Illusionment

Inaugural lecture delivered by

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upon acceptance of the position of professor
with the chair
Technological innovations in neuropsychology
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"Those of us who are willing to rumble with vulnerability, live into our values, build trust, and learn to reset will not be threatened by the rise of the machines, because we will be part of the rise of daring leaders."

Brené Brown, in *Dare to Lead*

It is 2009 and Mrs. AC comes to the UMC in Utrecht. She is desperate because she gets lost. Not occasionally, but very often, and at moments that can be very dangerous. A seemingly healthy, young, smart woman, not a care in the world... But she is driving 120 kilometers per hour on the highway with her three young children in the backseat. Suddenly, she doesn't know how to continue and panic sets in. Did I miss my exit? Or was it the next one? Or am I still far away, where was I going? With these problems, Mrs. AC ended up at Martine van Zandvoort, clinical neuropsychologist, after many detours. She had unknowingly suffered a brain haemorrhage and the only noticeable effect was getting lost. But what was known? None of the existing neuropsychological tests could demonstrate this deficit. It simply wasn't possible to describe the intense experience of this woman in a test report. So what is needed to study getting lost? Martine involved me in this puzzle, in search of the solution, and here we are, 14 years later.

Madam Rector Magnificus, members of the board of the Leiden Faculty of Social Sciences, dear colleagues, beloved family and friends, highly esteemed audience! With great pleasure, I officially accept today my appointment as professor with a chair in Technological Innovations in Neuropsychology. The story and puzzle of Mrs. AC have set me on the path that leads to the technological innovations we are going to discuss today. I am very excited to share that path with you, and especially how we can use technology to get closer to the patient's experience.

Technology

What do we mean by technological innovations? Are we talking about complex devices, or simply the increasing role of computers, smartphones, and wearable devices? When we look at the use of technology in neuropsychology, we can discover different forms. The most accessible form is simply digitizing existing tests. Traditionally, tests of cognitive functioning are often administered on paper. With the increasing accessibility of computers in the 1980s, it became easier to administer these tests via a screen. The test itself doesn't change; for example, the same images are still used in a memory task. But the measurement of the given answers becomes more precise and less prone to errors. This relatively passive form of technology use is also seen in our daily lives: things that we used to write down, like a shopping list or an address, are now simply entered into our phones. As technology continued to develop, more became possible. In addition to simple digitization, replacing paper with a screen, we see increased use of the additional possibilities that technology offers. Test questions can be adjusted to the performance of the person being tested; is it too easy? Then we skip a few questions, or automatically offer a different type of question. Our shopping lists evolve in this way too, automatically arranging items in the supermarket app based on the layout of the store or showing us the relevant offers. We can make is easier for ourselves.
More recently, we see the growth of interaction with technology: we can have people do exercises when they need treatment. A computer program can teach them something. These exercises serve a serious purpose, such as improving memory strategies, but take the form of a game: serious games. The game format makes the exercises motivating, can provide more insight into progress, can be done at home, and simply make things more enjoyable. We see this more and more in places like museums, schools, and various workplace training programs. My children are regularly assigned to play games at home to improve their math skills in a "gingerbread cookie battle" or to better remember geography by exploring an interactive map.
In recent years, a special form of technology has taken flight: spatial technology. With the emergence of virtual reality and augmented reality glasses that allow us to display digital environments, a unique opportunity has emerged. We can give people a complete experience of another world and measure how they experience that world. In the short time that this technology has been readily available, with the first realistic and widely accessible virtual reality glasses Oculus Rift being on the market for only 10 years, we already see impressive applications of this technology in healthcare. With spatial technology, we can realistically recreate the real world. This has the advantage that participants are not unnecessarily physically burdened and logistical barriers can be eliminated. You don't have to walk or drive far because the experience comes to you. The persuasive power of spatial technology

means that emotions are strongly experienced. This is why it offers the ideal conditions, for example, to expose people with anxiety disorders to situations that frighten them, such as flying or triggers of traumatic experiences. But at the same time, the user is fully aware that what they are experiencing is not real. The glasses can be taken off at any moment. It is an illusion.
In addition to striving for a world that is as realistic as possible, we can also create an alternative world. A world in which things exist or happen that are not possible at all. An impressive example is SnowWorld. People who have suffered severe burns can enter a virtual world here. They have to undergo the painful procedure of changing their bandages regularly. During this procedure, wearing a VR headset, they can participate in a snowball fight. Not only does this distract them from the unpleasant situation they are in and the pain they have to endure, but the fact that they seem to be standing in the snow and can throw cold snowballs at snowmen, penguins, and robots causes them to physically react differently to the treatment. They experience less pain, and fMRI brain scans show that pain-related brain activity decreases significantly. That's how strong the illusion is. We can change the patient's experience.

