MEMORY ASSESSMENTS USING REAL-WORLD SITUATIONS

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Abstract

How does the use of working memory (WM) differ between laboratory measures and how WM is used in real world situations? In occupational therapy, universal day to day activities such as preparing one's breakfast are often used as a marker for where a patient is cognitively after a brain injury. However, these methods, although practical and helpful, do not result in detailed quantitative data. Other cognitive neuropsychological tasks have participants memorize words, letters or pictures and then report back what they were shown a certain amount of time later, such as in the immediate recall task. Although these tasks can be computerized and can even adapt to the participant's performance (i.e: adding longer words or making the lists longer), the conditions in which participants are tested and how the participants use their memory in these tasks differ than when one uses their memory in the real world. In real world situations, using one's memory is typically not a conscious decision and strategies have been developed over time. This differs from standard cognitive assessments in the sense that in a typical cognitive assessment, a participant will be aware that they are being tested and are ideally putting in more of an effort. In this project, we will create an app that uses a simulated version of real life tasks (i.e.: memorizing a phone number) by designing possible situations that are easier to convert into an assessment while also fitting an overall theme that connects the assessments logically. After this design phase, the app will be developed and beta tested on tested in research participants. From this process, we hope to create a tool that blends both assessments with practical applications and assessments that provide quantitative data.

Acknowledgements

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Memory assessments using real-world situations

Occupational therapy (OT) is a type of therapy that aims to help people reach their maximum level of independence and functionality for daily living (Legg et al., 2006). A large portion of this training involves cognitive training (CT) to help patients retain or regain cognitive functioning. OT typically uses universal day to day activities such as buying groceries as a marker for patients' cognitive status after a brain injury; however, the data acquired is often qualitative. Traditional CT tasks are used in an attempt to solve this problem by providing quantitative measurements however, these traditional forms of the tasks use artificial questions that might not relate to the real world. On the other hand, more contemporary computerized assessments introduce adaptive methods that can be even more sensitive, but also differ from how working memory is used in ecological conditions. In order to address these issues, we must first understand the populations that typically receive OT.

Post-Stroke & Alzheimer's Studies

Legg et al. (2006) reviewed previous studies to determine whether OT that focused specifically on daily tasks improved recovery for patients following stroke. They examined 64 different trials that totaled to 1,258 participants. The study found that OT interventions increased personal activity of daily living scores. They also found that for every 11 patients receiving an OT intervention, one patient was spared a poor outcome (poor outcome meaning having the patient was spared from losing the ability to perform personal activities of daily living, being dependent on institutional care and/or death). It is important to note that the trials chosen in this meta-analysis included therapy that was provided by a qualified occupational therapist or under the supervision of a qualified occupational therapist however, it is still unclear what types of OT should be provided and when. Also of note is the fact that interventions are being used in order

to improve personal activity of daily living — meaning how much of typical daily activities can a patient perform independently (i.e. showering, brushing their hair, etc.) but, traditional assessments were still being used.

Another meta-analysis conducted by Merriman et al (2019) aimed to identify the possible psychological interventions from studies that aimed to improve post-stroke cognitive function and their quality of life in terms of being able to independently perform day to day tasks (i.e. brushing one's teeth). The population of participants in the study were all over the age of 18. They found a small effect on cognition across the studies that included an active group and a control group. A moderate effect was found on cognition— specifically memory and attention— in pre-post studies examined. The pre-post studies examined largely included CT between pre and post testing which suggests that a pre-post test model with training in between each assessment is particularly helpful to this population.

Park & Lee (2019) conducted a study with 30 stroke patients using the pre-post study model. The 30 participants were randomly divided into two groups where 15 were in a dual-task group and 15 received conventional OT. While both groups had significant improvements in cognitive function, the dual task group showed more improvement all around. This study shows that the combination of CT and OT may help improve cognitive function of patients after a stroke.

