Mining Twitter for Alzheimer's: Use of Virtual Reality Technology

Abstract

The United States experiences multi-trillion-dollar healthcare expenditures each year, and chronic diseases remain a driving force behind these costs. With an aging population, Alzheimer's disease poses a major threat to society, and there is significant need for alternative treatment options. The goal of this paper is to reveal the current usage of virtual reality in treating Alzheimer's by reviewing earlier publications and mining social media data. SAS Enterprise Miner was the selected tool for text mining three Twitter datasets (tweets_Alzheimers, tweets_VirtualReality, and tweets_VR). Text parsing enabled an analysis to be performed of the frequencies of terms. From the text clustering, the identification of nine clusters helped to further explain the contents of the tweets and their relevance. The overall findings revealed a lack of overlap in the discourse between Alzheimer's and virtual reality. A review of the socio-technical approach to designing systems was followed by specific recommendations on the best strategy for implementing virtual reality in medical settings to treat Alzheimer's.

Introduction and Healthcare Information Systems Importance

Virtual Reality and Alzheimer's Management

Alzheimer's and dementia are oftentimes used synonymously; however, Alzheimer's disease is the progressive neurological disease that takes the form of dementia, a collection of symptoms (Alzheimer's Association, 2020). Dementia is a common cause of disability and dependency for the elderly. The World Health Organization (WHO) predicts that the number of individuals with dementia will reach 75 million by 2030. From 2010 to 2015, costs related to dementia rose by 35%. Mild cognitive impairment (MCI) falls between normal aging and dementia in the cognitive spectrum (Kim, Pang, & Kim, 2019).

The rise of virtual reality (VR) applications in the healthcare industry serve as a promising avenue for patient management. Researchers found that using VR to treat patients with deteriorating cognitive abilities helped reduce their stress levels. In the past, VR interventions have been especially common in dealing with anxiety, behavioral therapy, phobias, and stress. They serve as a practical option for patients with limited accessibility to attending outpatient appointments due to various limitations. Additional benefits include being affordable and flexible. That said, the VR intervention guidelines on the recommended amount and length of VR treatment to yield effective results remain lacking (Kim et al., 2019).

Originality of Approach

This paper reviews unstructured social media data sources to determine the prevalence of VR usage within Alzheimer's and vice versa to determine the adoption rates of the technology. The methods of recent publications involved searching databases for relevant studies on the usage of VR treatment on chronic conditions before extracting and aggregating data for analysis. These papers aimed at reviewing the technological effectiveness of the VR interventions performed (Gohari, Gozali, & Kalhori, 2019; Snoswell, A. & Snoswell, C. 2019). Instead of solely focusing on the technology, the approach for this paper involves both social and technological components.

Diffusion is defined as "the process through which an innovation is communicated through certain channels over-time among the members of a social system" (Dearing, 2009). The model for diffusion of innovations can best be described as an S-shaped curve with early adopters at the lower curve and late adopters at the upper curve. Diffusion takes place due to combination of the following influences a) individuals are faced with uncertainty caused by new information, and b) individual perceptions are influenced by the actions and thoughts of credible people, and c) social pressures cause a need to follow others footsteps (Dearing, 2009).

Dissemination and implementation (DI) science focuses on the adoption, implementation, and continuation of scientific evidence. DI science and public health practice aim to implement more evidence-based practices within public healthcare systems. The main challenge with executing evidence-based interventions is transferring the same expertise, protocols, resources from the research setting to real-world settings. To address the challenge, an iterative learning process often serves the selected systems-thinking tool. The five steps involved are 1) determine the areas or needs that take priority 2) pair the evidence with the identified area or need 3) test or implement the strategy 4) evaluate outcomes 5) decide whether to continue, modify, or abandon the strategy. The DI approach has the potential to efficiently transfer advanced scientific research to practitioners and policymakers alike (Estabrooks, Brownson, & Pronk, 2018).

Literature Review:

Virtual Reality

The origins of VR date back to the 1960s, but VR tools began gaining public attention in the late 1980s. Over the past several decades, thousands of scientific publications on VR technologies have arisen. Researchers collected a total of 21,667 VR articles from the Web of Science Core Collection database. An analysis of the literature involved measuring the frequency (percentage and count) and subject category. Based on category statistics from 1990’s to 2016, the top subject categories were Computer Science (n=9,131, 42.15%), Engineering (n= 6,210, 28.66%), Psychology (n=1,779, 8.21%), and Neuroscience & Neurology (n=1,548, 7.15%) (Cipresso, Giglioli, Raya, & Riva, 2018).

Top VR vendors and their products include Facebook Oculus headset, Google Cardboard and Google Daydream View, Microsoft HoloLens, HTC Vive, and Samsung Gear VR. The pricing of the headsets ranges from $15 to thousands of dollars, while most cost less than $1,000 (Patrizio, 2017). In general, the aforementioned VR products appear to be geared towards consumers looking for immersive gaming entertainment. Nevertheless, VR is also relevant in other industries such as healthcare.

There are several advantages to implementing VR technology in healthcare. Due to the immersive nature, VR can aid in the training of medical professionals by making difficult concepts easier to understand and remember. Furthermore, VR allows for consultations that once had to be conducted in-person to be done virtually. The ability to communicate remotely is especially beneficial in situations where a specialist's expertise is needed in real-time by eliminating distance barriers. VR also provides an engaging platform for patients to be actively involved in managing their health (VR on Cloud, 2019). These benefits of VR can be highly beneficial to both medical professionals and patients alike.