Illusions

Spatial technology has given us another illusion. You have just experienced it in the IllusionLab. Hopefully, the illusions there were entertaining and maybe surprising or even frightening. Illusions are used for entertainment. David Copperfield could confuse an entire audience by seemingly making a whole plane disappear. But illusions also have scientific value: they show us how our brains process information and how they deal with conflicting information.
I had already come up with the title of this inaugural lecture when I realized that my very first scientific experiment was also about an illusion. As a new master's student, I started working with Chris Dijkerman and Marjolein Kammers. Chris had a device in storage that he wanted to use. It was a large contraption with a machine suspended in it, and at the end, there was a small cylinder that would vibrate when you turned on the device. When this cylinder vibrated on the tendon of your upper arm, something miraculous happened. Due to the vibration, it seemed as if the tendon extended. And the only logical explanation for this elongation is that the whole muscle elongates and thus moves your forearm downward. It was a very strange sensation; as long as the device was on, you felt your forearm making a downward movement. And what made it so interesting was that we investigated the impact of this sensation. We had people use their other arm to indicate where they felt their forearm was located – the perception condition: lower than the actual arm position, of course. We also asked them to point to the position of their fingertip with a quick movement – the action condition. And what did we find? The quick finger movement was hardly affected by the illusion (see figure 1). So, the illusion revealed that perception and action processes rely on different sources of information. The selective effect of the illusion provided evidence in psychological theory formation.

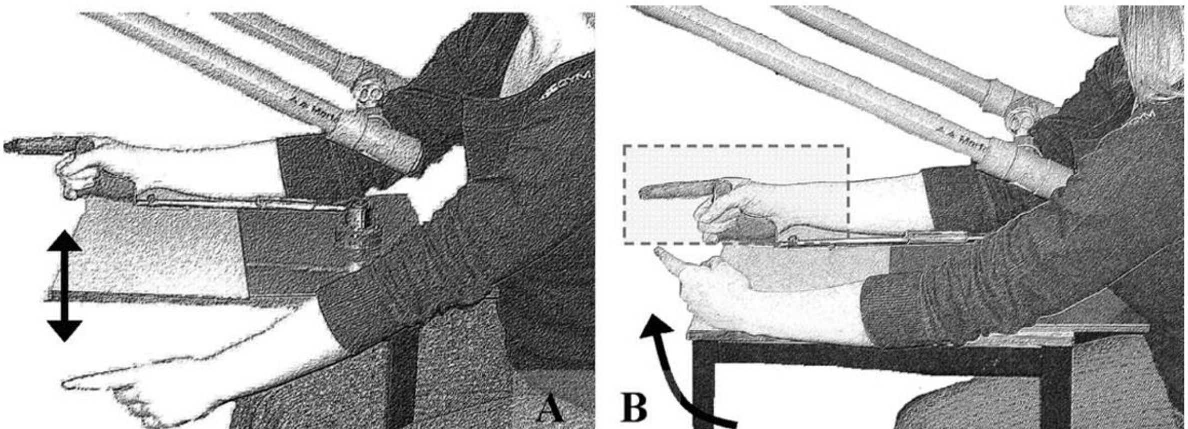

Figure 1. Representation of the influence of a vibrotactile illusion on A) perception and B) action [15].

The illusion of spatial technology is that we find ourselves in a world that seems real but is not. This is also described as the place illusion and plausibility illusion: we find ourselves in an imaginary place and perceive it as a believable situation. This is clearly illustrated by the Richie's plank experience. In the physical world, there is a plank on the floor only a few centimeters high and wide enough to stand on comfortably. In the virtual world, we see the same plank, but without the floor. Instead, we see a deep abyss because the plank extends from the rooftop of a skyscraper. No matter how much we try to convince ourselves that the abyss doesn't exist and that we can easily step off the plank, it is nearly impossible to take that step without fear and tension. There are plenty of videos showing people even falling off the plank because of this terrifying illusion. Reason and emotion are played against each other.

When using virtual reality, it is crucial to be aware of this illusion effect, as it can significantly influence our perception of space. However, this effect is not necessarily problematic. In fact, we can harness it to our advantage. I will tell you more about that later. There are several conditions for achieving a successful virtual illusion.

