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Embracing virtual reality in rehabilitation of post-stroke aphasia

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Abstract

About one-third of stroke survivors experience aphasia, i.e., language dysfunction caused by brain damage. Aphasia affects not only a person's ability to communicate, but it often leads to the inability to return to work, loss of close relationships, diminished quality of life, negative self-perception, and depression. Yet persons with aphasia are globally underserved due to limited access to resources, which limits their chance for recovery. Immersive virtual reality (VR) has the potential to solve this problem and deliver efficient, personalized treatments to millions of people worldwide who need access to rehabilitation services or more flexibility in treatment delivery. To reduce the global burden of stroke experts recommend taking bold, pragmatic actions across all four pillars of stroke quadrangle–surveillance, prevention, acute care, and rehabilitation. Embracing immersive VR-based rehabilitation of poststroke aphasia would be one step in that direction.

Keywords

Stroke, aphasia, intervention, virtual reality, chronic aphasia, rehabilitation, language, cognition

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Introduction

Stroke is the second leading cause of death and the third leading cause of disability globally.[1] According to the World Stroke Organization, over 12 million people worldwide will have a first stroke in 2024 and as a consequence 6.5 million will die.[2] Those who survive a stroke often have multiple impairments, including motor dysfunction; deficits in speech, language, and cognition; and other disorders.[3] Both mortality and disability caused by stroke are expected to rise in the future, mainly because of the world population growth and longer life expectancy.[4] Although stroke is more common in older people than in other age groups, the incidence of stroke is rising in young and middle-aged people (<55 years of age) and more so in low- and middle-income countries than in high-income countries.[1] This implies an additional increase in the need for rehabilitation after a stroke.

Stroke imposes an enormous global economic burden. For example, estimated healthcare expenses associated with stroke in 2017 were $315 billion, and the loss of income due to stroke was $576 billion.[4] An estimated total cost is predicted to increase from $891 billion in 2017 to $2.31 trillion by 2050.[4] Such economic burden is likely to be difficult, if not impossible, to endure. Various expert groups dealing with the question of how to reduce the global burden of stroke recommend taking urgent actions across all four pillars of the stroke quadrangle—surveillance, prevention, acute care, and rehabilitation.[1,4] The key activities across the four pillars range from monitoring of risk factors and healthcare services, engagement of prevention strategies to minimize effects of modifiable risk factors, to further development of healthcare services for acute stroke and rehabilitation supported by multidisciplinary teams and services that extend to the community.[4,5] Here we focus on one aspect of stroke rehabilitation: recovery of language after stroke based on virtual reality (VR) treatment and whether such use of this technology has the potential to reduce the burden of stroke. More specifically, considering the remarkable human brain potential for recovery,[6] effectiveness of speech–language therapy (SLT),[7,8] and recent advancements in and increasing

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availability of immersive VR,[9] we discuss the idea that innovative use of this technology in recovery of language after stroke may improve access to rehabilitation, thereby reducing the burden of stroke.

Neurocognitive potential for recovery of language after stroke

Every year, about 4.5 million people worldwide are diagnosed with aphasia due to stroke.[8] Aphasia is a language disorder caused by focal brain damage.[10] One of the basic organizing principles of human cognition is hemispheric lateralization, i.e., which means asymmetries in the functional organization of the cerebral hemispheres.[11] "Directional biases" in hemispheric functional organization are manifested, for instance, as left-lateralized language in the majority of right-handed people.[12] Thus, in right-handed people, a stroke in the left cerebral hemisphere may cause aphasia, in left-handed people – a right hemisphere stroke, while in rare cases of crossed aphasia, right-handed people may experience aphasia after a right-hemisphere stroke.[13]

Severity and type of aphasia depend on the size and location of the lesion, with the impairments manifesting to various degrees in speech production and comprehension, reading, writing, the use of gestures, and even in inner speech.[10,13] Furthermore, aphasia affects not only a person's ability to communicate, but it often leads to the inability to return to work and thus loss of income, loss of close relationships, negative self-perception, and diminished quality of life.[14,15] A recent study involving 66,000 residents in Ontario hospital-based long-term care facilities found that among 75 diseases and conditions, aphasia had the highest negative relationship with these individuals' quality of life scores, ahead of cancer, quadriplegia, and Alzheimer's and Huntington's diseases.[15] Depression, which affects about one-third of stroke patients and is often left untreated, negatively affects functional outcomes.[16,17] Aphasia affects not only people who directly experience this disorder but also their family members (and caretakers), and it may lead to "third-party functioning and disability" in a significant other,[18] which in turn may negatively affect persons with aphasia (PWA) recovery.