VR and Chronic Conditions Management

Researchers reviewed published works on VR applications for the treatment and rehabilitation of chronic conditions. In April 2016, they retrieved 117 published papers from January 2001 to December 2015 from the MEDLINE database accessible through PubMed. 52 of the 117 papers met the study criteria and had full texts available. Next, they extracted data from the qualifying articles and performed a descriptive analysis. Data included the type of applied VR and the outcome of the VR application. Papers were classified as either treatment-oriented (n=23, 73%) or rehabilitation-oriented (n=14, 27%). The results indicated that 40 papers (77%) reported the VR application as having strong results, 11 papers (21%) with the application of VR being partially strong, and only (2%) of papers with weak results. They concluded that the use of VR technology for prevention and rehabilitation for patients with chronic diseases has grown in recent years (Gohari et al., 2019).

Founded in 2015, AppliedVR is the leading virtual reality therapeutics (VRx) company. Their mission, as stated on their website, is "to address unmet needs and improve clinical outcomes for patients with serious health conditions" (AppliedVR, 2020). AppliedVR offers two products to treat anxiety and general pain management. SootheVR is geared towards hospitals and health centers, and RiseVR is intended for military health. Their VR products are currently being used in over 200 hospitals to treat 30,000+ patients (AppliedVR, 2020).

Healthcare Chronic Conditions

According to the Centers for Disease Control and Prevention (CDC), health care in the U.S. remains one of the costliest in the world (2020a). Each year the nation spends approximately $3.5 trillion on healthcare. Of the total expenditures, 90% can be attributed to chronic and mental health conditions (Centers for Disease Control and Prevention [CDC], 2020a). The CDC defines chronic diseases as "conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both" (2019a). Examples of chronic diseases include heart disease and stroke, cancer, diabetes, obesity, arthritis, Alzheimer's disease, epilepsy, and tooth decay (CDC, 2020a). Three-fifths of adults in America have a chronic disease and two-fifths have two or more (CDC, 2019a). On the current track, these numbers are only expected to increase. In 2017, the top ten leading causes of death were heart disease, cancer, unintended injuries, chronic lower respiratory disease, stroke, Alzheimer's disease, diabetes, influenza and pneumonia, kidney disease, and intentional self-harm (CDC, 2017).

The four major risk factors of chronic disease include cigarette smoking, poor nutrition, a lack of exercise, and excessive alcohol consumption (CDC, 2019a). Cigarette smoking is the main cause of chronic diseases and deaths. Despite the recent decline of U.S. adult smokers from 20.9% to 13.7% between 2005 and 2018, there are currently a staggering 34 million smokers. Over 16 million smokers acquire one or more diseases, and approximately 480,000 people die from smoking each year (CDC, 2019d). Expenditures total $170 billion annually (CDC, 2020a). Poor nutrition and a lack of exercise are two related risk factors. They both have been linked with chronic diseases such as obesity, heart disease, stroke, type 2 diabetes, and cancer (CDC, 2020b). Body Mass Index (BMI) measures provide insight into a person's weight. BMI ranges from 25.0-29.9 to be considered overweight and exceeds 30.0 to be regarded as obese (Harvard School of Public Health, n.d.). Healthcare spending on obesity totals $147 billion every year (CDC, 2020b). Only one in four adults get the recommended 150 minutes of moderate-intensity aerobic activity in addition to muscle-strengthening exercise two or more days per week (CDC, 2019e; CDC, 2019f). Furthermore, less than a tenth of all U.S. adults and adolescents consume enough fruits and vegetables (CDC, 2020b). Foods high in sodium, saturated fat and trans-fat, and sugar should be avoided. A nutritious, well-balanced diet consists of fruits, vegetables, grains, proteins, and oils (U.S. Department of Health and Human Services, 2017). Another risk factor is excessive alcohol consumption, which can take the form of binge drinking, heavy drinking, drinking by pregnant women, and underage drinking. Heavy drinking oftentimes impairs cognitive abilities such as learning and memory. It also leads to heart disease, stroke, liver disease, and cancer (CDC, 2019b). On an annual basis, excessive alcohol consumption results in 88,000 deaths, a tenth of fatalities occur among individuals between 20 and 64 years of age (CDC, 2020a). Chronic diseases can typically be managed but not completely cured. Most chronic diseases are easily preventable through healthy lifestyle choices.

Alzheimer's Disease

Alzheimer's disease ranks as the fifth leading cause of death for seniors 65+ years and the sixth leading cause of death for adults of all ages (CDC, 2019c). It is the most common precursor of dementia (National Institute of Aging [NIA], 2017). The chronic disease has damaging effects on parts of the brain controlling language, memory, and thought, which can severely hinder a person's ability to perform daily tasks such as cooking and driving (CDC, 2019c; NIA, 2017). Common behaviors include repeatedly asking the same question, easily getting confused, and frequently misplacing things. The duration from diagnosis to death depends on the patient's age (NIA, 2017). The development of Alzheimer's typically begins well before the symptoms show around the age of sixty (CDC, 2019c). Early-onset Alzheimer's occurs between the ages of thirty and mid-sixty. Signs of late-onset Alzheimer's tend to show up in people in their mid-sixties. Understandably, the sooner the disease is detected the better (NIA, 2017). In 2018, an estimated 5.7 million U.S. adults were predicted as living with Alzheimer's disease (CDC, 2019c). Due to the current trend of an aging population, the number of affected people is only expected to increase (NIA, 2017).

According to the published work of Cummings, Tong, & Ballard, there are five approved treatment options in the U.S.: three cholinesterase inhibitors (donepezil, galantamine, rivastigmine), one N-methyl-D-aspartate receptor antagonist (memantine), and a combination of a cholinesterase inhibitor and N-methyl-D-aspartate receptor antagonist (2014). The combination of donepezil and memantine was the most recently approved treatment in 2014 (Cummings et al., 2019). Medications can reduce the speed at which the disease develops but cannot serve as a cure (NIA, 2018). The greatest impact has been found with treating early to mid-stages of Alzheimer's. Treatment differs depending upon the severity of Alzheimer's disease. For people with mild-to-moderate Alzheimer's, doctors prescribe one of the three cholinesterase inhibitors.