Firstly, the technology itself is important. Are we using a flat screen or a head-mounted display, such as a VR headset? The technology determines the level of immersion, which refers to how absorbed we are in the virtual environment and how disconnected we are from the real world. Other factors such as synchronizing head and arm-hand movements with the visual display increase immersion, as well as the presence of an avatar, a visible representation of the user in the virtual world. However, maximum immersion is not always automatically the best choice. For many applications, displaying the virtual world on a computer screen or even a phone is sufficient. It depends on what you want to achieve. For example, if you want to measure memory for objects, immersion may not be necessary. But if you want to elicit three-dimensional movements, stronger immersion is a good solution.

Secondly, we need to consider the user, and this is more complicated. There appear to be important individual differences that have often been ignored. Sense of presence is a central concept in this regard: to what extent does the user feel present in the virtual world? This is difficult to measure. Often, it is limited to subjective measures where the user indicates their level of presence. We want to explore attempts to use more objective measures in the coming years because it is crucial for the effectiveness of spatial technology applications. There are some indications that sense of presence may differ based on gender and age, with younger people and men experiencing a stronger sense of presence than older people and women. This raises the question of whether experience with technology contributes to faster and better acceptance of a virtual environment. If sense of presence is indeed a predictor of how well the virtual illusion works, it is important to maximize sense of presence for all users. Especially when we start using immersive techniques on a larger scale in healthcare and education, systematically advantaging or disadvantaging certain groups would not be desirable.

Creating a successful virtual illusion of an alternative world is a topic that both science and the arts deal with. The COVID-19 pandemic has given a powerful impetus to the development of alternative performances, such as virtual dance performances. Together with Anouk Keizer and Cinedans, we are researching how dancers and non-dancers experience the virtual world. This is essential knowledge for creating a convincing performance. It is expected that someone who is an expert in devising and executing precise movements is more aware of the experience of their own body. At the same time, we observe that dancers actively explore the virtual world. Does this make you more or less sensitive to input from the virtual world, and what does it do to your sense of presence? This is important to know, especially when creating virtual art, as your own experience as a creator may differ significantly from that of your audience. I will be conducting research with the dance company 'Another kind of blue' in the coming months to explore audience experiences during VR performances. They will be touring with a performance specifically designed for a VR experience. How does the audience's experience of a VR performance differ from that in a traditional theater? And where are the opportunities to use VR for a convincing illusion in a performance? The illusion of spatial technology is, therefore, a valuable tool for mapping individual experiences.

Care and education

If illusion is the tool, then what is the task at hand? The benefits of innovation in neuropsychological care seem to be mainly practical so far; through digitalization, we can measure and treat more effectively. But spatial technology offers us more than that. We have complete control over the world we can present. For example, the user can walk down the street without the distractions of heavy traffic, and we can always make the sun shine. As a result, the virtual space can provide us with a new experience. The patient's experience, that's the story we get, the puzzle we need to solve. It is our task to capture that experience with our toolbox of neuropsychological tests. And although we are very capable of mapping the different traditional domains of cognitive functioning in isolation, with the current means available, we don't always succeed in capturing that experience accurately in test results. Just look at the example of Mrs. AC. And even with other cognitive complaints, such as certain memory problems, we find that we reach the limits of traditional testing materials.

I would argue that we should use spatial technology to be able to capture that individual experience. Like someone with navigation difficulties told me during a navigation test in a virtual world, "Ah yes, this question, this is exactly what I can't do." There was recognition. I would like to note that, in my opinion, it is not necessary to approach the real world as realistically as possible. We already have the real world. But the technology enables us to better separate and examine the different elements of a cognitive task individually. We can insert the context we need and virtually transport ourselves in space and time. Apart from the possibilities for measurement, there may also be a need to change how we interpret measurements of spatial skills. Our daily lives have undergone significant changes in recent decades. Our spatial skills are increasingly in demand in a world where we are becoming more mobile and have more tasks and information to process in a single day. GPS systems can provide some relief, but certainly not always and not for everyone. For example:

Interviewer: *You mentioned that you sometimes get lost, what happens then?*
Person A: *Well, for example, at a festival, when I go to the bar or the bathroom, I learn where my friends are by heart. But it doesn't always work out. Once at Lowlands, I couldn't find my friends anymore, and I was sure I was in the right place. Even after sending messages, I couldn't find them, and I was really mad at them. I had to go outside; the party was over. And you know what happened the next day? I realized that I had walked back to the wrong tent with a completely different DJ.*

Interviewer: *You mentioned that you often get lost, do you struggle with it?*
Person B: *Oh, sometimes, for sure. I had a meeting in the building next to where I work, and I had to use a walkway between two buildings. I only know one route from here to that walkway, and I tried to reach it, but it was closed because of construction. Well, I couldn't figure out how to get to that walkway! I went outside, it was raining, pouring rain. And in the end, I arrived late, irritated, and soaked at the meeting.*

