

Review article

An overview of the digital solutions for helping people with aphasia through bibliometric analysis

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ABSTRACT

This paper gives insights into recent research developments in the field of digital solutions for people with aphasia and tries to analyse its impact on their rehabilitation. A bibliometric research approach is used for data collection. Relevant studies were extracted from seven major academic databases from years 2000 to 2019 inclusive. The systematic process resulted in 986 studies. The average growth in this field is 4%, which is less compared to other research areas. However, the average citations per paper is 7.27, which represents a medium level of publication quality. Scopus and Web of Science are leading databases for the number of studies (379 and 264) and quality of publications (P-Index: 49.26 and 32.85), respectively. The USA, with 42% of publications, leads this research field, followed by the UK with 15%. Both countries have national aphasia strategies in place through charities (not government level strategies), which potentially contributed to their research leadership. The results show that recent advances in digital solutions have the potential to support people with aphasia. However, further work is needed at both academic and government levels to deliver more research contributions and funding for the rehabilitation of people with aphasia.

1. Introduction

1.1. Stroke and aphasia statistics

Stroke has emerged as one of the most dangerous diseases in the 21st century. The World Health Organization (WHO) revealed stroke as the second-largest cause of death worldwide after heart disease. Over the last 15 years, heart disease and stroke have remained the top causes of deaths globally. About six million people die each year due to complications caused by a stroke (WHO [51]). It is predicted that the number of people with stroke will increase due to increasing life span and an ageing population (WHO [51]).

The United Kingdom (UK) is not immune to this alarming WHO statistic, as stroke is the fourth most significant contributor to annual deaths. There are 100,000 new cases of stroke recorded in the UK annually, which means there is a new case every five minutes (Association [9]). Additionally, 1.2 million stroke survivors are living in the UK currently (Association [9]).

The Centre of Mental Health released a report which indicates that 10% of the annual healthcare budget for the National Health Service (NHS) (equivalent to £15 billion) is spent on traumatic brain injuries in

the UK. This consists of cost for premature deaths, health and social care, lost work contributions, as well as long term disabilities (UKABIF [9]). Stroke survivors have a high risk of damage to one or more language areas of their brain, resulting in aphasia. It has been found that 45% of aphasia cases result from a stroke (Ali et al. [2]). Aphasia is a communication disorder that can cause communication challenges throughout life (Association [7]).

1.2. Aphasia challenges

People suffering from aphasia face challenges in using language as their speaking, speech comprehension, reading, and writing abilities are impaired. The severity of the impairments can vary from one individual to another. Some people suffering from aphasia can speak only a few words, while others can talk smoothly, but with minor errors. People suffering from aphasia face challenges in conveying their daily needs, having detailed conversations or social contacts (Beeke et al. [12]). These can result in social isolation, lack of leisure activities, loss of social network and mood disorders, which can impact their lifestyle and quality of life (Cruice et al. [18]).

Most people suffering from aphasia are referred to speech therapists

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for short or long-term treatment based on the severity of their impairments. However, speech-therapists within the NHS have seen drastic budget cuts leading to longer waiting times, while the numbers of referrals are ever-increasing (R. Long [39]).

1.3. Potential solution

A recent Government Debate on Brain Injury recommended establishing joint research efforts to better evaluate and improve practical assessment tools and develop diagnostic markers to understand the recovery process better and assess long-term risks (UKABIF [9]). The advances in digital solutions have led to potential solutions capable of assisting speech therapist with their treatment plans for people suffering from aphasia. Digital solutions can be cost-effective and can provide better control for the speech therapists as therapies can be repeated in the same manner time after time. Such solutions can reduce workload for the speech therapists and reduce waiting time for people suffering from aphasia as they will only need guidance from the therapists, and then they can use these tools in the comfort of their own homes.