The effects of the cholinesterase inhibitors are comparable, although the specific response from one drug versus another can vary depending on the individual. Memantine is often prescribed to those with moderate to severe Alzheimer's. Patients must be aware of the potential side effects that come with taking medications such as a loss of appetite, nausea, vomiting, and diarrhea (NIA, 2018).

Further development of successful Alzheimer's treatments remains a challenging endeavor. In a recent publication, researchers attribute challenges to the complex pathologic nature of the disease. Other complications are an insufficient understanding of the connections between the many pathways that cause Alzheimer's and the potential lack of successful treatment agents. Scientists continue to work on formulating new drugs; however, most trials fail to pass phase III trials for not reaching efficacy benchmarks (Cummings et al., 2019).

One study reviewed the effectiveness of current Alzheimer’s treatments. A meta-analysis of randomized controlled trials (RCTs) provides the most concrete support for interventions. The analyses have consistently found statistically significant evidence on the effectiveness, although the clinical significance varies amongst clinicians. Still, past studies pose limitations such as the duration of the treatment and the methodology. There are also concerns about the costs versus benefits. While many challenges have yet to be overcome, the possibilities of emerging disease-modifying therapies present a significant opportunity ((Lanctôt, Rajaram, & Herrmann, 2009).

A literature review explores the usage of combination therapy (symptomatic and disease-modifying) for treating Alzheimer's disease. Combination therapy trials compare the effects of two drugs, both separately and together. Trials are typically tested on patients already taking Alzheimer's medications. With all of that in mind, there is still a lot to be understood about the intricate inner workings of Alzheimer's. The authors recommend pursuing additional clinical trials involving combination therapies. Potential benefits of combined therapeutic agents include "lowering doses of individual agents, reducing costs and side effects" (Cummings et al., 2019). Additionally, clinical trials could determine specific agents for treating patients in the various progressive stages of Alzheimer's. In the past, other serious diseases such as cancer and human immunodeficiency virus-1 (HIV) have been successfully treated with combination therapies (Cummings et al., 2019).

As an expanded study of chronic diseases which includes Alzheimer’s and HIV, clinical data from an Italian general practice database was studied to determine the impact of aging on age-related chronic diseases and healthcare utilization. Based on the findings, researchers revealed that chronic disease and medical treatment increased with aging. The results concurred with prior studies that ninety percent of elderly adults suffer from one or more chronic diseases and three-fifths have two or more. The data also indicated a rise in outpatient care such as diagnostic tests and prescriptions. Medications and diagnostic tests increased more than twenty-five percent over the course of ten years leading up to the study, and the percentages will continue to rise if preventative measures fail to be implemented. A concerning increase in healthcare costs associated with chronic disease extends beyond Italy to other countries such as the U.S. thereby necessitating concerted efforts towards developing alternative treatments (Attela et al., 2019).

Methodology

Social Media Mining

A plethora of information exists on the Internet, an accessible resource for individuals seeking health-related information. With the Web 2.0 paradigm, the Internet also offers a place where people share personal health information and insights to the public (Prieto, Matos, Álvarez, Cacheda, & Oliveira, 2014).

Social media platforms contain massive amounts of user-generated content (UGC), which provides a wide range of data mining opportunities. For example, Twitter is a micro-blogging platform where users can post “tweets” in 140 characters or less. The number of active users exceeds 200 million and over 400 million new tweets are created every day (Prieto et al., 2014).

The study focuses on UGC from Twitter that pertains to specific health conditions, flu, depression, pregnancy, and eating disorders, in Portugal and Spain. Researchers follow a two-step approach in which they formulated regular expressions to extract relevant tweets and utilized machine learning to classify the user posts. The machine learning techniques include Support Vector Machines (SVM), Nearest Neighbor (kNN), Naïve Bayes, Decision Trees (DT). By testing multiple models, they were able to compare results and determine the best classifier (Prieto et al., 2014).

Local health departments (LHDs) in the United States are utilizing Twitter to educate the public and provide updates on health conditions. In 2012, researchers analyzed the contents of tweets made by LHDs to determine the prevalence of tweets about diabetes. They found that 126 out of the 217 LHDs with Twitter accounts posted about “diabetes” or a related term for a total of 976 tweets. In conclusion, LDHs are starting to take advantage of social media platforms, such as Twitter, to communicate about diabetes. That said, the effectiveness of social media can be fully maximized if public health professionals gain a complete understanding of its potential and reach (Harris, Mueller, Snider, & Haire-Joshu, 2013).

Dataset Description

Tweets posted by Twitter users were collected as the data for this study using hashtags #Alzheimers, #VirutalReality, and #VR. The tweets_Alzheimers, tweets_VirtualReality, and tweets_VR datasets contain a total of 8,356 records, 11,227 records, and 26,727 records, respectively. Each data consists of the same 17 variables. To achieve a parsimonious model, five of the variables irrelevant to the analysis were removed during the File Import step. They include latitude, longitude, replyToSID, replyToSN, and replyToUID.

RecordID serves as a unique identifier for each record. The input role is assigned to the following eight variables: Favorited, FavoriteCount, Created, Truncated, ID, RetweetCount, IsRetweeted, and Retweeted. Text, StatusSource, and ScreenName are set to the text role.