Interviewer: *What do you do to manage it?*
Person C: *Well, for example, when I go running... I moved six years ago, and I haven't been able to learn many different routes. But now I have one that's five kilometers long, and it's actually very safe because it always runs along the water, so I can't get lost. And I just run that route a few times in a row. Oh, and one thing I often do is pay close attention to things in the environment. So I'm very good at remembering details about houses, details about sidewalks, quirky posts, plants, and trees in people's gardens. It works quite well, but it goes wrong when it suddenly gets dark or when people change their garden, then I don't know anymore.*

These examples illustrate how significant the impact can be when you have difficulties with navigation. And this does not only apply to a handful of people with severe brain damage. In people with mild acquired brain injury, we see this occurring in about 30 to 40 percent. Moreover, the examples above don't even involve people with brain injuries. The individuals I spoke to are perfectly

healthy, intelligent, and function very well except for these complaints. So what could be going on here?
In 2009, Developmental Topographical Disorientation (DTD) was first mentioned. This is a condition where individuals are born with the inability to mentally visualize spatial information, similar to a kind of "spatial dyslexia." People with DTD do not have any visible neurological abnormalities, yet they struggle to form mental representations of spaces, such as the layout of their own kitchen or how a street will look after the next turn. Interestingly, this impairment persists regardless of how well they know a particular environment. In 2021, together with Ronald Veldhuizen, a journalist at the Volkskrant, I spoke with a woman who shared her experiences of getting extremely lost. This led to about 20 spontaneous responses from people who recognized themselves in her story and have spent much of their lives trying to figure out what is "wrong" with them. Even two years after the article was published, I still receive such responses. It is noteworthy that this woman mentioned that her mother and uncle had the same experiences. However, her mother's life was much more manageable since she was always at home, and everyone in their small town knew that. If someone wanted to speak to her, they would just visit her at home. This is not necessarily the case in today's society.
This condition of spatial dyslexia, although recently described, has existed for much longer and can vary in severity. This raises the question of what we consider as a "disability" in spatial skills in modern society. Are you only considered limited if the majority of people are better than you in this area? Or perhaps mainly if it creates difficulties in your daily activities? One could argue that we are overtaxing our biological abilities with how we currently organize our environment. Think about complex hospital hallways with various coloured and numbered routes, for instance. Additionally, we rely less on practicing our spatial skills due to our dependence on others, such as bus drivers, or technology like GPS systems. It is expected that the group of people with limited spatial skills is considerably larger than we suspect and will continue to grow in the future.
Spatial skills also exhibit a wide variation within the healthy population. This was also observed in a study conducted with medical students here in Leiden, involving Katja Bogomolova, Jos van der Hage, and Beerend Hierck. Practical experiments were conducted to explore the use of augmented reality in the classroom. Specifically, for complex spatial information like human anatomy, this form of education proved beneficial. A digital representation of the human body could be viewed from all angles, as if it were a hologram. We found that this form of studying resulted in better test results than studying from a book or a flat screen. Interestingly, this was the case mainly for students who struggled with spatial insight, as measured by a mental rotation task.
Therefore, these spatial forms of education offer a solution particularly for those who may find it more challenging to visualize. I am eager to explore this form of learning with our own students. With the exceptional teaching team of the clinical neuropsychology specialization master's program here in Leiden, we focus on training future neuropsychologists who possess a solid clinical foundation combined with insights and skills related to upcoming developments within the field. Therefore, I look forward to piloting immersive videos with our own students, allowing them to experience what it is like to live with dementia. Together with Judith Schomaker and Monika Theron, we will explore how this approach can enrich the curriculum. I see many possibilities in the future for incorporating this form of virtual experience in education.

To get lost
Getting lost is a significant problem. So, how do we find a solution? One of the main reasons why it is challenging to capture getting lost with traditional testing material is that these tests focus on small spaces. The required space is often no larger than an A4 sheet of paper and at most, as big as the surface of a table. However, getting lost occurs in large spaces. Research shows that the abilities needed to understand and remember small and large spaces only partially overlap. Once you start moving, different processes come into play to process spatial information. Therefore, it's not surprising that you can't measure a problem in large spaces using a test in a small space.

When we saw Ms. AC, the question was how we could effectively measure large spaces. The use of virtual environments provided the answer. We brought the large space into a small space using a regular computer screen. We showed her videos of virtual worlds and then tested her memory for various elements of that environment, such as landmarks, turns, and maps. With this approach, we were able to precisely identify where her limitations lay: remembering the order of landmarks. Another question that arose was how common this issue is. As mentioned before, she was not an exception. Through our research using the Wayfinding Questionnaire, we found these types of complaints in a significant portion of individuals with acquired brain injury in the Netherlands alone, totalling hundreds of thousands of people.