Aphasia is a heterogeneous disorder. Differences in the manifestation of aphasic symptoms are so great that attempts to neatly classify PWA into syndromes fall short of the goal.[13] Simply put, such attempts overestimate similarities within syndromes as well as differences between them, which causes issues in the diagnosis, assessment, and treatment of PWA.[13] Furthermore, differing degrees of language impairment in PWA may reflect intermittent deficiency or deficits in abilities other than language,[3] such as slowed cognitive processing[19] or problems in attention,[20] working memory,[21] and executive functions,[22] all of which are crucial for the use of language. Deficits in these abilities characterize other neurological conditions, such as Alzheimer's and other dementias,[10] and it is not uncommon for PWA to develop dementia.[23] Furthermore, neuropathology associated with Alzheimer's dementia unfolds over one or more decades[24,25] and its interaction with the effects of stroke may further modify the neurocognitive potential for recovery. Thus, heterogeneity of aphasia is related not only to differences in the location of stroke-inflicted neuronal injury and its size, but also to individual differences in neurocognitive potential for recovery of the damaged function. To promote improved recovery, future treatments of aphasia need to address language dysfunction together with other stroke-related cognitive deficits rather than as an isolated deficit.[26,27]

Beyond trivial effects

Heterogeneity of aphasia has important implications for diagnosis, assessment, and treatment. One often debated question in the rehabilitation of language after stroke is effectiveness of SLT.[28,29] Over the last 50 years, the debate has revolved around questions related to optimal intensity (hours per week), dosage (time on task), and frequency (days per week), optimal timing for treatment, and its length.[29] Current evidence suggests that SLT is effective, even in chronic aphasia, if an appropriate dose, frequency, and intensity are provided.[8,30,31] As an illustration, Doppelbauer and collaborators[31] reported considerable improvement after a short-term (2–4 weeks), intensive language–action therapy (6–12.5 h/week) in chronic aphasia; the effects were present 2.5 years posttreatment. Importantly, the effects generalized to untrained materials, which led the authors to recommend replacing "long-term sparse therapy by intervals of short-term intensive treatment," for instance, with a single 2-week intensive therapy per year (p. 869). Furthermore, a recent meta-analysis that included 959 individuals from 25 trials also suggests that much higher dosage, intensity, and frequency of treatment, relative to those typically offered by clinical rehabilitation services, are associated with better intervention results.[8] The language gains were greatest when interventions were functionally relevant and combined with additional tasks prescribed for individual practice at home. Other evidence suggests that personalized treatments, tailored to address specific speech, language, and communication needs of PWA, are considered more beneficial than traditional therapy.[32]

However, delivering intensive, personalized treatments for aphasia has some challenges. One major obstacle to implementing such programs is a lack of resources, including a shortage of speech–language pathologists (SLP). According to the American Speech–Language–Hearing Association (ASHA), there are only 59.3 ASHA certified SLP for every 100,000 residents in the USA.[33]

Furthermore, countries with large and nearly continuous influx of migrants face a problem due to general lack of both appropriately normed tools for assessment of bilingual/multilingual PWA and appropriate models of treatment of aphasia in bilingual and multilingual people.[34] The extent of the problem is perhaps easiest to see in the European Union example. In the EU, there are 24 official languages and 60 regional or minority languages, and out of 448.4 million people in total, about 40–50 million speak one regional or minority language.[35] This fact deserves consideration because aphasia may affect a speaker's languages to different degrees, and thus it is recommended to provide assessment and treatment in PWA's both/all languages when possible.[34] How can we harmonize the recent recommendations to increase dosage, intensity, and frequency of treatment for aphasia[8] with apparently insufficient rehabilitation capacities and lack of SLP,[16,36] considering also further increase in needs caused by population growth, aging, and earlier incidence of stroke worldwide?[1,4]