Nominal level variables are categorical and unordered such as Text, StatusSource, and ScreenName. At the binary level, Favorited, Truncated, RetweetCount, and IsRetweeted can either be classified as FALSE or TRUE. Interval level variables, characterized as numerical and continuous, include RecordID, FavoriteCount, ID, and RetweetCount. There are no ordinal level variables present.

Table 1: Dataset Variables

Data Set Variable	Role	Level
RecordID	ID	Interval
Text	Text	Nominal
Favorited	Input	Binary: TRUE/FALSE
FavoriteCount	Input	Interval
Created	Input	Date
Truncated	Input	Binary: TRUE/FALSE
ID	Input	Interval
StatusSource	Text	Nominal
ScreenName	Text	Nominal
RetweetCount	Input	Interval
IsRetweeted	Input	Binary: TRUE/FALSE
Retweeted	Input	Binary: TRUE/FALSE

Text Analytics

SAS Enterprise Miner is the selected tool for mining Twitter posts. The data mining software was designed for Sampling, Exploring, Modifying, Modeling, and Assessing, referred to as SEMMA, to process large quantities of data (SAS, 2017). The required nodes for this paper included the *File Import* node from the Sample section and the *Text Parsing*, *Text Filter*, and *Text Cluster* nodes from the Text Mining section.

The *File Import* node allowed the importing of the tweet_Alzheimers spreadsheet. After running the node, the edit variables option was selected to view a table of all the variables. Several updates needed to be made on the roles and levels as well as setting the drop option to yes for the variables irrelevant for mining purposes. The *Text Parsing* node followed. The two nodes were linked before running the text parsing node. The results provided a table of the terms, their role, attribute, frequency, and rank. The data was recorded for the most frequent and relevant terms such as alzheimers, dementia, chronic disease, virtual reality, and vr. Lastly, the *Text Cluster* node was attached and ran. A table of all the clusters, their descriptive terms, and frequency helped in the analysis process. The steps were repeated for the tweet_VirtualReality and tweet_VR spreadsheets.

Text Parsing Node:

Table 2: tweet_Alzheimers Data

Term	Role	Attribute	Frequency	Rank for Variable Numdocs
dementia	Noun	Alpha	924	1
alzheimers	Prop	Alpha	909	2
caregiving	Noun	Alpha	129	7
remember	Verb	Alpha	120	8
mentalhealth	Noun	Alpha	114	10
alzheimers	Noun	Alpha	102	13
health	Noun	Alpha	87	16
medical	Adj	Alpha	76	20
everyday language	Noun Group	Alpha	57	23
disorder	Noun	Alpha	52	31
virtual	Prop	Alpha	66	54

In the tweets_Alzheimers spreadsheet, the top two keywords were dementia with alzheimers with frequencies of 924 and 909, respectively. Other keywords in the top 10 include caregiving 129, remember 120, and mentalhealth 114. Both virtualreality and vr were mentioned twice.

Table 3: tweets_VirtualReality Data

Term	Role	Attribute	Frequency	Rank for Variable Numdocs
virtualreality	Prop	Alpha	1073	1
vr	Prop	Alpha	920	2
ar	Prop	Alpha	704	3
augmented	Prop	Alpha	404	4
iot	Prop	Alpha	156	13
virtualreality	Noun	Alpha	153	14
emergingtech	Prop	Alpha	104	27
mixedreality	Prop	Alpha	99	28
virtual	Adj	Alpha	70	48
virtual	Prop	Alpha	66	54

For the spreadsheet titled tweets_VirtualReality, virtualreality appeared 1073 times, vr 920 times, and ar 704 times. There were no tweets mentioning alzheimers, chronic conditions, dementia, or disease.

Table 4: tweets_VR Data

Term	Role	Attribute	Frequency	Rank for Variable Numdocs
vr	Prop	Alpha	3110	1
ar	Prop	Alpha	1671	2
iot	Prop	Alpha	1260	3
ai	Prop	Alpha	1006	5
virtualreality	Prop	Alpha	743	6
emergingtech	Prop	Alpha	537	9
vr	Noun	Alpha	497	11
tech	Noun	Alpha	498	10
mixedreality	Prop	Alpha	480	12
augumentedreality	Prop	Alpha	350	17

The tweets_VR spreadsheet included the following most common keywords vr, ar, iot, ai, virtualreality, and emergingtech. That said, most of the posts contained references to virtual reality in the contexts of gaming. Like the tweets_VirtualReality results, none of the keywords related to chronic conditions such as alzheimers and dementia.

Presentation and Interpretation of Findings

The heatmap provides a visual representation of the frequencies of the nine terms within the three spreadsheets. At one extreme, the boxes in red indicate terms that appear either 0 or 1 time, and the one term in orange appears 5 times. Yellow boxes signify that the term's prevalence was in mid-range, between 12 and 743, when compared to the other frequencies. The boxes in green represent the terms with the highest frequencies ranging from 909 to 3,110.

Several useful conclusions can be drawn from the relationship between the terms' frequencies and the different spreadsheets. tweets_Alzheimers does not contain tweets mentioning emergingtech or gaming. Additionally, terms related to virtual reality and vr only appear four times. Both tweets_VirtualReality and tweets_VR appear to be completely void of the terms alzheimers, dementia, and disease. Each column has a relatively drastic spread of colors which indicates a lack of overlap between Alzheimer's and VR. It also suggests that healthcare professionals taking care of Alzheimer's patients have yet to adopt VR technology for treatment purposes.