This motivated us to work on a theoretical model of getting lost, a test, and treatment options. I am delighted that after all these years, we have achieved all three. It's important to note that this was a team effort, bringing together various expertise. The first bridge was built by Albert Postma, and Anne Visser-Meily has been part of it from the beginning to connect science and care. Merel Braspenning, Michiel Claessen, and Milan van der Kuil have done tremendous work in setting up and conducting the research with both individuals with acquired brain injury and healthy participants. Based on literature research combined with experiments, we have developed a model for getting lost. When someone gets lost, it is important to determine what goes wrong: is it the what – landmarks, the where – locations, or the how – connections between different locations. With this information, we were able to create a test that takes just a few minutes to administer and provides insight into whether there is an abnormality in navigation ability, and if so, in which area. We use a virtual environment that can be easily viewed online. Through our involvement in the Weekend of Science in 2017-2018, approximately 20,000 people have already taken different versions of this test. As a result, we now have a good understanding of the average scores for men and women of various ages. Variants of this test are being used worldwide in healthcare, research, and education.

While it is not possible to share all the findings in detail in this speech, one of the questions we asked the participants led to the following graph (figure 2). From informal empirical research, I would consider this the funniest graph of my career. Before the experiment went live, we decided to quickly add a question; it fit within the maximum 10-minute duration of the experiment. We were curious about how people perceived their own navigation abilities. What was their perception of their own ability? The interesting part is that we could also determine how accurate their self-assessment was for each participant. There was a systematic pattern based on both age and gender, according to the group averages. As people get older, they tend to overestimate their ability more. Men overestimate their ability, while women underestimate. Some people might find this an obvious finding, a trivial fact, and maybe even a source of an amusing map-reading conflict in a car during summer vacation. However, I believe that this pattern should be taken seriously and has implications for how we listen to complaints in the doctor's office, for example. An elderly man expressing problems seems to mean something different than when a young woman does. Perception is highly personal, with systematic patterns.

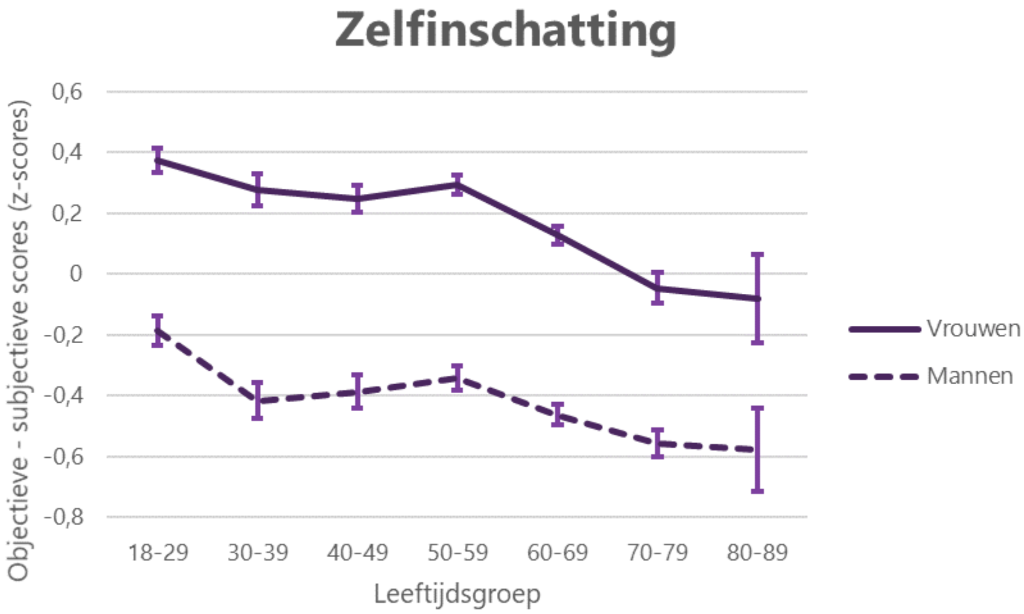

Figure 2. The quality of self-assessment of navigation ability: objective score-subjective score. A positive value indicates self-underestimation, a negative value indicates self-overestimation [44].