1.4. The need for bibliometric study

This paper performed a bibliometric study focused on aggregating knowledge on the potential of existing digital solutions for treating people with aphasia. Bibliometric studies have gained a lot of attention from academic researchers over the years. However, most of the bibliometric studies carried out in the literature has been in the field of nano-science (Tang and Shapira [45]), knowledge management (Akhanvan et al. [1]), science and technology (Huang et al. [26]), etc.

There is still limited literature on bibliometric studies relevant to the rehabilitation of people with special needs. Recently, Asghar et al. performed a bibliometric analysis of assistive technology support for people with dementia. This study helped to understand the status, opportunities and needs of research related to assistive technology support for the people with dementia (Asghar et al. [5]). Another study analysed the use of virtual reality (VR) as an educational tool for autism (Fernández-Herrero et al. [9,21]). Similarly, another article analysed the impact of Information and Communication Technologies (ICT) on students with Down syndrome (Fernández Batanero et al. [22]). However, to the best of the authors' knowledge, there is no bibliometric study available on aggregating knowledge related to digital solutions for treating people with aphasia.

Traditionally, bibliometric studies cover a research domain from broader angles, as well as provide an in-depth analysis of that research domain. Therefore, this paper aims at aggregating knowledge from major research databases related to technology assistance in the rehabilitation of people with aphasia and highlighting important research themes within this research domain. This aim is achieved by accomplishing the following research objectives.

Objective 1: Exploring the quantity and quality of digital solutions research for people with aphasia.

Objective 2: Identifying leading academic databases for digital solutions research.

Objective 3: Identifying world-leading research countries and their contributions to this field.

Objective 4: Exploring important research themes for digital solutions.

Objective 5: Exploring open areas that need further research efforts.

The remaining paper is organised as follows: the second section outlines the details of the research methodology. The third section contains the results and discussion for this study. The fourth section highlights open research areas that need further investigations. The fifth section summarises the limitations of this study and the sixth section is the conclusions.

2. Research methodology

This study used the bibliometric research process recommended by (Braun et al. [14]) and (Bajwa et al. [11]) to achieve the stated research objectives in Section 1.4. This approach focuses on observing the trends of a technological field through bibliometric quantification of that field in academic databases for a specific period.

2.1. Bibliometric research process

This paper aims to explore relevant research progress on digital solutions for people with aphasia in recent years. The different aspects explored in the study include:

- Growth of publications and citations in the 21st millennium
- Exploration of leading databases for the number of publications and citations
- Publication quality through average citations per paper and P-Index
- Exploration of the top 10 leading countries related to digital solutions research
- Exploration of current research trends and open research areas

For data collection, the systematic search process is adapted from (Jalali and Wohlin [28]) and summarized in Fig. 1. Just like any other research study, the research process started with a broader research area in mind, i.e., digital solutions for supporting people with aphasia. Initial literature review helped the authors to identify the scope of this paper and the formulation of potential research objectives. Keywords helped in the formulation of search strings, which were then used for exploring further literature from academic databases. The data for this paper is extracted from seven major academic research databases (Scopus, ACM, IEEE, ScienceDirect, Web of Science, EMBASE/MEDLINE and PubMed).

Previous bibliometric studies mainly focused on Scopus or Web of Science databases. These databases are comparatively easy to perform bibliometric analysis on, as they have built-in tools to help such analysis. This paper searched databases beyond the two most commonly used databases (Scopus and Web of Science). Considerable time was spent performing the bibliometric analyses manually through a careful, systematic process. In some cases, the citations data is collected manually with the help of google scholar.

The titles and abstracts were initially used to scrutinise those papers relevant to this study. The irrelevant and duplicate studies were removed, and the remaining studies were kept for further analysis. The research string used to gather information between 2000 and 2019 from the various academic databases is given below:

((Virtual Reality* OR Simulation* OR Video Games* OR Virtual Model* OR 3D* OR Cyberspace* OR Artificial Intelligence* OR Virch* OR Computer Model* OR Computer Graphic* OR Illusion* OR Fantasy*) AND (Aphasia* OR Muteness* OR Loss of Speech* OR Speechlessness* OR Aphasic* OR Speech Defect* OR Mutism*))

2.2. Inclusion and exclusion criteria

The inclusion (IC) and exclusion (EC) criteria were used to identify a relevant paper within the scope of this study. The papers that fulfil the below-mentioned conditions were considered for further analysis:

IC1: The study focused on virtual reality assistance for people with aphasia.

