Review Article

Exploring the Neurocognitive Effects of Magic Intervention on Mild Cognitive Impairment and Alzheimer's Disease

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ABSTRACT

Magic, the art of conjuring, has fascinated people around the world for millennia. Magicians have mastered manipulating attention (misdirection) and exploiting the human mind to create seemingly impossible tricks and illusions. In the past few decades, neuroscientists and psychologists have researched the methods of magic and produced a significant amount of literature relating to how magicians manipulate people. With this surge of new knowledge, it is worthwhile to investigate whether magic can be used in treatments for mental disorders and diseases. Mild Cognitive Impairment (MCI) and Alzheimer's Disease (AD) are two of the most common neurological conditions among elderly, where behavioral interventions are crucial for slowing down the progression of neurocognitive impairment. This paper analyses and proposes how magic intervention can impact neurocognitive function in patients with MCI or AD, by reviewing current literature in the related areas of magic and the science behind it. In particular, it is found that magic intervention can positively affect executive functioning, learning, and memory in individuals with MCI and AD. Furthermore, emerging areas of research in the field indicate that magic intervention may promote curiosity and engage sensory systems, further improving neurocognitive function in these individuals. Therefore, the paper shows that magic intervention is effective in enhancing neurocognitive function in patients with MCI and AD, and in slowing down the progression from MCI to AD.

Keywords: Neuroscience; Cognitive Science; Alzheimer's Disease; Mild Cognitive Impairment; Magic; Multi-component Intervention

INTRODUCTION

Alzheimer's disease (AD) is the most common form of neurodegenerative disease, most often affecting people over the age of 65. AD is classified under the umbrella term dementia, a category of neurodegenerative disorders that involve memory loss and cognitive impairment. AD can present in various ways, but the most common symptoms are difficulty recalling past events, poor judgment, and frequent mood swings. However, these symptoms become more prominent and serious as the disease progresses. Biologically, AD is marked by the accumulation of amyloid plaques and tau tangles. Moreover, AD is further categorized into two types - sporadic and familial. Sporadic AD, also termed late ons*et al*zheimer's, takes

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up 90-95% of all AD cases. In these patients, symptoms become noticeable after ages 60-65. In contrast, familial AD, or early onset AD, only occurs in 5-10% of AD cases. Its symptoms appear much earlier than sporadic AD cases, at around 30-40 years old. While the exact causes of AD are unclear, a combination of genetic and environmental factors are thought to be involved.

There are several approved pharmacological treatments for AD, once diagnosed. These drugs either slow disease progression, or alleviate symptoms of AD. Medications that slow disease progression are currently all amyloid-targeting; i.e. they work by removing beta-amyloid protein buildups. Two of these drugs are Donanemab (Kisunla) and Lecanemab (Leqembi). However, amyloid-related imaging abnormalities (ARIA), which are temporary swelling in the brain, are common side effects. These effects may become serious, hense these medications should be taken with caution and under professional supervision.

Alternatively, drugs which help treat symptoms of AD are also used. For instance, acetylcholinesterase-inhibitors are often prescribed, which increases levels of acetylcholine, promoting healthy cognition and memory. However, these drugs do not stop neurodegeneration due to AD. Other pharmacological drugs such as anti-inflammatory drugs are currently undergoing testing, but have yet to be approved for treating AD. Despite these recent advancements in the area, the pharmacological approach still has its share of limitations. For example, most of these drugs only work effectively for patients in the early or middle stages of AD, but not the later stages. Furthermore, no such medications can cure AD, but can only either slow down disease progression or improve symptoms.

In hopes of further improving the lives and cognitive functions of AD patients, behavioral interventions are often used in conjunction with pharmacological methods. These interventions combat different symptoms arising due to AD, ranging from memory decline to frequent mood swings to reduction in inhibitory control. Common behavioral interventions include computerized cognitive training, physical exercises, memory compensation training, wellness education etc. Accordingly, different treatment approaches are able to improve different aspects of life of patients.