Aside from stroke patients, it seems as though patients suffering from Alzheimer's Disease (AD) can benefit from CT. A meta-analysis conducted by Sitzer et al. (2006) examined 19 different controlled trials and the results suggest that CT can improve the cognitive and functional abilities of AD patients. The findings correlate with previous studies suggesting that cognitive stimulation is helpful for AD patients, however it is important to note that these 19

trails seem to highlight the importance of having a personal connection with the stimulation. It is not clear whether a stimulated personal connection (i.e. virtual pets) would have the same effect, so more research is necessary to determine whether or not the same effect can be found.

Brain Injury Studies

A brain injury can result in cognitive deficits that could limit all areas of daily living for the patient. Katz et al . (1989) conducted a study using two groups of brain injured adults and a third control group of non-brain injured adults. Through their follow up assessments they found that all groups had a significant improvement in areas of perception, visuomotor organization and thinking operations. This suggests that CT based tasks could lead to significant improvement and leaves the question of what a task that combines the best of both CT and OT could do.

This improvement can also be found in a case study conducted by Landa-Gonzalez (2001) on a 34 year old man with a traumatic brain injury. After six months of the intervention, the patient showed improvements in their awareness level and needed less attendant care. The results of the study suggest that cognitive training could improve independence in terms of self-care (i.e. brushing their own teeth and changing on their own). It goes without saying that additional studies would need to be conducted however, it is worth acknowledging the fact that training has the potential to develop positive outcomes for different groups of people.

Schizophrenia Studies

Schizophrenia patients can experience cognitive deficits and cognitive training studies tend to be inconclusive. A study conducted by Trapp et al. (2008) examined the effects of computer-aided CT using motivational software that intended to provoke positive emotions into schizophrenia patients. The study consisted of 40 patients that were separated into two groups of 20. One group received CT and the other group of 20 received OT. Although the study found no

correlation as they had hoped, their findings do imply that a pleasant and gamified version of CT tasks may be beneficial to schizophrenia patients due to the motivating effect.

A large population of people could potentially benefit from computerized CT training that involves situations used in typical OT. We hope to bridge the gap between computerized assessments and introduce adaptive methods that can be even more sensitive, while also differing from how working memory is used in ecological conditions with our novel app called *Saving Memo*. With the development of this app, we hope to create a tool that blends both assessments with practical applications and assessments that provide quantitative data. We also hope to create a system in which participants are able to choose the amount of items being held in their memory rather than being held to a certain number as they are in traditional CT tasks.

Methods

Brainstorming

Concept Creation

To begin drafting, we sat down and listed all real-world situations we could think of that could easily be transformed into games while also being comparable to assessments previously validated by the UCR Brain Game Center (BGC). In the beginning, it was hard for us to come up with diverse ideas that would not end up being reskins of the same concept over and over. Using the CEDAR administration manual (Thomas, 2016) as inspiration, we were able to come up with concepts using real-world situations. Some initial ideas we came up with include a cooking game in which the player chooses how many items they are memorizing by clicking on different recipes using a certain number of ingredients. Another idea came in the form of an online shopping simulation where the player would need to memorize discount codes in a certain amount of time before the page refreshed or the code was no longer valid. After narrowing down

the list we decided on a phone number task, supermarket task, post office task and restaurant task — all to be described in detail further in the task description section. All that was left was to figure out a way to connect all the tasks with an overarching narrative.

Game Narrative

The narrative of the game was largely inspired by the types of games that were popular in our childhood — games like *Nintendogs* and *Tamagotchi* — in the sense of the games revolving around completing tasks for the benefit of your pet. The overall narrative revolves around the main character (MC) needing to fulfill the needs of their cat named Memo. MC lives in a small town where everyone helps everyone which is why they find themselves doing different jobs in order to have funds to spend on Memo. As time went on, the universe of the game seemed more post-apocalyptic than originally planned. Current screenshots of the games have humans in the direction screens however, future versions of the game will include robotic animals that will be giving the player directions and explaining the steps in the playable tutorials.