IC2: The study used empirical research methods.

IC3: The study described technology development or user testing.

IC4: The study is either a journal or a full or short conference paper (not abstract).

On the other hand, the studies that conform to any of the following conditions were excluded:

EC1: The study was published before 2000.

EC2: The study was not written in the English language.

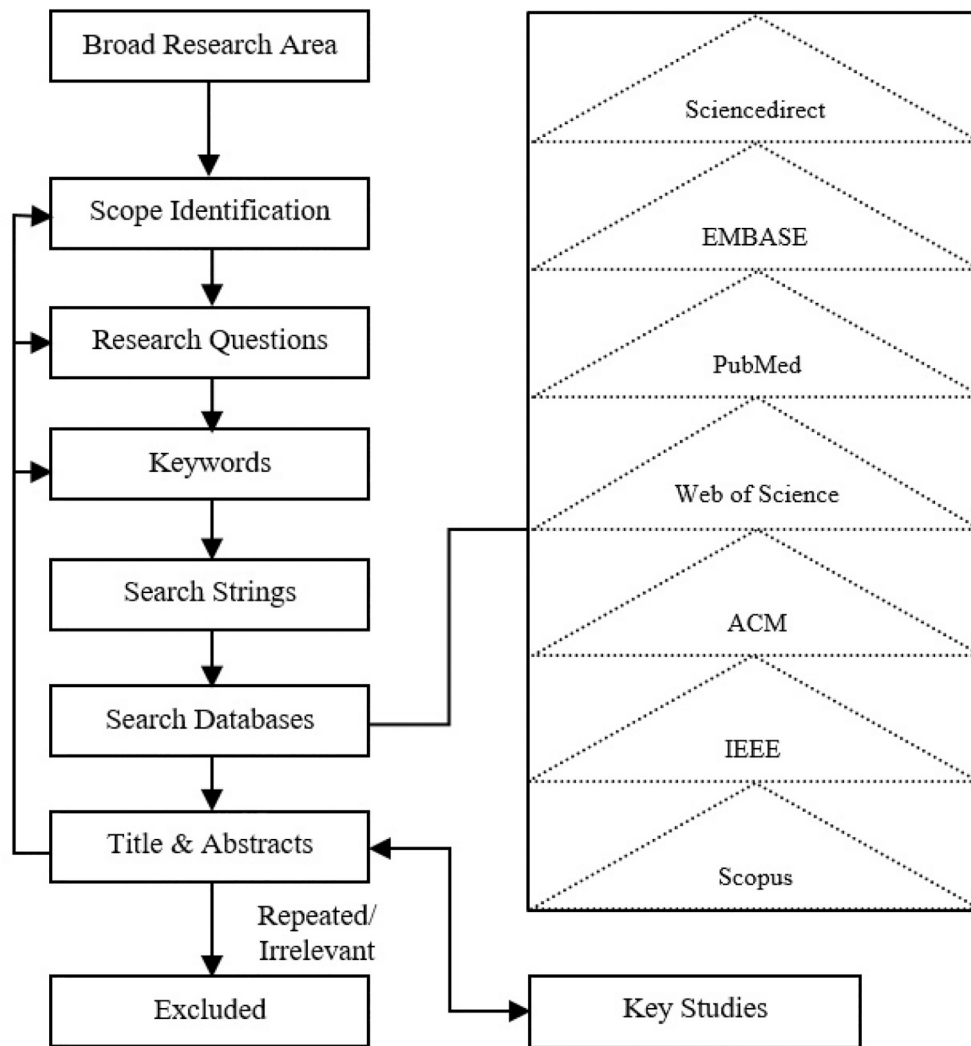


Fig. 1. The Systematic Research Process for the Bibliometric Study.