Embracing technology

Psychologists have often emphasized that, depending on a desired level of performance, acquiring a new skill may take hundreds of hours of practice.[37] An increased amount of time, rather than "homeopathic doses,"[29] is also necessary for successful treatment of language dysfunction due to stroke.[8,30,31] Growing evidence suggests that computer-based language exercises, targeting for instance word retrieval, verb production, sentence production, and comprehension, help PWA to improve these skills.[38,39] The most notable features of remote digital treatments of aphasia are an increased amount of time in treatment (through individual practice at home or community-based telerehabilitation) and flexibility in scheduling remote sessions with an SLP.[40,41] While telerehabilitation is convenient in cases when PWA cannot travel to a rehabilitation center, when SLP cannot assemble a treatment group locally, or when other reasons prohibit one-on-one physical treatment, as in the case of the COVID-19 pandemic, remote computer-based treatments of language typically require the presence of an SLP.[42] This means that such a way of treatment delivery fails to overcome the global shortage of SLP. Even when designed for use with a virtual therapist, computer-based treatments are often a digital version of the exercises used in one-on-one physical sessions with SLP.[43] Thus, a novel approach to the delivery of aphasia rehabilitation is needed.

Ideally, such a solution would allow PWA to transition upon release from the hospital from a treatment that is fully led by an SLP to an SLP-designed but self-administered treatment. In this approach, the SLP becomes a consultant in intervention, where most of the work is carried out by PWA. This concept is aligned with the efforts to increase home-based treatments, which is among the goals and pragmatic recommendations for improvement of stroke rehabilitation by 2030.[4]

Immersive VR is a powerful tool that combines simulation of natural environments with well-controlled conditions in real time, allowing assessment and treatment of patients in settings with high ecological validity.[44] VR is becoming more present in the assessment and treatment of various mental and physical conditions.[9] However, only a handful of studies so far investigated immersive VR interventions for poststroke aphasia (e.g.,[45–49]). Some of the studies lack rigorous experimental design, or they do not fully utilize the advantages that VR has over conventional treatment.[45]

An obvious advantage of VR compared to the traditional setup of aphasia treatment is that it allows simulation of real-life situations, where treatment features can be parametrized to suit highly personalized individual needs and abilities. For example, picture naming is the most common task in conventional therapy reported in the literature on aphasia.[50] Unlike retrieving names of 2D representations of everyday objects, such as when using the Boston Naming Test[51] to assess progress during conventional treatment, VR affords immersion of a person into a simulated, virtual environment (VE), where the user can interact with the objects and other avatars (i.e., other users or virtual agents).[9] This interactivity provides better ecological validity than the conventional approach, and it enhances the transfer of effects from the simulated to real-life settings. In addition to interactivity, VR also allows adjustment of treatment through control of parameters in different scenarios so that the environment is optimally adapted to a person, given the severity of their aphasia, combination of symptoms, degree of damage to other cognitive functions, and the person's progress throughout the treatment. The technological capability of VR to adjust to fine-tuned features of a specific treatment can resolve the issue of how to deal with heterogeneity in aphasia rehabilitation.

However, novel therapeutic opportunities based on VR are still relatively rare in aphasia treatment. For example, Bu and colleagues[46] have developed a mobile-based, immersive VR application specifically for PWA treatment of speech, auditory comprehension, cognition, and "comprehensive application," i.e., the use of language in a series of specific everyday life tasks (e.g., shopping in a supermarket and ordering food in a restaurant). This cost-effective app for recovery of language in PWA is intended to increase self-managed treatment by allowing users to practice when they want as well as to reduce the burden on rehabilitation services. As another example, EVA Park is a non-immersive VR platform for multiuser interaction, created specifically for the treatment of PWA.[47,48] Its main purpose is to help PWA improve functional communication and overcome social isolation. EVA Park is a virtual island with many simulated locations typical of everyday life, such as houses, shops, a restaurant, a health center, and so on. Studies on EVA Park report that this engaging environment has been associated with a high level of compliance with VR therapy.[47,52] The results further suggest that using EVA Park considerably improved PWA's functional communication, but not their communicative confidence or feeling of social isolation.[48] The literature on VR health applications, such as treatments of phobias, suggests that fully immersive VR treatments are effective, that they boost clients' confidence, and that a sense of "virtual togetherness," induced through performing joint actions in an immersive VE, improves social interaction, rapport, and sense of belonging to a group.[9]