Mild Cognitive Impairment (MCI) is thought to represent early-stage AD, whereby MCI is the stage between typical healthy aging and dementia. The condition causes memory loss and trouble with language and judgment, but doesn't affect daily activities. In other words, MCI is the intermediate stage between normal cognitive function and dementia. MCI has similar symptoms as AD, but at a milder extent. MCI is diagnosed around the 60-year mark, but the risks of developing MCI increases with age. People diagnosed with MCI have an increased risk of developing AD or other related dementia later in life. MCI currently has no distinct biomarkers used as targets for treatment, in comparison to AD. As a result, there are currently no approved medications for treating MCI. Instead, patients with MCI are often prescribed behavioral treatments, like those of AD patients, due to the similarity between the symptoms of AD and MCI.

Moreover, it is noteworthy that behavioral interventions of different nature are often simultaneously adopted as a multicomponent (multimodal) approach to improve AD and MCI. In fact, such a multicomponent approach has been found to have comparable to larger effects on cognition than pharmacological methods for patients with MCI (1), which can likely be extended to patients with AD as well.

Furthermore, due to the severity of AD, MCI is a focal point in research because there is still ample time for intervention. Aside from that, researchers tend to focus on MCI as there are more people diagnosed with it when compared to AD, making it possible for larger sample sizes and a higher power for their results. Given the overlap between MCI and AD symptoms and outcomes, the findings from these research papers are also largely applicable to AD.

A promising avenue of a multicomponent intervention is magic, as was first looked into by Lee *et al.* in 2022, where the authors published an inaugural paper on the effects of magic intervention on the neurocognitive performance in elderly individuals with MCI (2). Magic, synonymous with illusions and conjuring, is the performing art in which the audience is entertained by seemingly impossible tricks and illusions which are done via natural means. Magic is innately multicomponent, and engages various areas of the brain, regardless of whether an individual is watching, learning, or performing it. While watching magic, error detection mechanisms are triggered due to the mismatch between expected and observed outcomes, along with stimulating the brain to think about possible methods (3); while learning magic, memory-associated parts of the brain e.g. the hippocampus and prefrontal cortex are required to encode complex methods into memory; while performing magic, aside from communication, memory-recall is also tested. Throughout these

processes, other cognitive functions may also be involved, such as inhibitory control (attention), visual and auditory processing, etc. As aforementioned, MCI and AD affect many of these factors. Hence, magic can serve as a multimodal approach to improve different symptoms and areas of cognition, in order to reduce the effects of MCI and AD overall. Magic intervention may be effective in improving the neurocognitive function of patients with AD and slowing down the progression from MCI to AD. This paper will review the current literature on how magic affects the cognitive ability of patients with AD and MCI. As MCI is essentially the precursor to dementia, magic intervention would likely be effective to patients with MCI as well, if not more effective due to the milder extent of cognitive decline. Moving forward, evidence will be presented on how magic intervention may be effective in improving the neurocognitive functions of patients with AD, and slow down the progression from MCI to AD.

EXECUTIVE FUNCTIONING

Executive functioning has been proved to significantly decline in patients with Alzheimer's Disease (pwAD), where it worsens as the disease progresses (4). Of the many facets of executive functioning, three in particular are closely related to magic - error detection, conflict monitoring, and complex attention.