Figure 1: Heatmap of Nine Terms from Three Spreadsheets

		Spreadsheet		
		tweets_Alzheimers	tweets_VirtualReality	tweets_VR
Term	alzheimers (Prop)	909	0	0
	dementia (Noun)	924	0	0
	disease (Prop)	5	0	0
	emergingtech (Prop)	0	104	537
	gaming (Noun)	0	12	33
	health (Noun)	87	1	193
	virtualreality (Prop)	2	1073	743
	vr (Prop)	2	920	3110
	vr gamers (Prop)	0	15	16

Text Cluster Node:

Table 5: Text Clusters

Cluster Name	ClusterID	Frequency	Descriptive Terms	Example Tweet
Medical	**2**	**50**	Medical, trust, research, 'medical research', 'medical information', information	"Medical information you can trust!"
Dementia Patient	**3**	**17**	+patient, +'dementia patient', aarp, potential, know, risk, dementia, alzheimers	"Medical Blog | What are the 15 Primary Dementia Types?"
Aging	**8**	**61**	alzhei, +age, +work, 'social care sector', relative, sector, social, ageinplace, +life, inn, care, +senior, health, +memory, brain	"People at higher risk of developing #Alzheimers disease due to #family history may show changes in #memory performa…"
Technology	**4**	**809**	vr, virtualreality, ar, ai, read, augument, oculusquest	"#AR and other #EmergingTechnologies will change the way we see the world"
Health Technology	**3**	**1853**	vr, ar, tech, health, educationtech, emergingtech, healthtech, gigadgets, vrchat, oculusquest	"#VirtualReality Changes the way Medical Professionals Prepare for Surgery #VR #AR #AugumentedReality"
Gaming	**10**	**496**	+technology, design, +character, dprinting, professional, +time, +learn,	"What is the name of this game? Only wrong answers.

			game, gaming, designer, +event, +student, futuristic	#vr #vrgaming #vrgame #Oculus"

Medical

The Medical cluster found in the tweets_Alzheimers spreadsheet refers to the broad idea of health care. Results indicated a ClusterID of 2 and Frequency of 50. Medical, as an adjective, ranked #20 and showed up 76 times. Another frequent term identified in the cluster, trust (Verb), appears 42 times. The terms medical information (Noun Group) and medical research (Noun Group) were identified 10 times and 32 times, respectively. An example tweet from the cluster reads "Medical information you can trust!"

Dementia Patient

Another cluster within the tweets_Alzheimers spreadsheet had a ClusterID of 3 and Frequency of 17. As opposed to the Medical cluster, the Dementia Patient cluster contains descriptive terms that are specific to Alzheimer's disease and dementia. The most prevalent term Dementia (Noun) appeared 924 times, and alzheimers (Prop), a close second, shows up 909 times. +patient (Noun) has a frequency of 14 times and +dementia patient (Noun Group) of 8. "Medical Blog | What are the 15 Primary Dementia Types?" serves as a relevant tweet.

Aging

The tweet_Alzheimers spreadsheet includes a third cluster called Aging with a Cluster ID of 8 and Frequency of 61. This cluster relates to the lifestyle, mental status, and needs of seniors as they grow older. Ranked as #16, health (Noun) has a frequency of 87. Less frequent words in the cluster Brain (Noun) and +age (Verb) appear 12 times and 11 times, respectively. A portion of an example tweet is "People at higher risk of developing #Alzheimers disease due to #family history may show changes in #memory performa. . ."

Technology

Within the tweets_VirtualReality spreadsheet, the top three words, virtualreality (Prop), vr (Prop), and ar (Prop), fall into the Technology cluster with a ClusterID of 4 and Frequency and 809. In descending order, their frequencies are 1073, 920, and 704. Other terms include ar (Prop) 704 and oculusquest (Prop) only are present 24 times. The following tweet accurately represents the cluster "#AR and other #EmergingTechnologies will change the way we see the world."

Health Technology

Health Technology is a relevant cluster within the tweets_VR spreadsheet. The ClusterID and Frequency are 3 and 1853, respectively. It contains three of the ten top terms: vr (Prop) 3110, ar (Prop) 1671, and emergingtech (Prop) 537. Healthtech (Prop) appears 243 times, educationtech (Prop) 186 times, and vrchat (Prop) 80 times. An example tweet from the cluster reads "#VirtualReality Changes the way Medical Professionals Prepare for Surgery #VR #AR #AugumentedReality."

Gaming

A popular adoption of virtual reality can be found in the video game industry, which explains the Gaming cluster. It has a ClusterID of 10 and a Frequency of 496. The term +technology, as a noun, appears 318 times. A list of less frequent words, their roles, and frequencies are +character (Noun) 48, +learn (Verb) 33, game (Adj) 32, and gaming (Noun) 33. "What is the name of this game? Only wrong answers. #vr #vrgaming #vrgame #Oculus" serves as a relevant tweet.

Recommendations and Contributions

Social Recommendations

The Alzheimer's Association remains a top source "in outlining principles and practices of quality care for individuals living with dementia" (Fazio, Pace, Maslow, Zimmerman & Kallmyer, 2018). Resources over the years include the Guidelines for Dignity, the Key Elements of Dementia Care, and the Dementia Care Practice Recommendations. The Alzheimer's Association's most recent publication is the 2018 Dementia Care Practice Recommendations, which provides information on best practices and quality care. It was created for professional caregivers working with dementia patients and their families (Fazio et al., 2018).

Quality care is centered around Person-Centered Focus. Surrounding areas of relevance are as follows: Assessment and care planning, Medical management, Information, education and support, Dementia-related behaviors, Activities of daily living, Workforce, Supportive and therapeutic environment, Transition and coordination of services, Detection and diagnosis (Fazio et al., 2018).

Figure 2: Alzheimer's Association 2018 Dementia Care Practice Recommendations

Technical Recommendations

VR design principles are essential when developing applications. Several major considerations for the optimal user experience include user control and feedback, brightness changes, button placement, ergonomics, and text readability (LeapMotion, 2015; Mealy, n.d.; Purwar, 2019).

