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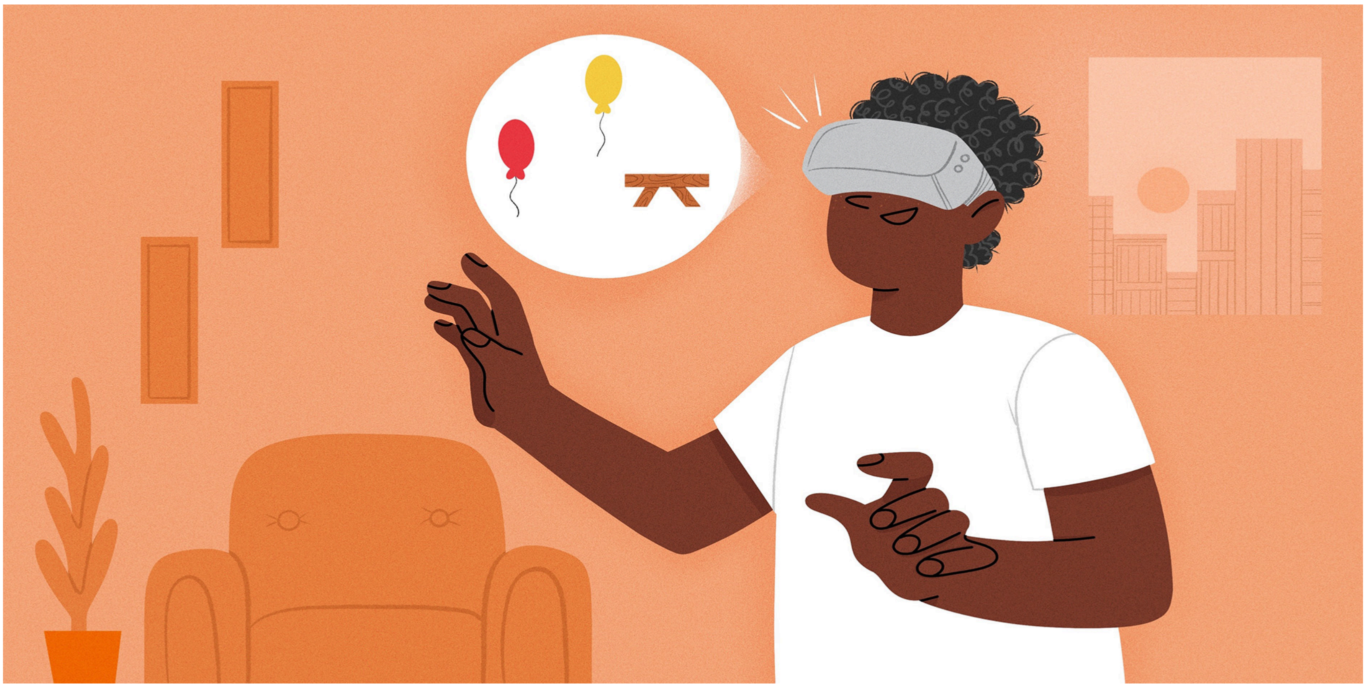

VIRTUAL REALITY VIDEO GAME IMPROVES MEMORY IN OLDER ADULTS

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YOUNG REVIEWERS:

BILLINGHURST MIDDLE SCHOOL
AGES: 11–12

SPANDANA
AGE: 15

The ability to remember detailed information is called high-fidelity long-term memory. We use high-fidelity long-term memory to remember the details of our favorite stories and how to track which family member a green pair of socks belongs to. As we age, the ability to remember these details declines as the health of the brain changes. We created a virtual reality video game called Labyrinth-VR, with the aim to restore memory. When playing Labyrinth-VR, participants practice figuring out where they want to go using the shortest route to get there. In Labyrinth-VR, participants learned a virtual neighborhood and then had to find their way around to run errands. In our study, 49 older adults played either 12 h of Labyrinth-VR or 12 h of iPad games. The results of tests of high-fidelity long-term memory showed that playing Labyrinth-VR, but not iPad games, led to improvements in participants' scores.