We followed this up with research into stereotype beliefs. These turn out to be strongly present for spatial skills. We see that people think that spatial performance is related to sex, but not age. This is notable because the major differences in actual performance are found between ages and not between sexes. Most people are convinced that men are better at finding their way than women, a belief that is strongest among young men. Therefore, it is necessary to conduct an objective test to gain a real insight into someone's navigation ability. And we not only want to know what is wrong, we also want to be able to do something about it. The results of this test give us insight into the patient's strengths and weaknesses. One person is better at remembering landmarks, the other in reproducing a route. This information allowed us to shape our navigation training, an intensive, cross-disciplinary process in which the efforts of Milan van der Kuil, Anne Visser-Meily, Andrea Evers and Michiel Claessen were essential. Caregivers, patients themselves, IT experts, and researchers combined their expertise to assemble the best possible training. It turned into a serious game that can be played at home. After just a few weeks, players almost entirely reach their treatment objectives.
One of the most educational moments of this process was the conversations with the occupational therapists involved. Where Milan had developed a beautiful game design with Greek mythology as a theme, with minotaurs in ancient underground labyrinths, it turned out this beautiful design was a mistake. It did not match the patient's experience. A much better approach was one that was recognizable and connected to daily tasks, and the moments when real problem of getting lost could occur. Fortunately, Milan could cope with this excellently and we now have a final design that includes the notorious hospital corridor and strolling around a regular residential area. For the success of a treatment using spatial technology, it is crucial to approach the patient's experience as closely as possible, even if that sometimes means not going for the most polished design.

Alternative reality
I just mentioned it before, with spatial technology we can especially create alternative realities. It is not advisable to assume that a virtual representation of a real situation is experienced the same way as that real situation. The perception of both space and time seems to be disturbed in a virtual environment. Space is generally underestimated, we experience a virtual copy of reality as slightly smaller. Moreover, we see that the quality of spatial information processing is positively influenced

when we actually walk through the environment. If you are standing or sitting looking at a virtual environment, your memory for distances is less good. And when the creators of the Oculus glasses suggested that time perception in virtual environments is also disturbed, we investigated that. We indeed found that the duration of clips in a VR environment was perceived as shorter. But this turned out to be due to a more intense emotional experience of those clips, not because of the VR glasses themselves.

The work of Anne Cuperus is a good example of the power of alternative realities. In his research we have looked in various ways at how manipulating the digital environment affects the user. With footballers we saw that they found a recording of their own penalty shots more realistic if these images reflected their performance favorably. The version where the balls came closer to the goal than in reality, they found more convincing, and they felt more competent after seeing these images. These results gave Anne the idea to apply this principle also in physiotherapy. People with claudication, also known as window-shopping disease, have to go to the physiotherapist every week to walk on a treadmill. Not the most stimulating environment, so maybe it helps to present a relaxing, enjoyable virtual environment during the walk (see figure 3). They indeed found this a pleasant experience, but nothing happened with their performance. Only when we started to unnoticeably stretch the environment did they walk further. We were so surprised by this effect that we repeated it with healthy participants and there we saw that you can even stretch the environment up to 150% in the walking direction, without it being noticed. So they had to walk one and a half times as far to reach the same virtual point, without them realizing that we had manipulated the environment. Apparently, we don't make a big fuss about an alternative reality.

Figure 3. The virtual environment used on the treadmill [53]

Just as with processing information in large spaces, the role of our body and our movements in spatial technology is very significant. The presence of a virtual body, an avatar, can also enhance the illusion. This is also referred to as a full body illusion. These types of body illusions can often be invoked very easily, think of a rubber arm that in most cases is effortlessly experienced as our own arm. We can make good use of this flexibility of the body image in the full body illusions. Therein lies a great strength. This illusion triggers the Proteus effect. Proteus is a Greek sea god who can predict the future. To prevent constantly being asked, he was able to change forms at will. In the virtual world, this shape-shifting works just as easily because we generally accept these other shapes as soon as they are presented. What makes this so powerful is that we not only accept those shapes, but also attach consequences to them. So far, most of the research has been done on the impact of avatars on our social function. For example, we are more empathetic towards minorities if our avatars look just like them. You also see that social behavior in groups can change. We are more likely to cooperate with characters of the same sex as our avatar and if our avatar is older, we offer more help. There is also some evidence that our motor skills can adjust imperceptibly. If you give young people an older virtual body, they start to stand a bit crooked and walk slower. And old people can get a boost from a young body.

So our perception, social interactions and motor skills are very directly linked to the illusion, but what about our cognitive abilities? Can body illusions possibly also be used when we want to increase people's cognitive abilities, as we want to do in education and cognitive rehabilitation?