Data Analysis Plan

For the general analysis of the overall data we plan on comparing the total number of correctly solved trials in a task (known as hits) and the total number of incorrectly answered trials during the task (misses) in the *Recollect* data to data from the *Saving Memo* task logs. More specifically, we will be comparing the perfect trials (trials answered perfectly) and imperfect trials of the Simple Corsi task to the average correct and average incorrect answers in the Telephone Number Task (now changed to Data Entry Task). For the SuperMarket task, we will be comparing the number of correct and incorrect actions the user has taken since the last time they looked at their shopping list to the hits and misses in the Letter Numbers task. The number of correct and incorrect responses per trial of the Post Office task will be compared to the hits

and misses in Complex Corsi. Memo's Meals will not be compared to any one specific *Recollect* assessment and will be compared to all the *Recollect* assessments. As an additional measure, all *Saving Memo* tasks will be compared to all *Recollect* assessments via a correlation. The analysis for the data gathered in this study is largely experimental. We expect to analyze the data according to our plan above however, it is very likely that after our planned analyses have been completed additional analyses will be needed.

Survey Data

Data gathered from surveys will be used to improve future versions of the game. For the first feedback survey, we will be looking at how the participant's perceived difficulty compared to their overall enjoyment of the *Saving Memo* tasks. In the second survey, we will be looking at how challenging and enjoyable the participants find each *Saving Memo* task in comparison to each other. We will also see how taxing to their WM the participants feel each task is.

Tasks

The tasks developed for Saving Memo are the following: Data Entry Task, SuperMarket Task, Post Office Task and Memo's Meals. The participants were instructed on which buildings to click from the menu selection screen (*See Figure 1*). The order of the tasks was the same as what was listed previously. A one minute break was offered to participants after completing the SuperMarket task, though not all participants opted to take a break. All tasks have a written instructions screen before the participant plays the game. At the time of proof of concept testing, the only task that had a playable tutorial to help the participant understand the task was Memo's meals. The rest of the tasks were explained verbally by the person administering the test if the participant did not understand the written instructions. Future versions of the app are expected to have playable tutorials for all tasks.

Recollect refers to the Recollect The Study app developed by the BGC. In this app there are several cognitive tasks that have been previously validated by the BGC. The tasks used in comparison to those in Saving Memo were the following: Letter Number Task, Cancellation Task, Simple Corsi, Complex Corsi, and N-Back. The order of the tasks were predetermined by a server code that took the participant through the tasks in the order listed previously. A one minute break was offered in the app to participants after completing Simple Corsi, though not all participants opted to take a break. Each task also has a short playable tutorial to help the participant understand what is expected of them in the task.

Saving Memo

From the main menu screen (*See Figure 1*) participants are able to choose which job they will be completing for the day. Tapping on the Supermarket takes the participant to the SuperMarket task, the Post Office takes the participant to the Post Office task, the Office takes the participants to the Data Entry task and Memo's Meals takes the participant to the Memo's Meals task. In future versions of the app, the House feature will be active. Here the participant will be able to tend to Memo for a certain amount of time before they need to continue working.