WHAT IS LONG-TERM MEMORY?

Think back to your 1st day at a new school, do you remember how big the building felt and complicated it was to find your classroom? After a few months it felt like you would be able to find your way around blindfolded. You could even show a new student how to get from your classroom to the cafeteria without getting lost. Your memory allows you to recall and use information you learned earlier. The memory system in the brain works in three steps. The first step is called learning, or **encoding**, and it involves taking in information. Before we can retrieve information, we first must pay attention and encode it.

ENCODING

The initial learning and storage of information into our brains.

In the second step, the encoded information is stored in the brain. Each day, our brains encode a lot of information. For example, when your teacher first showed you your classroom, you encoded information about the room number, whether you had to go upstairs, and which other rooms were nearby. Most of that information is stored in the brain in a more stable state when we sleep. These memories can be updated over time, or they can fade away. **Long-term memory** is the ability to remember information that we encoded and stored from a past experience. The third step of memory is called retrieval. Retrieval is when we try to remember specific information, either using effort, such as for a test, or more automatically, such a walking to your classroom every morning.

LONG-TERM MEMORY

The ability to remember information that we encoded from past experiences.

There are several forms of long-term memory, but one of the most important forms is called **high-fidelity long-term memory**. Sometimes when we recall our memories, we leave out or confuse certain details because we cannot remember exactly what happened. The word "fidelity" means that something is accurate or loyal, so "high-fidelity long-term memory" means that we remember experiences with specific details about how they happened. This type of memory is demanding on the memory system because it requires us to encode detailed information, store its details in long-term memory, and retrieve it accurately. This process is dependent on a part of the brain known as the **hippocampus** [1].

HIGH-FIDELITY LONG-TERM MEMORY

The ability to remember highly detailed information from an experience.

HIPPOCAMPUS

A brain region that is necessary for learning, memory, and spatial navigation.

High-fidelity long-term memory often declines as the brain ages and goes through normal, age-related changes in the health of the hippocampus [2]. As people get older, they have a harder time learning, remembering, and maintaining fidelity in their long-term memories. This means that when they remember—or retrieve—something, they may leave out key details. There are currently no treatments that can restore high-fidelity long-term memory.

WHAT IS SPATIAL NAVIGATION?

Have you ever found your way out of a corn maze? Then you have used **spatial navigation**! Spatial navigation refers to the ability to

SPATIAL NAVIGATION

The ability to learn your surroundings, to navigate your path to where you want to go using the most efficient route.

take information from our surroundings and navigate from where we are to where we want to go, in the most efficient way. Spatial navigation uses many of the same brain systems that are used for long-term memory. From studies in animals, we know that exploring in new, complicated environments can improve function in these same memory systems [3–5].

We were curious whether the same type of spatial navigation tasks that showed memory improvement in animals could also improve memory in humans. Since older adults often experience a decline in long-term memory, we believed they would benefit the from spatial navigation training as a way to strengthen their long-term memory system.

HOW CAN A VIRTUAL REALITY VIDEO GAME IMPROVE LONG-TERM MEMORY?

VIRTUAL REALITY

Computer-code generated 3D images that you can interact with *via* a special headset. These are not at all actual images.

For our experiment, we developed a **virtual reality** video game called Labyrinth-VR, for human participants to practice spatial navigation. Virtual reality is a 3D computer-simulated environment that participants can interact with and move through by wearing a special headset (Figures 1A, B). In Labyrinth-VR, participants learn new neighborhoods, then demonstrate what they have learned by efficiently navigating to complete assigned errands. For example, a participant may be assigned to navigate to a grocery store, a bank, and a restaurant as their errands.

Labyrinth-VR gets more difficult the more people play, to make sure participants are consistently challenging their memory systems. When a participant successfully completes the errands in a neighborhood, they then move up a level and they must complete all the errands again in a thick fog that limits their visibility. Once they complete all the levels in a neighborhood, they move up to a bigger, more complex neighborhood with new errands.

