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Rewind/Remind - A cognitive tool for people with associative memory deficits

Theodora Toutountzi
Heracleia Lab
University of Texas at Arlington
theodora.toutountzi@mavs.uta.edu

Cheryl Abellanoza
Heracleia Lab
University of Texas at Arlington
cheryl.abellanoza@mavs.uta.edu

Arnav Garg
Heracleia Lab
University of Texas at Arlington
arnav.garg@mavs.uta.edu

Dylan Ebert
Heracleia Lab
University of Texas at Arlington
dylan.ebert@mavs.uta.edu

Fillia Makedon
Heracleia Lab
University of Texas at Arlington
makedon@uta.edu

ABSTRACT

In this paper, we present Rewind/Remind (RR), a tool designed to help people assess and improve their associative memory. Rewind/Remind also serves as a tool for therapists by providing cognitive training based on memory research on helpful encoding strategies. RR is a flexible web browser application that is composed of two different interfaces: the Patient Interface (PI), and the Therapist Interface (TI). The PI consists of two different games – Game 1: "Find the Link" and Game 2: "Create the Link". For Game 1, users have to find the link that connects two objects, while for Game 2, users have to define an association between objects. The TI provides analytical reports, allows for off-line monitoring of user performance, and gives the option to modify the sequence of tasks. These novel functionalities and approaches introduce promising new directions for cognitive remediation.

CCS Concepts

•**Human-centered computing** → **Interactive systems and tools;** *Systems and tools for interaction design;*

Keywords

Aging, Brain Game, Memory Game, Improve Associative memory, Human Computer Interaction, User interface

1. INTRODUCTION AND RELATED WORK

Almost half of older adults in the US have reported having memory issues. Most often, older adults complain of associative memory problems[6]. Associative memory is defined as the type of memory that allows a person to link items and meanings together. People with associative memory deficits lack the ability to make these connections between objects and their meanings. For example, people who have suffered from stroke or traumatic brain injury have trouble remembering the names of household items, even though they may remember how to use those items[7, 8]. Also, healthy aging causes what is known as "retrieval shift", which limits people's ability to remember associations accurately. It has been suggested that as part of the healthy aging process, older adults especially have difficulty encoding and retrieving associative information[12, 13].

Two hypotheses currently shape our understanding of this phenomenon. First, the Associative Deficit Hypothesis states that older adults cannot encode information properly because of age-related deficits in brain structures, as well as deficits in attention related to associative memory. Next, the Environmental Support Hypothesis states that older adults cannot encode or retrieve information properly; not only do older adults have a harder time recruiting brain activity to learn information, but they also have difficulty recalling that information in a way that is helpful for them[11, 12, 13].

To remediate these memory problems, computerized cognitive training games have been created[10]. These types of games have many benefits: they are cost-effective, they use quantitative methods to measure player performance in the game, and they are free of negative side effects that may arise due to drug interactions. However, these games also have many issues: they are often made available to the public without being supported by empirical research, they often have limited scopes (e.g., only for patients, or only for certain cognitive tasks), and most importantly, they are subject to practice effects. The term "practice effects" (also known as "testing effects") describes the increased performance on a task, but no change in performance on daily activities that are supposed to be measured by that task[14].

With regard to associative memory, this may look like a user who performs well on a memory game over time, but who does not experience memory benefits in his daily life as a result of playing the game. This user may have learned how to play these games well, rather than support his own memory processes in a useful way. Practice effects may arise because game designers do not take findings like the Associative Deficit Hypothesis or the Environmental Support Hypothesis into consideration. An example of this comes from Lumos Labs. Lumosity [5] is an online collection of smart games claiming to provide cognitive benefits. However, users may have only experienced practice effects,

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meaning that their scores did not truly represent cognitive enhancement[2]. Another similar example comes from Focus Education's[4] Jungle Rangers game. Jungle Rangers is a game designed for kids claiming that permanently improves executive function and also can help to alleviate the symptoms of attention deficit hyperactivity disorder (ADHD). This claim is not supported by any scientific evidence according to the FTC [3], and there are no permanent results.

On the other hand, recent studies revealed that the brain can reorganize and change in adaptive ways, over time. Furthermore, there is some evidence that this flexibility is preserved with aging [9], and that well-researched cognitive training games can take advantage of this plasticity. For instance, SharpBrains [1], an independent market research firm tracking health and performance applications of brain science, reports that there has been a growth of the digital brain health market since 2005, with increased growth expected for the coming years. Research for SharpBrains and other research-based cognitive training games (e.g., BrainHQ []) has shown that such cognitive training can be used in conjunction with other behavioral and pharmaceutical interentions to help support memory functioning. This shows a need for smart games like Rewind/Remind.

There is a great demand for cognitive games, and according to the authors' knowledge, there is no game like Rewind/Remind that specifically targets associative memory deficits by employing encoding strategies that address the Associative Deficit Hypothesis perspective of memory failures in healthy aging. The aim of Rewind/Remind is to build upon existing technologies to create a cognitive training application that helps people make connections between objects and their meanings in a way that is free of practice/testing effects.