1. **User Control and Feedback**: Users should be given complete control when using the simulator to mimic real life. A failure to incorporate user control can lead to "simulator sickness" caused by an inconsistency between visual and physical motion cues (Mealy, n.d.; Purwar, 2019). Simply put, simulator sickness occurs when the eyes signal that you are moving but the body thinks you are still. Users who experience simulator sickness are apt to feel nauseous. Additionally, best practices are for VR to incorporate some sort of user feedback in response to each of their actions. Tactile feedback is still limited, however other forms of sensory responses such as audio and visual cues can be incorporated into the application (Purwar, 2019).
2. **Brightness Changes**: Designers should also be aware of sudden adjustments in brightness. When switching from a dark to a light scene, the user will need some time for their eyes to acclimate to the new level of brightness (Mealy, n.d.; Purwar, 2019).
3. **Button Placement**: An optimal design is when fuse buttons are large and spaced far apart from one another. This will reduce the likelihood that the user presses the wrong button by accident (Purwar, 2019).
4. **Ergonomics**: The normal ranges of motion are an important ergonomic consideration. These include up/down, left/right, side-to-side movements of the head as well as viewing zones (LeapMotion, 2015; Purwar, 2019).
5. **Text Readability**: Resolution limitations can cause text outside of the central field of view (FOV) to appear blurry (LeapMotion, 2015). To maximize text readability, it is best not to use large text blocks and super detailed user interface elements. The intended viewing distance will influence the screen and content sizes in addition to the content density (Purwar, 2019).

Socio-Technical Approach

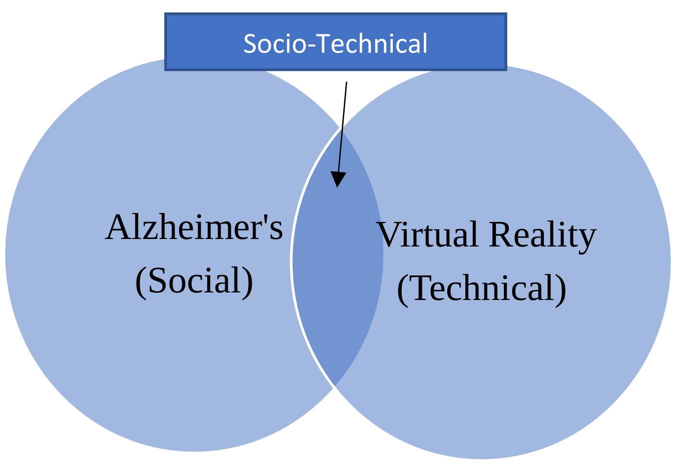
Socio-technical systems design (STSD) methods follow an approach that involves both the social (human, organization) factors and technical factors. The STSD methods are meant to provide a way of better understanding the multi-factor interactions in the workplace. While managers acknowledge the significance of implementing STSD methods, the prevalence is few and far between. An explanation for the lack of adoption could be due to the complexity of applying the methods and incomplete understanding of the issues at hand (Baxter & Sommerville, 2011).

The article focuses on a practical approach to grow the field of socio-technical systems engineering (STSE). Researchers found four systems engineering activities central to all organizational IT systems development projects including procurement, analysis, construction, and operation. The order will vary depending on the situation; however, the fundamental activities remain the same. To avoid a breakdown between change processes and systems development processes, the vision of STSE is bridge the two processes by 1) educate and support system stakeholders on socio-technical issues and 2) give support on how to use information regarding socio-technical factors both in the organizational change process and technical systems design (Baxter & Sommerville, 2011).

The rise of Artificial Intelligence (AI) and VR technologies provides new preventative and treatment options for healthcare systems. The proposed solution is a combination of patient-centered care and VR to help patients with Alzheimer’s Disease. Below are specific recommendations following the socio-technical approach to developing a successful Alzheimer’s treatment using VR.

1. Explain the significant need for advancements in Alzheimer's care to key stakeholders such as patients and consumers, healthcare providers, clinicians, researchers, policymakers and regulators, and insurers.
2. Coordinate the collaborative efforts of medical professionals (geriatricians, neurologists, neuropsychologists) and VR specialists (engineers and clinicians) to develop a VR application for Alzheimer’s patients.
3. Perform clinical trials to determine the overall effectiveness of the developed VR treatment and receive FDA approval.
4. Provide extensive training to clinicians and other medical staff on how to properly administer VR treatment to patients with Alzheimer’s. Certifications must be obtained by all health providers involved before implementation to ensure quality care.
5. Perform annual evaluations of all facilities with certified health professionals to determine that standards are being upheld.

Figure 3: Venn Diagram of Social-Technical Approach



Conclusion and Contributions

The aging population is driving healthcare requirements for new chronic condition interventions through VR technologies as discussed in this manuscript. Globally, the human population is aging with the typical life span nearly doubling over the last century and a half (Atella et al., 2019). The three demographic processes indicative of the size and age of a population are fertility, mortality, and migration. Since 1950, life expectancy has been rising worldwide. Meanwhile, fertility rates are declining. Both serve as key drivers in the aging population. International migration often leads to shifts in population age structures. Countries with an influx of young, employed migrants could experience a reduced speed in aging, but migrants who decide to stay will inevitably age and become part of the older population. This social transformation is extremely significant due to the impact on almost every part of society. According to data from the World Population Prospects: in 2019 Revision, one-sixth of the world's population will be upwards of age 65 by 2050 (United Nations, n.d.). Aging serves as a major risk factor in chronic diseases. The related medical expenses continue to take a heavy toll on the national healthcare budgets, and experts are raising concerns about the overall financial sustainability of public healthcare systems in the years to come (Attela et al., 2019).