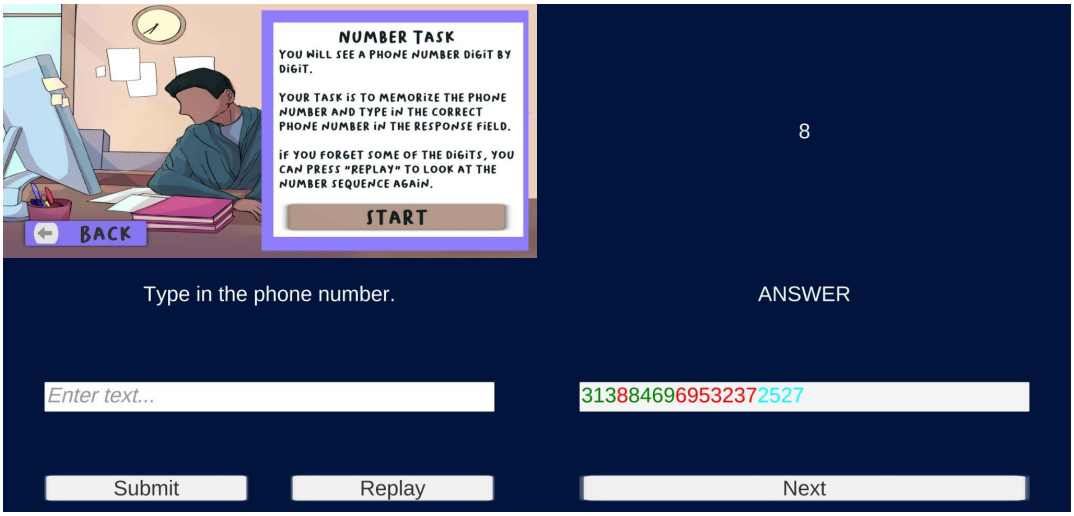
Figure 1

Note: Screenshot of the menu screen in *Saving Memo*

Data Entry Task. In this task, the participant is presented with a string of numbers one number at a time and are expected to memorize that string of numbers (the strings of numbers are 15-20 numbers long using 0 through 9). If the participant needs a refresher, a "Replay" button is available for them to review the string of numbers from the beginning of the sequence. Once the participant hits the "Submit" button, the numbers submitted will change colors to show the participant how they performed on the trial. The color green is used to signify correct numbers in the correct place, red numbers are incorrect and blue numbers are ones that were missed. During the proof of concept testing, the game was called "Phone Number Task" but, upon feedback from participants was changed to the "Data Entry Task" (*See Figure 2*).

This task was inspired by the Simple Corsi task in *Recollect*. In Simple Corsi, participants are shown an array of gopher burrows where gophers pop out in a specific sequence the participant is to memorize. Once the sequence is completed, the participant is to repeat the sequence by tapping the gophers in the same order as the sequence. In the case of our Data Entry task, the gopher is replaced by the sequence of numbers. After the sequence is done, participants still tap in order, however they are instead typing numbers into a keypad instead of tapping on gophers in the order in which they popped out. All in all, the concept of recalling the order in which the stimuli were shown is the same.

Figure 2



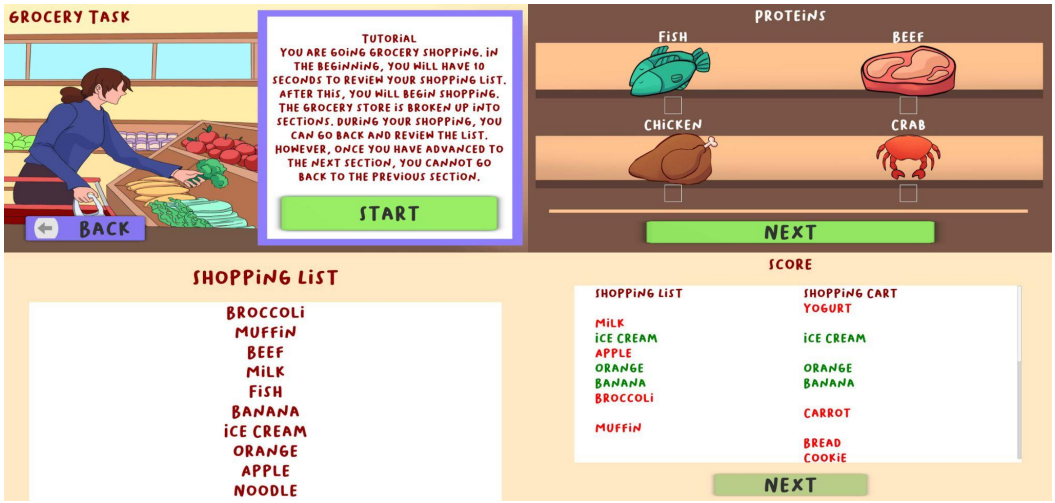
Note: Screenshots of instruction screen, stimuli, response and feedback (from left to right)

SuperMarket Task. In this task, the participant is told that they are going grocery shopping. At the beginning, they are given ten seconds to review a randomized shopping list. For the purpose of the proof of concept testing, the number of each item needed was defaulted to one. The grocery store was broken up into different sections: fruits/vegetables, bread/grains, dairy, and protein. The order of which aisle the participant arrives at after seeing the list and after each finishing in one section is randomized but, every section is shown only once. Participants can only go back and review their shopping list once they have gone through all four sections of the market (*See Figure 3)*. After the participant submits their items, the original grocery list will pop up on the right side of the screen beside a written list of what the participant "bought" on the left. Items on the right will change color. Items with red text are incorrect while green text signifies a correct item.