EC3: The study was based on virtual reality, but not for people with aphasia.

EC4: The study just discussed the virtual reality ideas for people with aphasia, not its development and implementation and user testing.

3. Results and discussion

This section presents findings from the bibliometric analysis, including the overall state of research, research quality, leading academic databases, leading research countries and different research popular within this domain.

3.1. Overall research scenario

The overall research scenario is aimed at achieving the first part of the objective one, i.e., “Exploring the quantity and quality of digital solutions research for people with aphasia”. This study analyses 986 publications after removing duplicate and non-English papers from the above mentioned seven databases. The average annual growth rate for research on the introduction/application of digital solution for treating people with aphasia is shown in Fig. 2. The number of worldwide publications in the last 20 years rose by:

- A factor of 9 (from 5 publications in the year 2000 to 49 publications in the year 2009)

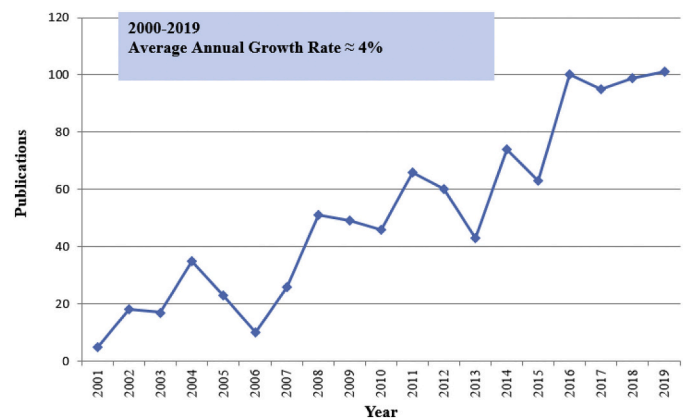


Fig. 2. Worldwide Growth of Digital Solutions Research for the People with Aphasia.

- By a factor of 2 (from 49 publications in the year 2009 to 101 in the year 2019)

Fig. 2 clearly shows that, at the start of the 21st century, the research related to the digital solutions for people with aphasia was at the exploratory stage. Only, five studies were conducted on the use of digital

technology for the treatment of people with aphasia in 2000. However, the number of studies in this domain has increased in the following years. This increase in digital solutions research is due to technological advances in this field and the realization on the part of people with aphasia that these solutions can be useful in their rehabilitation [47].

On the other hand, due to substantial economic implications, governments have started investing in research related to digital solutions and many companies are developing these solutions to help people with aphasia. Such a realization on the part of governments and companies has helped to boost this research area. However, looking at Fig. 2, there is only a 4% annual growth rate for digital solutions research for treating people with aphasia, which is far less than the growth in various other health conditions. For example, the growth rates for dementia-related assistive technologies stands at 29% (Asghar et al. [5]), for telemedicine at 18% (Yang et al. [53]) and mobile health technologies at 10% (Sweileh et al. [44]). Additionally, the overall growth for science disciplines for the last century also stands at 8 to 9% (Bornmann and Mutz [13]). This demands intensive efforts to boost academic and commercial research on the digital solutions that can help in the rehabilitation of people with aphasia.

3.2. Research growth in academic databases

The contribution of major academic databases is summarized in Table 1. The seven considered databases were explored for the same period and with the same search strings to achieve second research objective, i.e. “Identifying leading academic databases for digital solutions research”.

At the start of 21st century, all of the research in this field was published in Scopus (four studies) and Web of Science (one study) and there were no studies found in other databases. However, from the year 2002 onwards, the research studies started to appear in all databases. Most of the published research in the last 20 years are in Scopus (379 papers) and Web of Science (264 papers). The surprise entry was MBASE/MEDLINE with (185 papers). On the other hand, ScienceDirect only had 14 papers. This could be due to the reason that ScienceDirect has limited scope for aphasia related journals and conferences.