Labyrinth-VR is designed to train spatial navigation by challenging participants to navigate through completely unfamiliar surroundings. Additionally, wearing sensors on their ankles, participants can walk through the virtual game environment just like they would in real life. Walking around in the game makes the experience feel more real, and participants get some exercise, which has been shown to improve memory and brain health [6].

TESTING LONG-TERM MEMORY

In our study, we wanted to see whether playing Labyrinth-VR could improve memory more than playing other video games could. To test this, we randomly assigned 49 healthy older adults (average age 68.7 ± 6.4 years, 20 females and 29 males) into two groups. One group played

CONTROL GROUP

The group in a study that does not get the experimental treatment, but completes the entire experiment procedure. Scientists compare the results of the experimental group to the control group to see if the experimental treatment had an effect.

12 h of Labyrinth-VR and the other group, called the **control group**, played 12 h of commercially available iPad games at home over 3–4 weeks (Figure 1C). Each training session was 45 min.

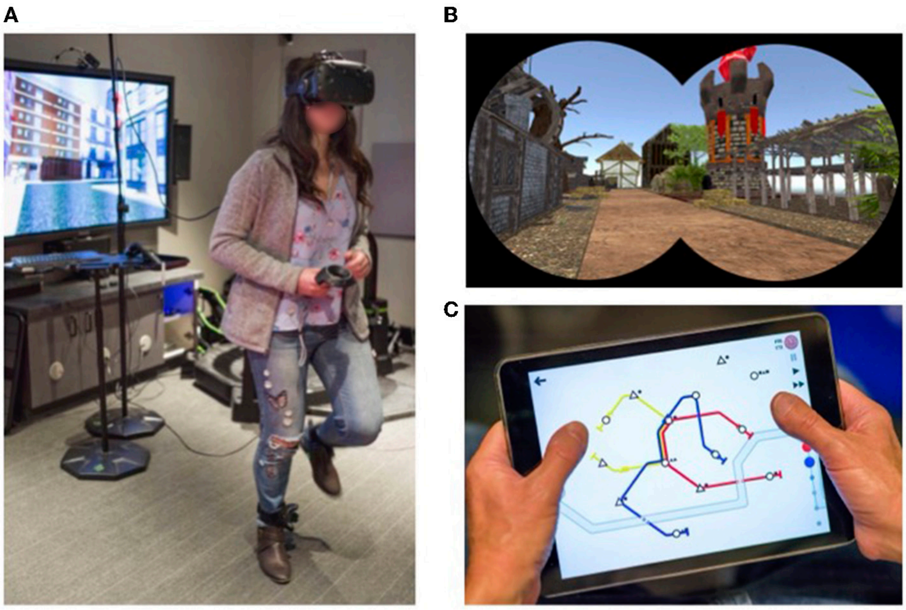

Figure 1

Figure 1

In our experiment, participants were assigned to one of two groups. One group played Labyrinth-VR and the other group played the control iPad games. **(A)** A participant wearing a VR headset and playing Labyrinth-VR. **(B)** The participant's view within the Labyrinth-VR game. **(C)** An example of a control iPad game.

The games played by the control group were rated as being similarly engaging as Labyrinth-VR but different enough from our game so they would not train the memory system. None of the iPad games required navigation, long-term memory, or physical exercise.

How did we measure long-term memory to see whether it improved or not? First, we needed a starting measure of memory performance before participants started training. We did this by testing all the participants in both the control and Labyrinth-VR groups with the same memory task. We then tested them again *after* they completed all 12 h of training, to see if their performance changed.

MNEMONIC DISCRIMINATION TASK

A task designed to test how well people can remember details about objects and tell the difference between identical and similar images.

The task we use to measure long-term memory is called a **mnemonic discrimination task**. The task is designed to assess how accurately participants can remember details about images they were shown (Figure 2). First, participants completed an encoding phase by studying images of common objects, such as a red balloon. After a 30-min break, participants were tested on their memory of the objects. They were shown one image at a time and were asked if they recognized the object from the encoding. They were shown three types of images: the exact object they saw in the encoding phase, like the red balloon; an object that was not in the encoding phase, like a table; and an object that was not in the encoding phase but was similar to one that was, like a yellow balloon.