As described in the data analysis plan above, we plan on comparing the Post Office task to the Letter Number Task in *Recollect*. The basis of the letter number task is for the participant to remember and sort the numbers and letters presented to them numerically and alphabetically using a keypad. For example the sequence 'E3T2H6' would be sorted into '236' and 'EHT'. The

SuperMarket task is similar in the sense that participants in future versions of the task would be asked to memorize different amounts of each food item (i.e. 4 ice cream cones) instead of just the one used in proof of concept testing. The sorting comes from the randomization of the order in the shopping lists and the randomization of the appearance of each aisle.

Figure 3

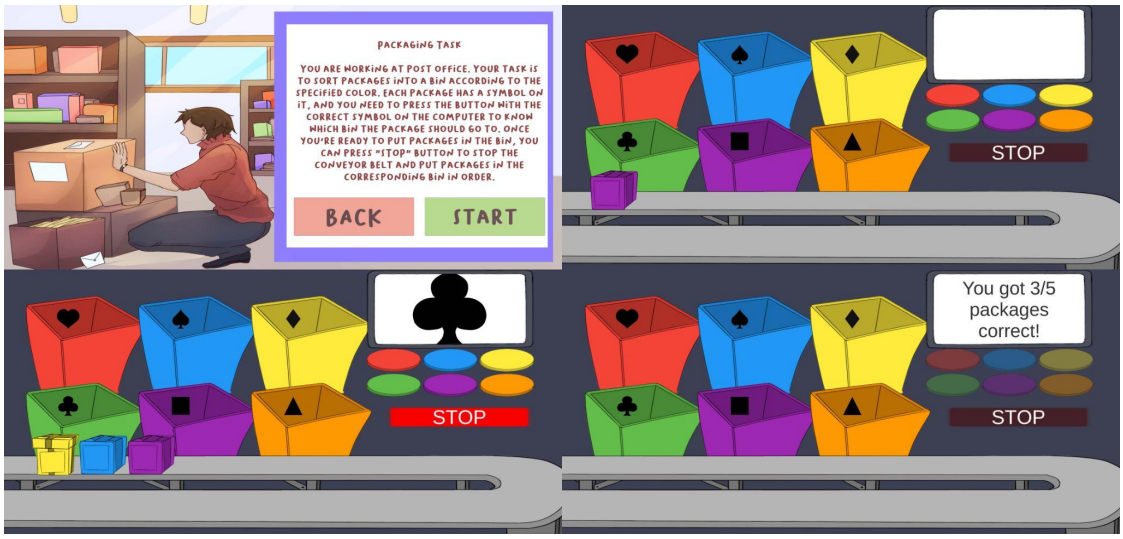


Note: Screenshots of instruction screen, example aisle, example shopping list and feedback (from left to right)

Post Office Task. In the Post Office Task, the participant is told that they are working at a post office. The goal of the task is for the participant to sort packages into a bin according to the specified color given after the participant records the symbol on the package. The packages in the task can not be sorted until the participant stops the conveyor belt. This means that the number of packages sorted at once will be determined by individual participants. Once the conveyor belt is stopped, it takes five seconds for the machine to release more packages onto the conveyor belt. Once all the packages are sorted, the number of packages sorted correctly is displayed on the in-game computer screen (*See Figure 4*).

This task was created with Complex Corsi in mind. The Complex Corsi task is similar to the Simple Corsi task however, between each trial, the participant must drag a dog to a bone or a monkey to a banana. The act of dragging the monkey or dog is a secondary task that the participant is told they must get at least 85% correct or else they will need to do the task again. In the case of the Post Office task, the act of inputting the color of the package to get the shape in which it will be sorted is the secondary task. It is also important to note that unlike Complex Corsi, the participant is choosing how many packages they are expected to memorize at once instead of going through a sequence that is predetermined.