3.3. Quality of publications

The quality of publications in this research field can be inferred at two levels. The first of which is the overall research quality and, the

second is the quality of its published database. According to literature, one of the most effective and easier ways of determining publication quality is determining the number of citations that publication has received (Bajwa et al. [11]). Therefore, the next part in the investigation aggregated the number of citations for each paper in the years 2000 to 2019. However, the citations statistics were readily available only for Scopus and Web of Science. The citation details for other databases were derived manually. The average annual citation statistics over the period covered in this study is shown in Fig. 3. These statistics aims at achieving second part of the research objective one, i.e. “Exploring the quantity and quality of digital solutions research for people with aphasia”.

The average citations per paper stand at 7.27, which means that on average, each publication related to aphasia and technology has been cited by at least seven other papers. In similar studies, the highest average citations per paper in (Asghar et al. [5]) stands at 9.75, and the lowest citations per paper in (Bajwa et al. [11]) stands at 5.43. This means the average citations for this study at 7.27 stands at the middle level, which indicates that digital solutions research represents a medium level of publication quality.

In academic literature, the quality of research has been determined through different parameters such as the G-Index (a set of articles ranked in decreasing order of the number of citations that they received), H-Index (reflects the number of publications and the number of citations per publication), GH-Index (computed as the geometric mean of H and G

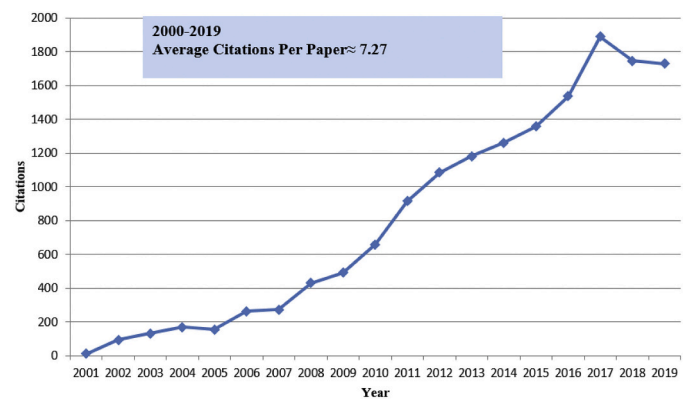


Fig. 3. Citations data from 2000 to 2019.

Table 1
Research growth for academic databases.

Year of Publication	Databases							Publications per Year
	Scopus	Web of Science	ACM	IEEE	EMBASE/MEDLINE	PubMed	Science direct	
2000	4	1	0	0	0	0	0	5
2001	2	3	0	0	0	0	0	5
2002	6	4	1	0	3	4	0	18
2003	7	4	1	0	2	3	0	17
2004	14	10	2	1	7	1	0	35
2005	14	5	0	1	3	0	0	23
2006	6	1	0	0	3	0	0	10
2007	14	5	0	1	3	2	1	26
2008	23	13	0	1	7	6	1	51
2009	23	12	2	2	9	1	0	49
2010	23	8	2	0	9	4	0	46
2011	31	17	3	1	10	4	0	66
2012	22	18	2	1	12	5	0	60
2013	21	10	1	0	8	1	2	43
2014	21	19	4	0	18	9	3	74
2015	20	20	2	1	16	3	1	63
2016	41	30	1	4	15	8	1	100
2017	28	27	1	5	21	11	2	95
2018	32	31	3	4	19	9	1	99
2019	27	26	5	8	20	13	2	101
Total	379	264	30	30	185	84	14	986

indices) and P-Index (measures quantity as determined by citations C and quality as determined by the ratio C/P) (Asghar et al. [5]). Literature shows that P-Index is the most popularly used for comparative studies in recent years (Asghar et al. [5]). The Performance Index (P-Index) offers a reasonable balance between quantity (determined through citations C) and quality (determined through the ratio C/P), where P represents the total number of publications (Braun et al. [14]) (Bajwa et al. [11]). The P-Index is defined as:

$$P - Index = [C.(C/P)]^{1/3}$$

The last column of Table 2 presents the P-Index for this study, which is calculated using the formula mentioned above. Following the criteria from (Asghar et al. [5]), the databases can be classified into two groups: the first group P-Index ($P \geq 22$) and C value ($C \geq 9$) and the second group with P-Index ($P < 22$) and C value ($C < 9$).