2. REWIND/REMIND ARCHITECTURE

As previously mentioned, the proposed system aims to help people with associative memory deficits. The major idea behind RR is to obtain common words from everyday life and ask the user to make connections between those words by selecting linkage phrases that make the most sense. For Game 1, users can see immediate feedback on their answers. For Game 2, users memorize pairs of objects before being tested on their memory of those pairs. When users give correct answers, they receive positive feedback and are shown their answers. When users give incorrect answers, they receive negative feedback and are shown the correct phrase.

The RR system architecture is shown in Figure 1. RR mainly consists of two different interfaces: one for the patient (the Patient Interface, or PI) and one for the therapist (the Therapist Interface, or TI). There is also another hidden interface, which is used by both the PI and TI to communicate and exchange information through a middleware software and the web database. This hidden interface is the Web Server (WS) interface.

In the following subsections, we extensively describe those interfaces, how the communication is established, and an extensive description of the technologies that we used.

2.1 Patient Interface (PI)

The main purpose of the PI is to provide a tool that can assist users with a moderate knowledge of computers and to require minimum interaction between therapists and patients. This reduces time demands for the therapist, as the therapist can monitor the patient off-line.

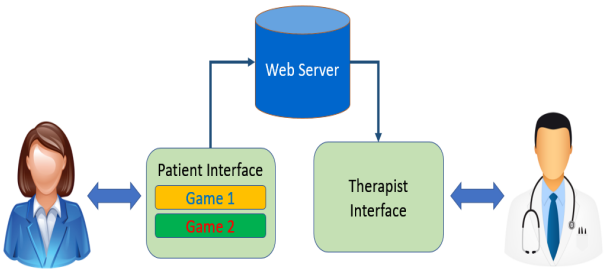

Figure 1: Rewind-Remind System Architecture.

Additionally, for users that are more technologically confident, the PI provides the option to perform tasks from home, through the Internet, without the presence of the therapist. A simple and easy-to-use interface could motivate the patient to increase compliance and active participation.

The patient login/register interface is shown in Figure 2.

Figure 2: Rewind-Remind - Patient login screen.

Initially, all users need to register for an account, either by themselves or with the help of their therapist. Once they are registered, and after a successful login, users can see the Dashboard (see Figure 3).

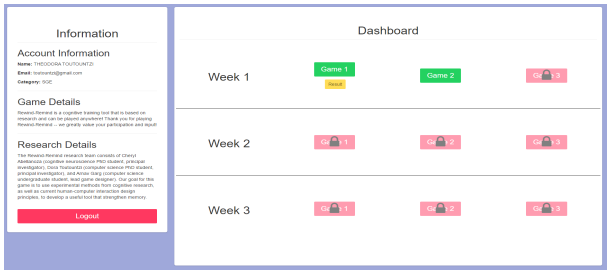

Figure 3: Rewind-Remind - Game schedule.

The Dashboard displays the user's weekly schedule. The predefined duration of the program is 3 weeks, with 3 interactions per week. After each interaction, users can immediately access game results to see their progress.

2.1.1 Game 1 & Game 2

Game 1: "Find the Link", is shown in Figure4. This game asks the user to select the correct association between the words by choosing the proper linkage phrase and submitting it. Then, the program replies if this is a correct or a

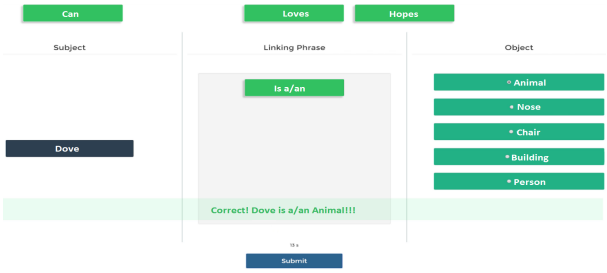

Figure 4: Rewind-Remind - Game 1.

wrong choice according to the dataset, with a corresponding message.

Game 2: "Create the Link", is shown in Figure 5.

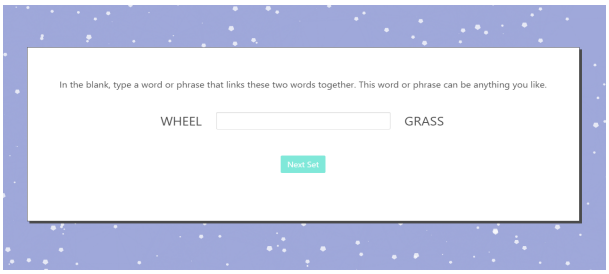

Figure 5: Rewind-Remind - Game 2.

This game asks the user to decide on an association between the two words, or a phrase that will later help the user recognize if this was an existing pair or not. We will present more details about the game structure in future work.

2.2 Therapist Interface (TI)

In this section, we present the contribution of the Therapist Interface (TI) to the whole system. The TI is the most valuable asset of the RR tool. The therapist interacts with the system and the user/patient, in order to decide the best strategy for the user/patient. The therapist has two options: either to let the system decide a game plan for the patient, or to manually assign a game plan to the patient. Through the user interface, the therapist can also access patient demographic information, as well as each patient's progress report. Furthermore, there are reports that compare patients' performance over time, as well as compare patients with others who may share similar characteristics.