Figure 4



Note: Screenshots of instruction screen, example parackages and feedback (from left to right)

Memo's Meals Task. In this task, the participant is taking orders for a restaurant. Orders come in one at a time and participants are expected to memorize them as they wait for food to come out from the kitchen. The goal is to sort the food in the correct bag while handling as many orders as the participant feels like they can handle. If the participant happens to forget an order as they go through, they have the option of cancelling the order. Order cancellation results in a deduction to their tips. Orders are automatically cancelled if they are not completed in a certain

amount of time. At the 60 second mark, the name pertaining to the order will start blinking yellow and if it is not completed one dollar will be deducted from the total tips. When the correct food item is added to a bag twenty-five cents will be added to the tips earned from the order but, if the wrong food item is added to the bag, twenty-five cents will be deducted from the tips earned from the order. If the participant tries to send an unfinished order to the pick-up area, fifty cents will be deducted from the tips earned from that order (*See Figure 5*).

As previously explained in the Data Analysis Plan, we were unsure what tasks could possibly be correlated with Memo's Meals as it was created last and incorporated a bit of everything. In addition to comparing Memo's Meals to the *Recollect* tasks mentioned above, the Cancellation task and N-Back task will also be examined. In the task, pictures of a cartoon dog and a cartoon monkey are used as stimuli. Participants are asked to tap on the "crazy monkeys" — meaning brown monkeys that have been rotated to be on their heads facing to the left of the screen and "good dogs" — meaning dogs that are on their feet, facing the right with a certain color pattern. In the N-Back, the participant is presented with a stream of animal pictures. The goal of the task is for the participant to tap on the animals that match those presented a certain number (N) of items earlier. Much like we expressed before, the major difference in the task we designed (Memo's Meals) and those from the *Recollect* app is that the participants are largely in control of their 'memory load'.

Figure 5

Note: Screenshots of instruction screen, example orderi and feedback (from left to right)

Proof of Concept Test

Participants

Participants in the proof of concept testing consisted of 20 college undergraduate students that were already research assistants (RAs) at the UCR Brain Game Center. The RAs were already familiar with *Recollect the Study* for the most part but knew nothing about *Saving Memo* other than who was working on the project. Participants were chosen based upon their availability and how many other participants for different studies were already scheduled due to the fact that RAs administer sessions for other studies. Because of the way participants were chosen, it is expected that there is not an even gender ratio.

Testing

Proof of concept testing was broken up into two sessions no more than two days apart. The first session consisted of playing all four *Saving Memo* tasks followed by a feedback survey in which participants were asked to rate each task on difficulty and enjoyment using a one to five likert scale. The survey also asked participants to make notes of anything the tasks were unclear about and if they had any suggestions on how to improve the tasks. In the second session, the

participants completed one session in the *Recollect the Study* app. After finishing their session, the participants were asked to complete a second feedback survey in which they ranked all tasks (four from *Saving Memo* and five from *Recollect the Study*) in order of most enjoyable / challenging to least enjoyable / challenging.