According to this criterion, the first group comprises Scopus, Web of Science, EMBASE/MEDLINE, PubMed and ScienceDirect. Table 2 shows that Scopus has outperformed others with both the highest number of publications and a P-Index of 49.26 and a good C value of 17.99. The publication quality from ScienceDirect is exceptional. Although it has only 14 papers, it has a P-Index of 40.21 and a C value of 62.05, which indicate that most of the papers published in ScienceDirect are of the highest quality among digital solutions research. Among others, Web of Science (P-Index: 32.85 and C: 11.76), EMBASE/MEDLINE (P-Index: 33.46 and C: 14.28) and PubMed (P-Index: 32.70 and C: 20.43) have performed well in this research area in terms of publications quality.

The second group comprises of ACM (P-Index: 8.18 and C: 4.30) and IEEE (P-Index: 6.10 and C: 2.70). These low statistics show that papers published in these two databases have received less attention from the research community as compared to other databases. This comes as a surprise because ACM and IEEE are considered popular databases among computing and engineering researchers. One possible reason can be that most of the research carried out for digital solutions for people with aphasia is done by researchers from biomedical, health and social fields. However, this reason needs further investigations.

3.4. Leading countries for digital solutions research

This section focuses on achieving the third research objective, i.e. “Identifying world-leading research countries and their contributions to this field”. Country-wise research output analysis can be a useful tool to access the research productivity of countries against governments institutional/research funding. The number of research outputs by a country can act as a measure for the research productivity of that country (Sahel [41]). Additionally, the number of papers from a country implies there is a greater chance of additional citations, resulting in a greater impact in the research field (Reuters [40]).

Fig. 4 shows the total number of publications for the top 10 leading countries in digital solutions research for the years 2000–2019. The country-wise statistics were collected considering the location of the first author. The USA emerged as the world leader in digital solutions research with 418 publications, which represents over 42% of global research in this field. There is a big gap between the USA and the next closest competitor the UK with 146 publications during this period. The UK contribution in this field of research stands at 15%. Other notable contributions are from Canada (8%) and Australia (7%) with 81 and 73 publications respectively. The rest of the contributions came from Germany (5%), Italy (4%), China (3%), Netherlands (3%), Ireland (2%) and Portugal (2%). In summary, almost 91% of publications related to digital solutions came from these top 10 research countries.

Additionally, the contribution of each country concerning their research inputs into different databases is summarized in Table 3. The USA leads the way again for their contribution to all databases. Similarly, the UK stood at 2nd place in terms of their contributions to individual databases. The rest of the countries also followed the almost same

Table 2
Citations comparison for different databases.

Database	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total Cites	Total Papers TP	Cite Per Paper (C/P)	P-Index
Scopus	0	6	8	27	36	41	84	94	169	216	306	430	537	617	607	679	698	807	725	732	6819	379	17.99	49.26
Web of Science	0	4	9	13	16	20	34	58	93	106	139	195	179	205	231	274	353	403	384	389	3105	264	11.76	32.85
ACM	0	0	0	0	3	3	5	8	7	7	14	7	10	11	7	13	7	10	4	4	129	30	4.30	8.18
IEEE	0	0	0	0	1	0	2	0	2	0	1	0	3	1	3	1	4	19	21	23	81	30	2.70	6.10
EMBASE/MEDLINE	1	0	54	63	76	56	110	69	80	87	101	109	189	183	245	214	217	301	260	226	2641	185	14.28	33.46
PubMed	0	0	22	28	37	35	29	32	47	44	69	122	86	92	101	89	157	254	249	223	1716	84	20.43	32.70
ScienceDirect	0	0	0	0	0	0	0	11	32	31	29	52	81	72	67	88	101	96	102	113	875	14	62.05	40.21
Total	1	10	93	131	169	155	264	272	430	491	659	915	1085	1181	1261	1358	1537	1890	1745	1730	15,377	986		