Error detection and conflict monitoring

Error detection and conflict monitoring function in tandem, where error detection is the brain's capacity to detect deviations from prior expectations, and conflict monitoring refers to the brain's ability to recognize conflicts between observed phenomena and expected outcomes, subsequently carrying out suitable actions (e.g. initiating an emotional response). As these two cognitive skills fall under executive functioning, they tend to decline in pwAD (5). However, these skills are centrally involved in watching magic performances, especially to elicit the emotion of surprise. This would be logically sound at its core, as magic is about making impossible events happen; in other words, contradicting with everyday life. Error detection and conflict monitoring naturally occur in response, as the observed phenomena does not match with what is expected, i.e. learned common sense. The link between magic, error detection, conflict monitoring, and surprise is effectively explored in Grassi and Bartels' paper (6), where they essentially present the aforementioned arguments within the framework of Bayesian predictive coding. Grassi and Bartel argue that magicians maximize and exploit the difference between the expectations (priors) and observed phenomena (sensory input) of the audience, in order to generate surprise (the difference mentioned); the larger the difference, the greater the surprise experienced. Hence, it is clear that magic creates a disparity between the expectations and sensory input of the audience, stimulating the brain to engage in error detection and conflict monitoring. Therefore, magic, particularly watching magic performances, can improve executive functioning in pwAD.

Attention

Furthermore, attention is another aspect of executive functioning which is involved in magic. Similar to error detection and conflict monitoring, attentional control as an executive function significantly declines in pwAD. Attention is primarily maintained by the prefrontal cortex, which typically experiences one of the greatest neuronal losses in the progression of AD. Regarding the relation between attention and magic, the attention of the audience is of great importance in magic. For the audience themselves, their attention to the performance determines the clarity and richness of the sensory input of the performance, affecting the extent of surprise they experience. For the magician, they manipulate the audience's attention through misdirection to ensure the success of the trick and the maximization of surprise (6). As both the magician and the audience's actions concern the audience's attention, it is natural to conclude that attention is involved when watching magic performances. Parris *et al*. (2009) have conducted a functional magnetic resonance imaging (fMRI) study on participants watching magic tricks, and have found that the dorso-lateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC) are recruited when participants watch the tricks (7). As the DLPFC is part of the prefrontal cortex, it also plays a role in attentional control. Therefore, it can be concluded that watching magic performances will activate parts of the brain (DLPFC) concerned with attention. Therefore, magic, especially watching magic, can improve attention in pwAD, due to its stimulation of related parts of the brain. In fact, the DLPFC and ACC are also areas associated with the detection of conflict, further reinforcing the previous argument that watching magic will improve error detection and conflict monitoring in pwAD. Accordingly, magic has demonstrated improvements in executive functioning in pwAD.

LEARNING

Learning difficulties, particularly difficulties in remembering newly attained information, is often reported by pwAD. There is evidence that other learning abilities e.g. some types of nondeclarative or procedural learning (learning of skills and habits) are impaired in pwAD as well (8), resulting in learning challenges among pwAD. Learning magic can be a method for helping pwAD improve their learning abilities, or to maintain their current ability in this area. Prior to the discussion on learning magic, it is worth mentioning that watching magic performances before learning the secret behind the trick also provides a learning opportunity. This is because when watching the performance, the audience is naturally prompted to think about how the trick worked. Coming up with a feasible method for a seemingly impossible phenomenon requires both creativity and application of prior knowledge, which stimulates various parts of the brain, such as the hippocampus, frontal lobe, amygdala (9). After learning about the secret, one can compare it with their proposed explanation, and learn about what the proposed explanation lacked, whether it be simplicity or practicality. They can then acquire knowledge on how to propose better explanations for other tricks or phenomena in general. Therefore, watching magic before learning the underlying method itself provides a chance to learn, which would engage learning-related areas of the brain. As both the hippocampus and amygdala are affected (atrophied) in pwAD, this way of learning magic can likely slow down disease progression.

Before moving on to discuss learning magic in general, it is crucial to recognize that learning magic involves several components if the trick is to be mastered. The process includes various steps in general:

1. Learning the "secret" or method behind the trick;
2. Learning to use the props and devices involved in the trick (gimmicks), and learning the techniques used (especially for sleight of hand magic);
3. Learning the sequence of actions in the trick;
4. Learning the presentation of the trick, which involves body language and the script (i.e. the patter);
5. Learning to perform all the previous steps smoothly without hesitation.

This set of instructions illustrates that learning magic tricks to a point of mastery involves many parts and takes time and effort. Magicians should also be familiar with the trick to the point that they can manage the audience and handle unexpected circumstances, alongside performing the trick (10).