Results

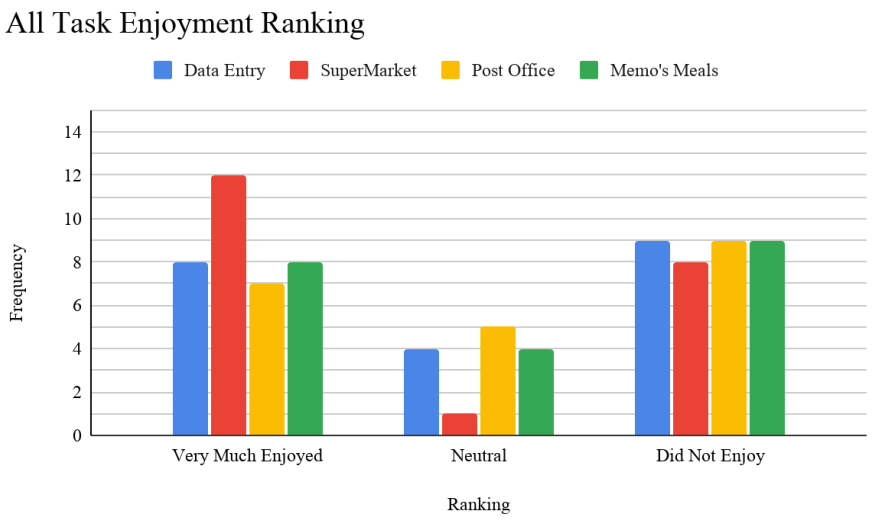
Proof of Concept Test

Survey

Participants were given feedback surveys after finishing both session one and session two. From these feedback surveys we found that participants found the Data Entry task to be the least enjoyable (*See Figure 6*) , the most taxing on their working memory (*See Figure 7*) and the most difficult (*See Figure 8*) . How difficult participants found the task greatly outweighed how much they enjoyed the task in comparison to the other three Saving Memo Tasks.

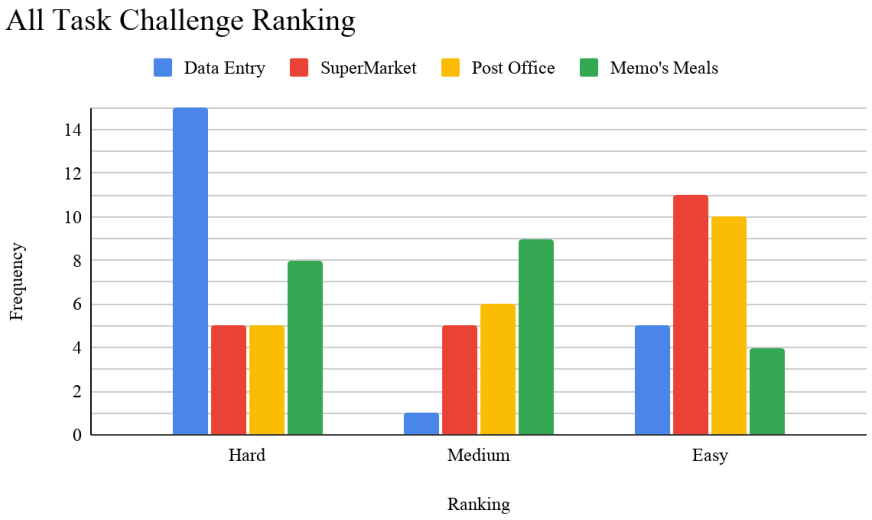
Based on these results, future versions of the Data Entry task will try to incorporate more visually appealing elements like the other tasks. Currently, we are working on a background to use to replace the solid blue background currently being used. We may also make the background look more like a desktop of a computer in order to make the task feel as though it has more of a connection to the overall game narrative.

Figure 6



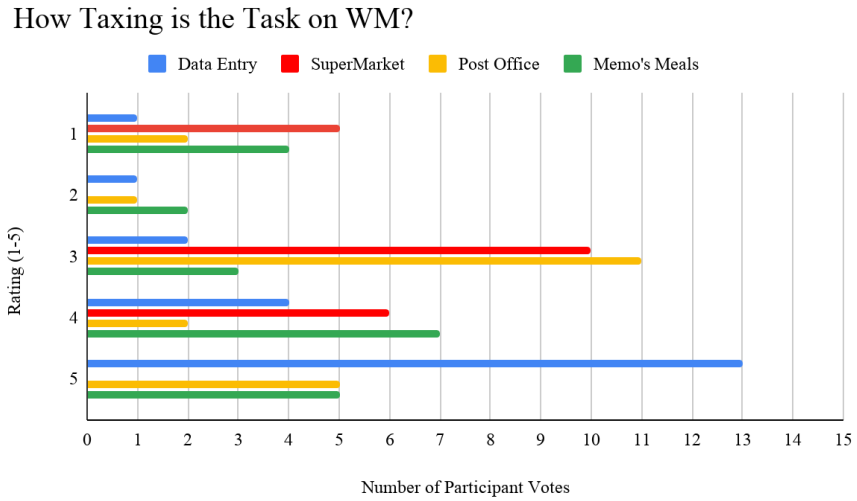
Note: Graph depicting the level of enjoyment participants found in each task.