These effects can be interpreted through the prism of illusory transformations evoked by immersive VR. Such transformations include not only the sense of being somewhere else instead of one's actual physical location (i.e., presence), but also illusions related to one's own body and sense of self, to changes in attitudes and behaviors that often transcend the VE and transfer to real-life situations, with or without the person's awareness of these changes.[9] Illusory modifications of non-modifiable factors (i.e., personal factors)[53] in a VE could help PWA overcome negative self-perception caused by stroke and increase their motivation for treatment.

The reasons for the relative lack of research on the use of immersive VR in the treatment of aphasia are complex and entangled. First, aphasia is underrepresented in stroke trials, which makes the disorder barely visible to a wider interdisciplinary community of researchers. As an illustration, randomized controlled trials of stroke interventions published between 2016 and 2022 included only 1.5% of participants with aphasia. Not including PWA in stroke trials may distort the validity of findings and their usefulness in clinical practice.[54] Another reason that VR is still left largely unexplored and underutilized in the rehabilitation of aphasia is insufficient funding for stroke-related disorders. For instance, between 2007 and 2019, the European Commission allocated less than half of financial support to stroke research relative to research on Alzheimer's disease and other dementias.[55] Finally, until recently, immersive VR hardware was prohibitively expensive, imposing limitations on how widely VR can be applied in training, health, education, and entertainment.[9] However, these costs have been steadily declining, affording the development of rehabilitation tools that could help delivery of treatment to millions of people worldwide who currently do not have access to treatment. Additionally, VR can offer effective support to family members and caretakers of PWA to attenuate "third-party disability," [18] which in turn would have beneficial effects on PWA treatment. Since VR has the capability to improve access to treatment while reducing cost, one may hope that the recent findings on the effectiveness of treatment of aphasia even at the chronic stage, more affordable technology, and effective VR-based treatments in other areas of health will facilitate a dialogue between researchers, clinicians, funding institutions, and the VR industry on how to make rehabilitation services more accessible to stroke survivors.

Future developments in aphasia rehabilitation will likely focus on enhancing effectiveness and widening availability of treatment, although not all of them will manage to bring these goals together. Most likely, improved rehabilitation for aphasia will be achieved through (i) increasing dosage, intensity, and frequency, as recently recommended,[8] while retaining the conventional way of treatment delivery, (ii) combining SLT with pharmacological interventions[56] or with brain stimulation techniques,[57] and (iii) the use of technological solutions, such as VR,[48] but in more innovative ways, such as immersive VR-based personalized, self-administered treatments. Solutions aligned with (i) and (ii) have advantages over traditional treatment, but they require the presence of an SLP and/or other health professionals, while providing treatment to a still limited number of PWA (i.e., those with means and access to services). In contrast, the development outlined in (iii) involves a technology-based wide-scale distribution of treatment potentially attainable even in low- and middle-income countries, where the use of mobile phones and the Internet is steadily growing. This allows for the implementation of such treatments via phone apps and/or the use of shared equipment that could be made available in community centers. Since language can improve even in chronic aphasia with an appropriate intervention,[30,31] one may hope that the idea of delivering VR-based treatment to millions of people with aphasia worldwide will spark curiosity of the booming VR industry.

Conclusion

The rising global burden of stroke has motivated various stroke expert groups to recommend taking immediate actions in stroke surveillance, prevention, acute care, and rehabilitation. Focusing on one aspect of poststroke rehabilitation, the present paper discussed whether immersive VR in the treatment of poststroke aphasia could help reduce the burden of stroke. Current evidence suggests that immersive VR has the potential to radically transform the treatment of poststroke aphasia by affording more efficient, personalized treatments to millions of people who need access to rehabilitation services or more flexibility in their delivery. Taking bold, concrete actions to reduce the burden of stroke has been recommended for all four key areas of stroke services, and embracing immersive VR in rehabilitation of aphasia would be a step in that direction.

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