The initial cautious indications from other researchers about this are exciting and hopeful. For example, for spatial tasks, we also seem to care about the avatar we see as ourselves. Stereotypical beliefs can get in the way of achieving optimum performance. For example, it has been shown in the Netherlands that women perform worse in mathematics if emphasis is placed on their gender. If that emphasis is not there, they perform on par with men. If women are shown a male avatar during the study, they perform better on assignments where such a stereotype exists. Conversely, we see the reverse effect when men are shown a female avatar; performance then decreases. There is also now conflicting research that shows that for optimal results, an avatar should strongly resemble yourself. This is something we need to investigate further.

Could avatar design also be the key to a cognitive placebo effect, with which we could better utilize our potential? And more importantly, how can we ensure that such a placebo effect also persists outside the virtual world? Along with Henriët van Middendorp as an expert in placebo effects, we have great plans to answer these questions. I'm curious if such a cognitive placebo effect could work and could possibly be used for better results in health care and education. Stereotypical beliefs about gender and cognitive ability are in fact strongest for spatial skills. A very persistent belief which we now know is much more nuanced in reality. Moreover, such assumptions about how we function are not limited to spatial skills. Such beliefs also exist for the use of technology. The perception prevails that it is especially young men who are best able to handle this. This could hinder the use of such technology in more diverse groups of people. It's important to revise this perception. Fortunately, the technology itself offers us the opportunity to steer the experience in a positive direction.

Sustainable innovation

I hope I have been able to convince you of the value and importance of technological innovation. That value is sometimes less visible in the traditional assessment criteria in science. Despite positive change, we are often judged on nice publications and similar outputs, fortunately more and more often on quality rather than quantity. Therefore, it remains a difficult decision to invest time and energy in innovation, in the innovation process itself. And you might wonder if that is still part of your job as a scientist. Aren't you already done when you have conceived and proven your idea? I think our role is greater than that. When you have bridged the entire distance from theory to practice with an idea, you know what all the obstacles are and where the resistance lies. For example, as we discovered, a nice game design that met all serious gaming guidelines did not fit our target group well. If we hadn't been engaged with implementation, we wouldn't have discovered this. Also, exploring the willingness of the intended end users is very important for the ultimate good landing of your idea.

I am therefore pleased that Leiden University mentions 'room for innovation' in its strategic plan. This document outlines how the necessary space for change and innovation will be made in the coming years. With people at the helm such as esteemed colleagues Hanneke Hulst and Marieke

Adriaanse, I expect positive changes in this area. With a scientific world in motion, and a revision of how we recognize and appreciate scientists, we have the opportunity to better assume our role as innovators in society. Hanneke and Marieke take the courageous step to lead this movement and I am very happy to join them. You can count on me.
Real innovation is only achieved when ideas are turned into actual use of the devised solution. Innovation therefore requires facilitation, more than just appreciation for a good idea or the noble intention. This requires an eye for the costs, both in time and money that shaping and implementing these innovations require. It requires intensive collaboration between different disciplines. The focus within LURIS to also bring social science research closer to society, I find very valuable in this regard. I am very curious how these initiatives towards social enterprise will develop in the future. I also expect valuable developments in this area from the Leiden-Delft-Erasmus Medical Delta initiative Healthy Society. By joining forces, we achieve more for and with society.
In our education, we also try to prepare our students for their role as potential innovators. This requires creativity and an open mind, but also a healthy critical attitude. In a field where many changes are expected in the coming years, healthcare, it is important that professionals are able to assess the quality of proposed innovations and, where possible, contribute positively to their quality.

Conclusion
I began this story with Mrs. AC's puzzle and the idea that technological innovations can bring us closer to the patient's experience. Because it is not so much the technology itself, but the users and their experience of the technology that is central. With virtual worlds we can create illusions that help us better understand the user's experience. Whether this is a patient, a student, or a healthcare provider. With today's story, we can outline the route for both measuring and learning using spatial technology. When we want to measure cognitive performance, spatial technology can be a solution (see Figure 4). With this illusion we get closer to the experience by using the large space. It is important to be aware of the small disturbances in space and time that occur in the transition from the real to the virtual world. Next is the user, who can respond differently to the virtual world, depending on factors such as gender, age and spatial abilities. And also, the beliefs about own abilities and stereotypes influence the performance that is measured. With an eye for these individual differences and beliefs, we can come to reliable use of spatial technology.