Figure 7



Note: Graph depicting how challenging the participants found each task

Figure 8



Note: Graph depicting how taxing on their WM participants found each task

Testing

We found a significant correlation between the median number of correct numbers per replay in the Data Entry task and the imperfect trials in the Simple Corsi task (r=.492 ; p <.05), the median number of correct numbers per replay in the Data Entry task and the score in Simple Corsi (r=.543 ; p <.05) and the score in Simple Corsi and the average of new numbers entered after a replay (r=.464 ; p <.05). This result suggests that the amount of correct numbers a participant inputs after replaying the number sequence has some relation to the participants simple corsi score.

We also found a significant correlation when comparing the SuperMarket task and the Letter Number task. The most significant finding to note is the correlation between average correct actions (meaning the addition or subtraction of items to the participant's shopping cart after revisiting an aisle), imperfect trials (r= .578 ; p<.01), score (r=.698 ; p<.01) and span (r=.71 ; p<.01). This suggests that the overall performance of a participant in the SuperMarket task does compare to their performance in the Letter Number task as we wanted.

We also found no significant correlation between the Post Office task and the Complex Corsi task as we had previously thought. However, further analysis is required to see if there is a significant correlation between the Post Office task and other *Recollect* assessments. It also may be the case that our current task logs do not record the information needed to properly compare both assessments.

Lastly, we found a correlation between Memo's Meals and a couple different mixed scores of the Cancellation task. Mixed refers to the fact that two stimuli were used in the trials. Our findings suggest that the amount a participant misses in the task is comparable to the average incorrect (r=.651 ; p<.01), median incorrect (r=.599 ; p<.01), median orders (r=.573 ; p<.05) and average orders (r=.599 ; p<.01) in *Saving Memo*.

Table 1

Correlation between the Data Entry task and Simple Corsi

	Average New Numbers Per Replay	Average Correct Per Replay	Median Correct Per Replay	Average Incorrect Per Replay	Median Incorrect Per Replay
Imperfect Trials	.377	.373	.492*	-.009	-.048
Score	.464*	.419	.543*	.019	.166
Span	.284	.262	.317	.037	.260

* p< 0.05 level
**p< 0.01 level

Table 2

Correlation between the SuperMarket task and Letter Number

	Average Correct	Average Correct Actions	Average Number Reviewed

Imperfect Trials	-.133	.578**	.411
Score	-.107	.698**	.562*
Span	-.037	.710**	.621**

* p< 0.05 level
**p< 0.01 level

Table 3

Correlation between Memo's Meals task and Cancellation

	Average Incorrect	Median Incorrect	Average Orders	Median Orders
Mixed Hits	-.239	-.236	-.359	-.436
Mixed Miss	.651**	.599**	.573*	.599**
Mixed Correct Rejections	-0.283	-0.264	-0.33	-0.41
Mixed Score	-.299	-.297	-.406	-0.482*

* p< 0.05 level
**p< 0.01 level

Conclusion

Given that the analysis of the tasks designed in *Saving Memo* is experiential in nature, it is quite possible that the fault lies behind the variables we decided to record not being enough to perform a thorough analysis. Although it seems this study does not address everything we wanted it to, the results of further study can have possible clinical implications. If we continue to develop and adapt *Saving Memo*, it is possible to develop an app that succeeds in the integration of OT concepts and CT could quite possibly lead to a better quality of life and better functioning for a wide variety of people.

One limitation of the study is that it was tested on RAs who were already familiar with the *Recollect* tasks. We attempted to control for this by having participants do the *Saving Memo*

tasks first however, it is still possible that their prior experience had a significant effect on our data. Future non-proof of concept testing will involve participants that do not have prior experience with either app.

This limitation aside, *Saving Memo* is still a necessary stepping stone in the field. There is a need for tasks that can be administered remotely or that can be done in the comfort of one's home. Not only this, but technology is integrating itself into many aspects of our everyday life and with that should come assessments that do the same.

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