The paper sheds light on the status of healthcare in the U.S. including the prevalence of chronic diseases and the expected increase in the elderly population. Social media data was used to determine the adoption rates of VR technology, specifically for Alzheimer's management. Data mining results indicated that a gap still exists between the dissemination and implementation of VR in the healthcare industry. The recommendations follow the socio-technical approach by involving medical professionals, patients, and technological gurus in the process of developing an effective VR treatment for Alzheimer's patients. Ultimately, there are numerous opportunities for medical improvements, but action must be taken before national health worsens.

References

Alzheimer's Association. (2020). *Alzheimer's and dementia*. Retrieved from https://www.alz.org/alzheimer_s_dementia

AppliedVR. (2020). Home —AppliedVR. https://appliedvr.io/

Atella, V., Piano Mortari, A., Kopinska, J., Belotti, F., Lapi, F., Cricelli, C., & Fontana, L. (2019). Trends in age-related disease burden and healthcare utilization. *Aging cell*, *18*(1). doi:10.1111/acel.12861

Baxter, G. & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering, *Interacting with Computers*, *23*(1), 4-17, https://doi.org/10.1016/j.intcom.2010.07.003

The Centers for Disease Control and Prevention. (2017). *Leading causes of death*. Retrieved from https://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm

The Centers for Disease Control and Prevention. (2019a). *About chronic diseases*. Retrieved from https://www.cdc.gov/chronicdisease/about/index.htm

The Centers for Disease Control and Prevention. (2019b). *Alcohol use and your health*. Retrieved from https://www.cdc.gov/alcohol/fact-sheets/alcohol-use.htm

The Centers for Disease Control and Prevention. (2019c). *Alzheimer's disease*. Retrieved from https://www.cdc.gov/dotw/alzheimers/index.html

The Centers for Disease Control and Prevention. (2019d). *Current cigarette smoking among adults in the United States*. Retrieved from https://www.cdc.gov/tobacco/data_statistics/fact_sheets/adult_data/cig_smoking/index.htm

The Centers for Disease Control and Prevention. (2019e). *Lack of physical activity*. Retrieved from https://www.cdc.gov/chronicdisease/resources/publications/factsheets/physical-activity.htm

The Centers for Disease Control and Prevention. (2019f). *Physical activity prevents chronic disease*. Retrieved from https://www.cdc.gov/chronicdisease/resources/infographic/physical-activity.htm

The Centers for Disease Control and Prevention. (2020a). *Health and economic costs of chronic diseases*. Retrieved from https://www.cdc.gov/chronicdisease/about/costs/index.htm

The Centers for Disease Control and Prevention (2020b). *Poor nutrition*. Retrieved from https://www.cdc.gov/chronicdisease/resources/publications/factsheets/nutrition.htm

Cipresso, P., Giglioli, I., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*, *9*. doi:10.3389/fpsyg.2018.02086

Cummings, J. L., Tong, G., & Ballard, C. (2019). Treatment combinations for Alzheimer's disease: Current and future pharmacotherapy options. *Journal of Alzheimer's disease: JAD*, *67*(3), 779–794. doi:10.3233/JAD-180766

Dearing J. W. (2009). Applying diffusion of innovation theory to intervention development. *Research on Social Work Practice, 19*(5), 503–518. https://doi.org/10.1177/1049731509335569

Estabrooks, P. A., Brownson, R. C., & Pronk, N. P. (2018). Dissemination and implementation science for public health professionals: An overview and call to action. *Preventing chronic disease*, *15*(162). https://doi.org/10.5888/pcd15.180525

Fazio S., Pace, D., & Maslow, K., Zimmerman, S., Kallmyer, B. (2018). Alzheimer's association dementia care practice recommendations. *The Gerontologist*, *58(1)*, S1-S9. https://doi.org/10.1093/geront/gnx182

Gohari, S., Gozali, E., & Kalhori, S. (2019). Virtual reality applications for chronic conditions management: A review. *Med J Islam Repub Iran*, *33*(67). doi: 10.34171/mjiri.33.67

Harris, J.K., Mueller, N.L., Snider D, Haire-Joshu, D. (2013). Local health department use of Twitter to disseminate diabetes information, United States. *Preventing Chronic Disease, 10*. doi: http://dx.doi.org/10.5888/pcd10.120215

Harvard School of Public Health. (n.d.). *Obesity definition*. https://www.hsph.harvard.edu/obesity-prevention-source/obesity-definition/

Kim, O., Pang, Y., Kim, J-H. (2019). The effectiveness of virtual reality for people with mild cognitive impairment or dementia: A meta-analysis. *BMC Psychiatry*, *19*(219). https://doi.org/10.1186/s12888-019-2180-x

Lanctôt, K. L., Rajaram, R. D., & Herrmann, N. (2009). Therapy for Alzheimer's disease: How effective are current treatments? *Therapeutic Advances in Neurological Disorders*, *2*(3), 163–180. doi:10.1177/1756285609102724

LeapMotion. (2015). *VR design best practices*. Medium https://medium.com/@LeapMotion/vr-design-best-practices-bb889c2dc70

Mealy, P. (n.d.). *Best practices and virtual reality design principles*. Dummies. https://www.dummies.com/software/best-practices-and-virtual-reality-design-principles/

National Institute on Aging. (2017). *What is Alzheimer's disease?* https://www.nia.nih.gov/health/what-alzheimers-disease

National Institute on Aging. (2018). *How is Alzheimer's disease treated?* https://www.nia.nih.gov/health/how-alzheimers-disease-treated

Patrizio, A. (2017). *Virtual reality companies: Top 20 vr companies to watch*. Datamation. https://www.datamation.com/mobile-wireless/virtual-reality-companies-top-20-vr-companies-to-watch-2.html