Accordingly, it is clear that learning magic is a complicated process, which is one of the reasons why learning magic is beneficial to pwAD. With reference to the steps above, learning magic involves understanding concepts and theories (Step 1), developing fine motor skills (Step 2), remembering sequences (Step 3), using appropriate body language (Step 4), memory, among others. These individual learning processes engage many distinct parts of the brain, including those closely associated with AD e.g. hippocampus, temporal lobe, parietal lobe etc., hence potentially alleviating symptoms in pwAD. Furthermore, fine motor skills are acquired when learning magic, especially for sleight of hand magic. As pwAD experience impaired fine motor skills (11), which would decrease their ability to carry out every day activities such as cooking and using scissors, learning magic tricks can improve these skills, and benefit pwAD in their daily lives.

Furthermore, to learn a trick effectively, one also needs to understand the concept behind the trick aside from rote memorization. When teaching tricks, magicians often explain why the trick works, i.e. why people will fall for that trick. It could be because of misdirection, common beliefs, or others. Only if a person understands the essence of these tricks, can they effectively exploit the audience's vulnerability and maximize surprise. For example, a magic trick might rely on the audience to follow the performer's gaze in order to conceal the method. If the performer doesn't understand this concept, they would arbitrarily look around, leaving the method prone to exposure and causing the trick to fail. However, by understanding the concept, the performer can adjust their gaze (e.g. by looking towards the audience's eyes) to catch the audience's eyes successfully and thus perform the trick well. Understanding these concepts underlying magic tricks requires higher-order thinking skills e.g. comprehension and application, not simply memorization. As these skills and related areas of the brain decline in pwAD, learning magic can help improve these skills in pwAD and slow down disease progression.

MEMORY

One of the hallmark signs of AD is decline in many areas of memory, including working memory, episodic memory, semantic memory etc. As the disease progresses, such impairment increases as well. Memory is an integral part underlying magic in general, as it is involved when watching magic, learning magic and even performing

magic. Therefore, magic intervention may be a viable option for improving neurocognitive performance, especially memory, in pwAD.

Firstly, memory is involved when a person watches magic. In magic tricks, preparation or premises are set prior to the actual effect in order to maximize the surprise experienced (6). For example, in a simple card trick, a card is selected and remembered by the audience. Then, the card is lost in the deck and the magician shuffles the deck. Afterwards, the magician asks the audience the card they selected, and immediately reveals the top card to be that card. In this case, as well as many other card tricks, the audience is asked to remember a card, which is then produced in an unsuspecting manner. The success of the trick relies on the audience's working memory, as they have to realize the card the magician found is the card they picked earlier. If they do not remember the selected card, it would instead seem like the magician arbitrarily found a card with no other significance. In other tricks, the audience might have to remember colors of objects or the number of objects, which changes as part of the magic trick's effect. Without an effective working memory, these tricks would seem random and not surprising at all. Hence, it is clear that working memory is crucial when watching magic performances, in order for the audience to be surprised.

Secondly, learning magic involves memory as well. To learn a trick which can be performed would naturally entail remembering all the steps and actions as part of the performance. In addition, learning magic is particularly challenging as the methods used in tricks are usually very creative and unusual, and are thus different from other things in daily life. This factor would cause encoding tricks into memory a more difficult yet more stimulating process due to the uniqueness of the concepts. Furthermore, magic is concerned with tiny details such as subtle body language for a trick to be increasingly convincing. These pieces of information are to be remembered for one to truly learn a trick, further increasing the amount of content that needs to be memorized when learning magic. Therefore, there is generally a substantial amount of memorization required when learning magic, potentially reinforcing memory skills in pwAD.