2.2.1 Assignment Task

The system automatically proposes the tasks for each interaction and adjusts the difficulty level based on a recommendation system (RS) module. The predefined duration is 3 weeks with 3 interactions per week. The therapist has the choice either to modify the RS suggestions, or to select and propose a task from the available pool of tasks. The therapist can assign games and weekly interactions, as well as run time and difficulty levels of each interaction. Different difficulties can be addressed. For example, in Game 1, a rare word could require more concentration. Similarly, a rare and lengthy word could possibly cause confusion. To address this, the system could provide the linkage phrase to a weak user, and the user would only need to match the object. According to the RS and the cold-start problem, the system decides the assignment of tasks based on some predefined strategies and then adapts based on patients' performance.

2.2.2 Performance Monitoring

Rewind/Remind can provide metrics according to all patients' performance over time, as well as compare one patient's performance with other patients. For instance, patients can undergo baseline, standardized memory testing with their therapist. Then, they can sign up to play RR, and therapists can format the duration of their cognitive training. Therapists can then follow-up with patients on future standardized memory tests to track how the patients' progress has changed.

Rewind/Remind provides many metrics. First, RR tracks the correct and incorrect responses within each game/interaction, which can allow for the calculation of proportions/hit rates. RR also measures response time for each trial within each game, as well as total gameplay duration. The game logs participants' responses, which can help provide information about how patients are encoding/learning the information. Because RR actively engages patients in creating associative links through both self-generated encoding and directed encoding strategies, patients can engage in a process that may give them new learning strategies.

Initial testing has been done with 40 younger adults (aged 18-25) and 30 older adults (aged 45+) who played RR for 3 weeks (3 games per week, 9 games total). Users in both groups had an average accuracy of about 85%. Though memory accuracy within the game did not differ based on age, reaction times did differ. Older adults had longer reaction times on all games, suggesting that RR does provide metrics that reflect age-related memory processes ($F(1,68) = 9.19$, $p = .003$, partial eta-squared $= .12$. On average, older adults spent about 2.22 more seconds when responding, as compared to their younger counterparts.

To ensure that findings are not due to practice effects, current testing is examining how RR may impact memory performance on standardized tests. Further within-game comparisons over time and between patients, as well as pre- and post-game memory testing, will provide more information on the effectiveness of RR.

2.3 Web Server Interface (TI)

The Web Server (WS) Interface is the middle-ware system through which all communication between interfaces take place. This includes the application files, the data storage, the recommendation system, and the information exchange. All possible combinations for games and responses, along with patients' results, are kept in data storage. We will explain relevant technical details in the "System Architecture" section.

3. SYSTEM ARCHITECTURE

3.1 Information Exchange

The information is exchanged between the two interfaces and the middleware program is solely based on RESTful programming and follows the client-server architecture. The reason for making that choice is that the HTTP communication protocol can support multi-modal communication between client and server, is secure and widely used in many

real-life applications. Thus, can be proved very helpful for our future extensions. The database query interface communicates with the database though the mongoose node package which is a object modeling tool designed to work in an asynchronous environment.

3.2 Communication Protocol

Since, Rewind-Remind web application is a RESTful API we can serve more than one user at a time with multiple requests from every user. Every connection to the database is a separate instance so, all users of the system are able to use the program simultaneously and have real-time access to the data stored.

All the queries and calculations are executed at the server side, and the result is transferred through the HTTP requests to the users. This minimized the end user hardware requirements.

3.3 Database

The web application is developed using the MEAN stack. The application stores the data in the MongoDB NoSQL database which is hosted on the cloud. The web application is hosted on the Heroku servers.

4. CONCLUSIONS AND FUTURE WORK

In summary, we have proposed Rewind/Remind, a cognitive training tool for therapists to use with patients who may experience memory deficits. This can be especially applicable to older adults, who experience specific associative memory deficits as a part of healthy aging. We offer this tool for therapists as a way to teach and implement encoding strategies specifically targeting associative memory, and we offer various capabilities for both patients and therapists.

By playing Rewind/Remind, patients may benefit from learning memory strategies that are rooted in memory research. We based our two Rewind/Remind games on research regarding the Associative Deficit Hypothesis and, based on our findings, aim to implement information derived through the perspective of the Environmental Support Hypothesis. Patients can easily implement this cognitive training as well as track their progress from any computer. Therapists benefit from being able to monitor patients' progress over time and in relation to other patients in an unobtrusive way. Therapists can also cater the cognitive training to each individual patient. We propose that Rewind/Remind can be a useful tool for cognitive training.

Ongoing work consists of experimental testing of the effects of playing Rewind/Remind. We are comparing performance on associative memory tests that are unrelated to Rewind/ Remind, therefore attempting to limit practice effects. We are also examining user attitudes about Rewind/Remind. Users will fill out a survey about their experience playing our game. Future work may involve possible changes or additions to the Rewind/Remind memory games (based on memory research), A/B testing of therapist and patient interfaces, and enhancement of cross-platform usability (e.g., mobile vs. desktop website and game designs).

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