Prieto, V. M., Matos, S., Álvarez, M., Cacheda, F., & Oliveira, J. L. (2014). Twitter: A good place to detect health conditions. *PloS One*, *9*(1), e86191. https://doi.org/10.1371/journal.pone.0086191

Purwar, S.(2019). *Designing user experience for virtual reality (VR) applications*. UX Planet. https://uxplanet.org/designing-user-experience-for-virtual-reality-vr-applications-fc8e4faadd96

SAS. (2017). *Introduction to SEMMA.* https://documentation.sas.com/?docsetId=emref&docsetTarget=n061bzurmej4j3n1jnj8bbjjm1a2.htm&docsetVersion=14.3&locale=en

Snoswell, A.J. & Snoswell, C.L. (2019). Immersive virtual reality in health care: Systematic review of technology and disease states. *JMIR Biomed Eng*, *4*(1), e15025. DOI: 10.2196/15025

United Nations. (n.d.). *Ageing*. https://www.un.org/en/sections/issues-depth/ageing/

U.S. Department of Health and Human Services. (2017). *Dietary guidelines for Americans*. https://www.hhs.gov/fitness/eat-healthy/dietary-guidelines-for-americans/index.html

VR on Cloud. (2019). *Top benefits and challenges of virtual reality in health care*. Medium. Retrieved from https://medium.com/@virtualrealityoncloud/top-benefits-and-challenges-of-virtual-reality-in-health-care-8a732f0853e0

Appendices

Figure 1: Medical Cluster

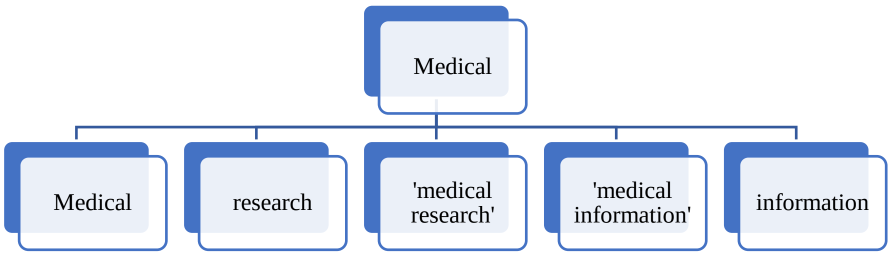


Figure 2: Dementia Patient Cluster

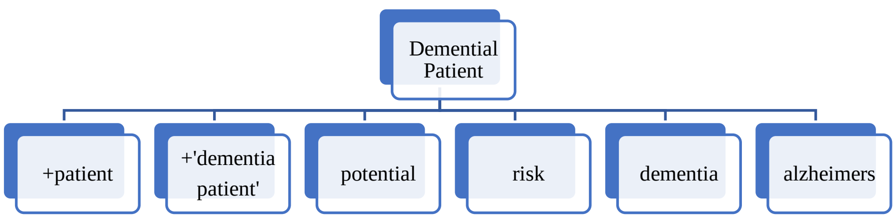


Figure 3: Ageing Cluster

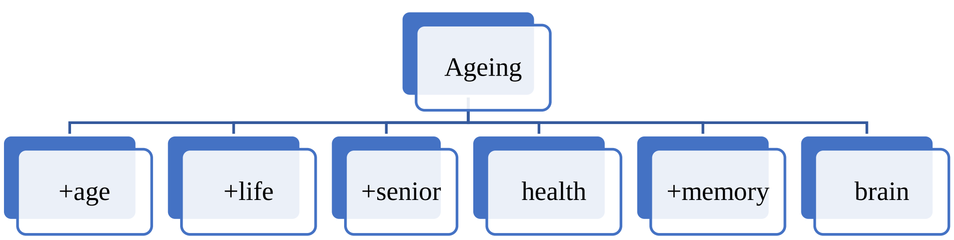


Figure 4: Technology Cluster

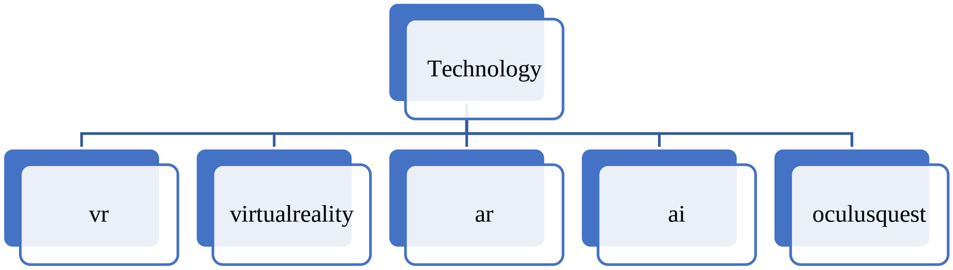


Figure 5: Health Technology Cluster

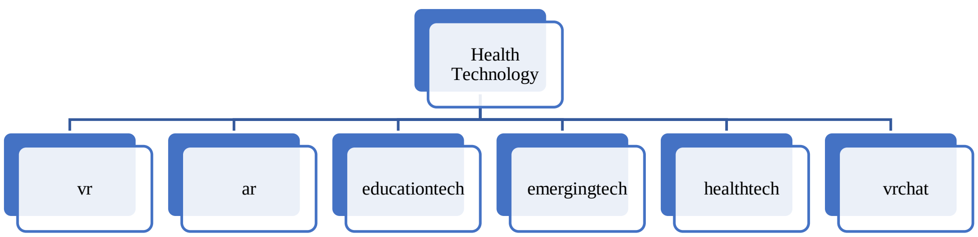


Figure 6: Gaming Cluster