions with older adults: a randomized controlled trial. *Jama*, 288(18):2271–2281, 2002.

[4] Paul B Baltes and Ulman Lindenberger. On the range of cognitive plasticity in old age as a function of experience: 15 years of intervention research. *Behavior Therapy*, 19(3):283–300, 1988.

[5] Shari S Bassuk, Thomas A Glass, and Lisa F Berkman. Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of internal medicine*, 131(3):165–173, 1999.

[6] Roy F Baumeister and Mark R Leary. The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological bulletin*, 117(3):497, 1995.

[7] Daphne Bavelier and Richard J Davidson. Brain training: Games to do you good. *Nature*, 494(7438):425–426, 2013.

[8] Gordon H Bower. Analysis of a mnemonic device: Modern psychology uncovers the powerful components of an ancient system for improving memory. *American Scientist*, pages 496–510, 1970.

[9] Christian Burgers, Allison Eden, Mélisande D van Engelenburg, and Sander Buningh. How feedback boosts motivation and play in a brain-training game. *Computers in Human Behavior*, 48:94–103, 2015.

[10] Tom S Chan and Terence C Ahern. Targeting motivation-adapting flow theory to instructional design. *Journal of Educational computing research*, 21(2):151–163, 1999.

[11] Fergus IM Craik. Memory changes in normal aging. *Current directions in psychological science*, 3(5):155–158, 1994.

[12] JR Crawford, LE Stewart, and JW Moore. Demonstration of savings on the avlt and development of a parallel form. *Journal of Clinical and Experimental Neuropsychology*, 11(6):975–981, 1989.

[13] Mihaly Csikszentmihalyi. Flow and the psychology of discovery and invention. *New York: Harper Collins*, 1996.

[14] Sanford I Finkel and Jerome A Yesavage. Learning mnemonics: A preliminary evaluation of a computer-aided instruction package for the elderly. *Experimental aging research*, 15(4):199–201, 1989.

[15] Paivio et al. Friendly, M. (1996). Word list generator, online application.

[16] Rosemary Garris, Robert Ahlers, and James E Driskell. Games, motivation, and learning: A research and practice model. *Simulation & gaming*, 33(4):441–467, 2002.

[17] James Paul Gee. What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE)*, 1(1):20–20, 2003.

[18] C Shawn Green and Daphne Bavelier. Exercising your brain: a review of human brain plasticity and training-induced learning. *Psychology and aging*, 23(4):692, 2008.

[19] Alden L Gross, Jeanine M Parisi, Adam P Spira, Alexandra M Kueider, Jean Y Ko, Jane S Saczynski, Quincy M Samus, and George W Rebok. Memory training interventions for older adults: A meta-analysis. *Aging & mental*

*health*, 16(6):722–734, 2012.

[20] Frédéric Guay, Robert J Vallerand, and Céline Blanchard. On the assessment of situational intrinsic and extrinsic motivation: The situational motivation scale (sims). *Motivation and emotion*, 24(3):175–213, 2000.

[21] Raymond Levy. Aging-associated cognitive decline. *International Psychogeriatrics*, 6(01):63–68, 1994.

[22] Cindy Lustig, Priti Shah, Rachael Seidler, and Patricia A Reuter-Lorenz. Aging, training, and the brain: a review and future directions. *Neuropsychology review*, 19(4):504–522, 2009.

[23] Eleanor A Maguire, Elizabeth R Valentine, John M Wilding, and Narinder Kapur. Routes to remembering: the brains behind superior memory. *Nature neuroscience*, 6(1):90–95, 2003.

[24] Mara Mather and Laura L Carstensen. Aging and motivated cognition: The positivity effect in attention and memory. *Trends in cognitive sciences*, 9(10):496–502, 2005.

[25] Allan Paivio. Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology/Revue canadienne de psychologie*, 45(3):255, 1991.

[26] Brad Paras. Game, motivation, and effective learning: An integrated model for educational game design. 2005.

[27] John E Partington and Russell Graydon Leiter. Partington's pathways test. *Psychological Service Center Journal*, 1949.

[28] George W Rebok, Michelle C Carlson, and Jessica BS Langbaum. Training and maintaining memory abilities in healthy older adults: Traditional and novel approaches. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 62(Special Issue 1):53–61, 2007.

[29] Richard M Ryan and Edward L Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1):68, 2000.

[30] RJ Saan and BG Deelman. De 15-woordentest a en b (een voorlopige handleiding). *Groningen: Afdeling Neuropsychologie, AZG*, 1986.

[31] Timothy A Salthouse. When does age-related cognitive decline begin? *Neurobiology of aging*, 30(4):507–514, 2009.

[32] J Ridley Stroop. Studies of interference in serial verbal reactions. *Journal of experimental psychology*, 18(6):643, 1935.

[33] WIM Van Der Elst, Martin PJ Van Boxtel, Gerard JP Van Breukelen, and Jelle Jolles. Rey's verbal learning test: normative data for 1855 healthy participants aged 24–81 years and the influence of age, sex, education, and mode of presentation. *Journal of the International Neuropsychological Society*, 11(03):290–302, 2005.

[34] Wim Van der Elst, Martin PJ Van Boxtel, Gerard JP Van Breukelen, and Jelle Jolles. The stroop color-word test influence of age, sex, and education; and normative data for a large sample across the adult age range. *Assessment*, 13(1):62–79, 2006.

[35] Paul Verhaeghen, Alfons Marcoen, and Luc Goossens. Improving memory performance in the aged through mnemonic training: a meta-analytic study. *Psychology and aging*, 7(2):242, 1992.

[36] David Wechsler. Wechsler adult intelligence scale–fourth edition (wais–iv). *San Antonio, TX: NCS Pearson*, 2008.

[37] Barbara Wilson, Janet Cockburn, Alan Baddeley, and Robert Hiorns. The development and validation of a test battery for detecting and monitoring everyday memory problems. *Journal of Clinical and Experimental Neuropsychology*, 11(6):855–870, 1989.

[38] Robert S Wilson, Laurel A Beckett, Lisa L Barnes, Julie A Schneider, Julie Bach, Denis A Evans, and David A Bennett. Individual differences in rates of change in cognitive abilities of older persons. *Psychology and aging*, 17(2):179, 2002.