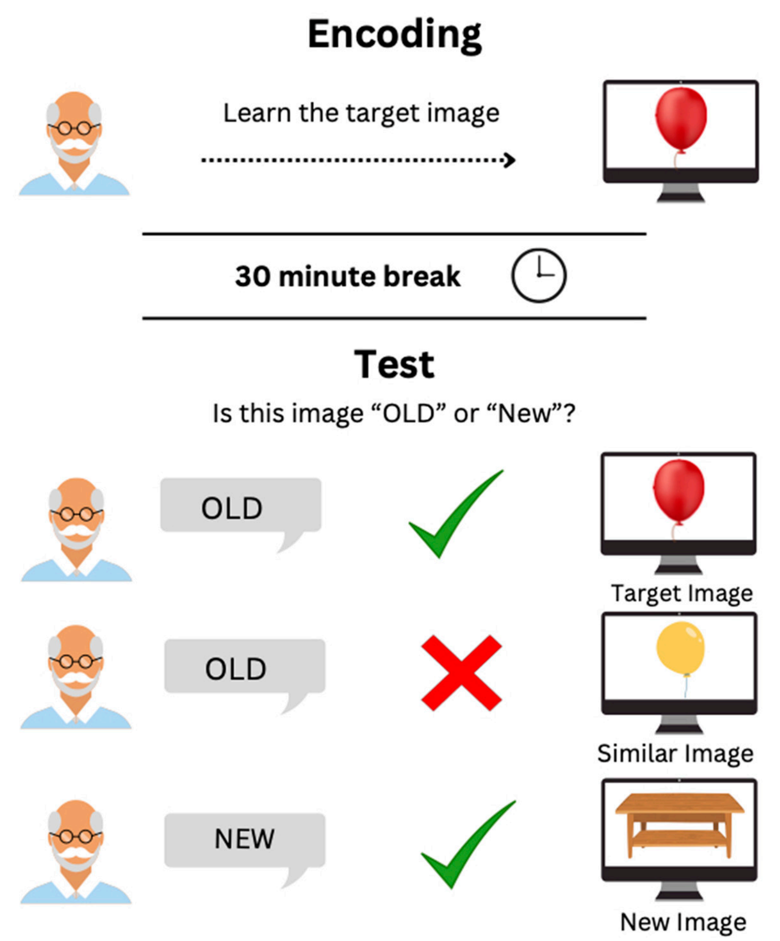

Figure 2

Figure 2

We used a test called a mnemonic discrimination task to measure long-term memory in our participants before and after they trained with either Labyrinth-VR or control iPad games. During the test, participants first had to encode target images. Then, they took a 30-min break. After the break, they were shown images and asked whether they were "old" (meaning the same image they saw during the encoding phase) or "new" (meaning they had not seen the image before).

If a participant remembered detailed information about the objects in the encoding phase, they would be able to correctly identify the red balloon as an "old" object they had seen before, and the table and yellow balloon as "new" objects they had not seen. If a participant could not remember detailed information about the objects in the encoding phase, they might incorrectly identify the yellow balloon as "old" because they did not remember the color of the balloon from the encoding. The proportion of correctly identified objects gives us a score to use as a starting measure of a participant's long-term memory.

After participants completed their training with either Labyrinth-VR or the iPad games, they took the same test of long-term memory. We wanted to see if, in the post-training test, they could correctly identify more objects, the same number of objects, or fewer objects compared to their starting score [7].

PLAYING LABYRINTH-VR HELPS LONG-TERM MEMORY

When we compared the starting and post-training memory scores for each participant, the results showed that the participants in the Labyrinth-VR training group gained greater improvements in high-fidelity long-term memory than the iPad control group did. We found that participants in the Labyrinth-VR group correctly identified more objects than before their training, which means their ability to remember detailed information had improved (Figure 3). They also improved more than the iPad control group did. This tells us that the increase in their scores was likely due to the Labyrinth-VR training and not to other factors [8].