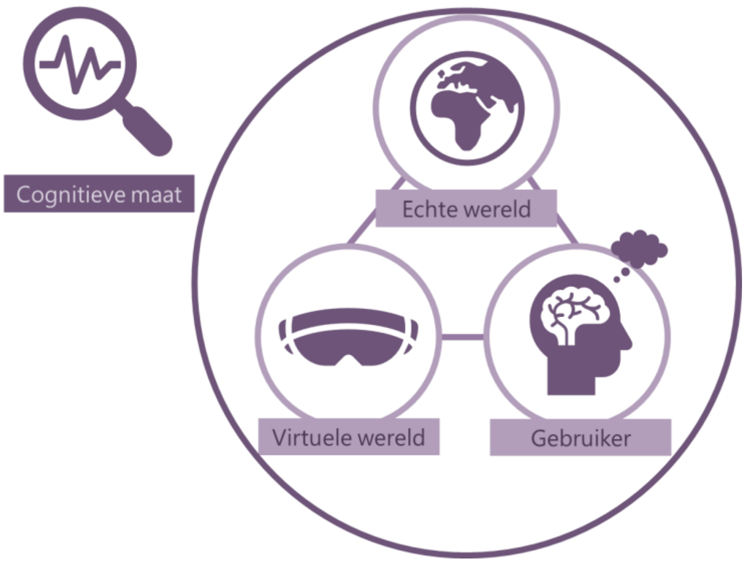

Figure 4. Schematic representation of the recommendations for measuring cognitive performance with spatial technology.

We not only want to be able to better determine what is going on, but also to be able to offer a solution (see Figure 5). Spatial technology provides many opportunities for treatment, as alternative worlds can be designed that fit with what we want to learn. An alternative 'self', an avatar, is particularly important here. There are promising indications that we can use avatars to increase performance. I see great opportunities for future research into the alignment between avatar and user and the beliefs of the user. This may hold the key to hidden cognitive potential; we can sometimes do more than we think. And finally, there is the challenge to retain what is learned in the virtual world in the real world. I look forward to the years to come, in which these issues will play a major role.

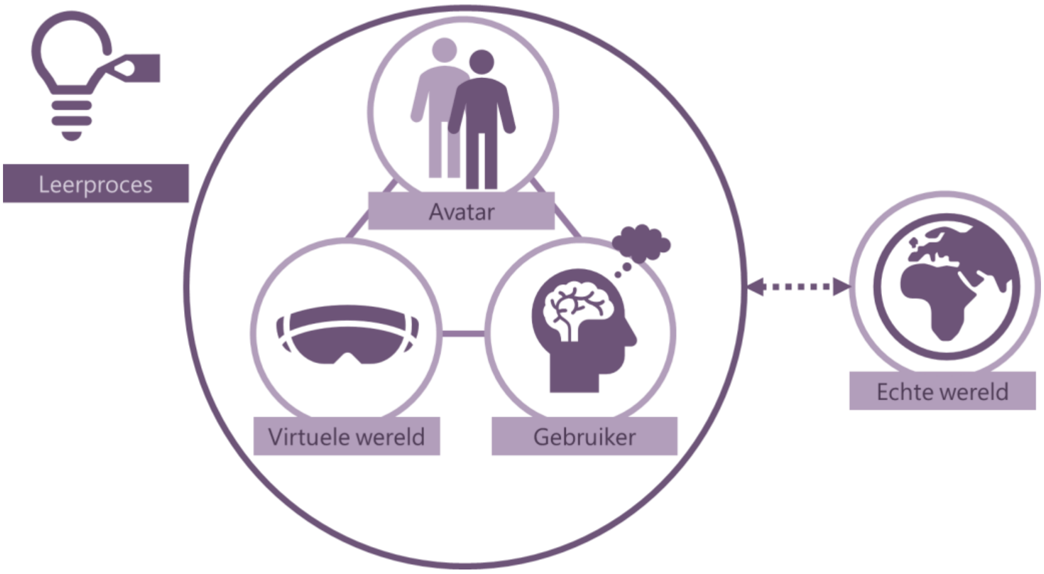

Figure 5. Schematic representation of the recommendations for improving cognitive performance with spatial technology.

Acknowledgment

It is 2023 and here we are, with a diverse group of people who are involved in education, research, healthcare, policy, administration, commercial enterprises, art, technology and communication. The coming together of all these backgrounds has already led to many valuable insights, successful projects and effective products. Moreover, it gives us reason to be hopeful for the future that we always manage to find each other, as we have today. I would like to conclude by reflecting on how much all this work and these plans rely on teamwork and the coming together of all sorts of different people with their unique perspectives and skills. First of all, thank you all for sharing this moment with me. I consider this a huge honor. Unfortunately, there is not time to mention everyone who has inspired, supported and motivated me in one form or another in recent years; thank you all!

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I have spoken.

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