Thirdly, performing and mastering magic tricks call for the complete memorization of the different parts of a trick. When performing, the magician does not only recite his actions and speech from memory, but also needs to engage with the audience. They have to guide the audience's attention, answer any questions and handle any unexpected circumstances which arise, while the magician is performing the trick (10). In order to do so, the magician would need to be thoroughly familiar with the trick and its procedures to the point that they would not need to pause to recall their memory. Therefore, performing magic tricks effectively would likely require tricks to be encoded into long-term memory systems, as information stored in long-term memory is more familiar (12). In combination with previous points, magic involves both working memory and long-term memory, amplifying its stimulation of brain structures related to memory. Accordingly, watching, learning and performing magic all stimulate memory systems within the brain. As these systems are among the most affected in pwAD, magic intervention may be effective in improving neurocognitive function in these patients and slow down disease progression from MCI to AD.

EMERGING AREAS OF RESEARCH

The neuroscience behind magic has long been overlooked by scientists and psychologists alike when compared to other types of intervention, e.g. music, physical activity etc. However, scientists have started gaining interest in this field in the past few decades and have conducted promising research. For example, magic tricks likely take advantage of blind spots in human senses, particularly visual ones e.g. change blindness and inattentional blindness. For sleight of hand tricks, curvilinear motions appear to be more effective in misdirection than rectilinear ones (13). Therefore, magic intervention may be beneficial in engaging human senses, which could promote healthy cognition in pwAD. Furthermore, various studies have also investigated the component of curiosity in magic, where they found that magic often encouraged curiosity in the audience. Increased curiosity might also help improve neurocognitive function in pwAD. Hence, current neuroscientific research on magic shows that magic intervention is a promising way to improve cognitive function in pwAD and to slow down the progression from MCI to AD. Moving forward, the emerging areas of research on how magic can lead to curiosity and manipulate the senses may further shed light on how magic can be used to treat AD and MCI, and possibly lead to other developments in neuroscience.

CONCLUSION

In conclusion, current research supports that magic intervention, including watching, learning, and

performing magic, may be a promising avenue to improve neurocognitive function in individuals with AD and slow down disease progression from MCI to AD. This is due to magic intervention's ability to tap into the areas of executive functioning, learning and memory, hense stimulating the parts of the brain affected by AD. There is also promising research in the area of sensory engagement and curiosity, which might also be engaged in magic intervention, thus further promoting healthy cognition in pwAD.

On the aspect of practicality, magic intervention has potential to be a feasible intervention. Compared with other types of interventions, such as computerized cognitive training and medical intervention, magic intervention uses less costly resources, as it only requires basic props and a teacher. pwAD would likely also find magic intervention more attractive than other options e.g. wellness talks, because magic itself is fascinating to humans. However, it should be noted that learning and performing magic is a complex task as detailed previously, as it involves multiple components of mental and physical functions. The use of props in magic may also call for a level of dexterity. As most pwAD are elderly, magic intervention might be more effective towards patients around 60 to 70 years old who still have the required dexterity to use props. In combination with the mental capacity demanded, magic intervention might not be well-suited to individuals in the late stages of AD, but is more suitable for individuals in the stages of early or mid-stage AD, or cases of MCI. In order to carry magic intervention out in a more feasible and manageable way, participants should learn to do magic tricks with methods and props which are not too sophisticated, yet stimulating enough to require practice and effort. The magic tricks chosen should cater to the ability of the participants.

Moving forward, more research regarding how magic may help pwAD should be conducted in order to find out if magic intervention is truly effective, and to help determine the best mode of magic intervention, i.e. finding the balance between watching, learning, and performing magic for maximum effect. Research in this area will likely lead to a deeper understanding of treatments for AD, and how magic affects the human brain, where both aspects are helpful to other fields of neuroscience. Aside from that, more research should be conducted on magic and its methods, which would likely reveal more about neurocognition, as magicians have been exploiting it for hundreds of years.

Accordingly, magic intervention is a feasible method for improving neurocognitive function in pwAD and to slow down the progression from MCI to AD. Its ability to address multiple areas of cognition further enhances its ability to do so.

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