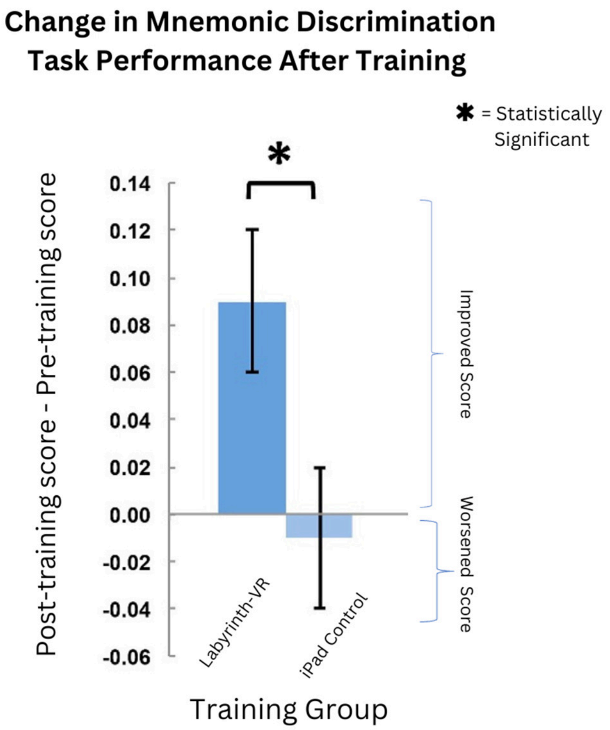

Figure 3

Figure 3

Participants that played Labyrinth-VR showed improvement in long-term memory after 12 h of training. The Y axis shows the difference in their mnemonic discrimination task score from pre-training to post-training. The group that played the control iPad games did not show any improvement in long-term memory.

Because participants made it to different levels of difficulty in Labyrinth-VR by the end of their training, we also looked at whether the level a participant got to was related to how much their scores improved on the memory test. The results showed that the higher the level they achieved in Labyrinth-VR, the greater the gains in memory test scores.

WHY IS THIS IMPORTANT?

In this study, we compared long-term memory performance before and after older adults trained with Labyrinth-VR or with control iPad games. We found that, after 12 h of training, the Labyrinth-VR group improved their long-term memory performance more than the control group did. We also found that the achievement of higher levels in Labyrinth-VR led to greater improvement in long-term memory.

High-fidelity long-term memory declines as people age, and this decline can impact daily functioning. There are currently no treatments or medicines available to help prevent this decline. Our study showed that training using a virtual reality game led to improved long-term memory capabilities in healthy older adults. Our findings also led us to new questions that can be answered by future research. For example, would Labyrinth-VR that did not involve exercise also improve memory? Could Labyrinth-VR improve memory for people experiencing memory loss as they age? What can we learn about the brain's memory system by scanning people's brains before and after they complete Labyrinth-VR training? By answering these and other questions, we may be able to develop a treatment to help adults maintain the health of their long-term memory systems as they grow older.

ORIGINAL SOURCE ARTICLE

Wais, P. E., Arioli, M., Anguera-Singla, R., and Gazzaley, A. 2021. Virtual reality video game improves high-fidelity memory in older adults. *Sci. Rep.* 11:2552. doi: 10.1038/s41598-021-82109-3

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

BILLINGHURST MIDDLE SCHOOL, AGES: 11–12

This paper was reviewed by Billinghurst Middle School 7th graders in Mrs. Callahan's science class. These students took time from all the important things (e.g., studying, sports, clubs, and TikTok) to think about older adults' memory. All of them are hopeful there will be more VR in their lives, and this paper convinced them that it would be really good for their brains, too.

SPANDANA, AGE: 15

Hello, my name is Spandana! I like to read fantasy books and play volleyball. I find science interesting and love to learn about psychology and space. Some of my hobbies are drawing, listening to music, and playing my guitar.

AUTHORS

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I am a Clinical Research Coordinator in the Department of Neurology at the University of California San Francisco. I received my undergraduate degree in Psychology from the University of San Francisco. I currently work with Dr. Peter Wais on research studying how virtual reality cognitive interventions can improve memory in older adults. Outside of work, you can usually find me in the yoga studio, exploring nature on a hike, or at home crafting.

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