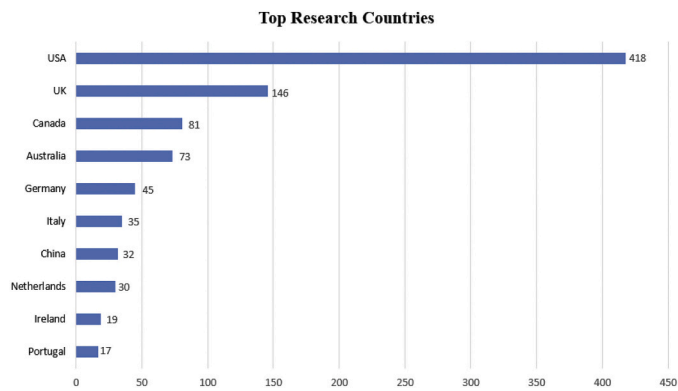


Fig. 4. Leading digital solutions research countries.

pattern for their database contributions as they did for country-wise contributions discussed above.

3.5. Major research areas within digital solutions

It is evident from the statistics mentioned above that recent years have seen a steady increase in the research activities related to digital solutions for people with aphasia. These digital solutions have a varying scope in their support. This section categorizes the types of support that digital solutions provide to people with aphasia to achieve fourth research objective, i.e. “Exploring important research themes for digital solutions”.

3.5.1. Communication aids

People with aphasia often face restrictions in communication due to their physical conditions that can contribute to their isolation from other people. Therefore, researchers have tried to compensate for this situation by proposing some communication solutions for them. Communication aids are the most focused research area as originated from the investigations done for this study.

The Touch-speak software program was one of the earliest computer-based communication aid for people with aphasia. This program based on multimedia functions included hierarchical vocabulary (based on a collection of pictures and audio recordings) that can be used to assist aphasia people in their communication. Additionally, the users can add their private images, sounds and text into the program (Wahn [50]). Another computer program called ‘Resound’ helped people with aphasia as a communication tool through the use of pictures, sounds, and writing text. It has more than 1000 words which can be used to construct sentences related to different environments including garden, house, etc. (van de Sandt-Koenderman [48]). The ScriptTalker was specifically designed to support simple conversations through simple, easy day phrases. It helped the people with aphasia to participate in

Table 3

Leading countries with contributions to academic databases.

Countries	Databases							Country Total
	Scopus	Web of Science	ACM	IEEE	EMBASE/MEDLINE	PubMed	Science direct	
USA	162	123	10	3	69	45	6	418
UK	58	38	8	0	31	9	2	146
Canada	35	24	4	0	12	5	1	81
Australia	24	27	1	0	16	5	0	73
Germany	27	13	0	0	3	2	0	45
Italy	21	7	0	1	4	1	1	35
China	11	7	0	4	7	3	0	32
Netherlands	16	8	1	0	4	1	0	30
Ireland	7	5	3	1	2	1	0	19
Portugal	5	7	1	3	0	0	1	17
Total								896

conversations with their contacts and thus help in their isolation (Kitzing et al. [30]).

A touch screen application helped the people with aphasia in conversational storytelling through the pictures they took earlier. The users can organize pictures over a calendar and can navigate to some specific event picture that they want to discuss. The pictures can be enriched through extra text by the users either during or after the conversation with their partners (Woudstra et al., [52]). The Communication board and Voice Output Communication Aids (VOCAs) has been used as a communication tool. This board has different pictures that match various moods like being thirsty, hungry, sad and happy etc. The users could point to the picture that corresponds to what they wanted to say (Association [8]).

Other than these, the digital advances in recent years have helped the people with aphasia in communication through visual scene displays (Hux et al. [27]), contextualized photographs (McKelvey et al. [35]) and text boxes and speak buttons (Dietz et al. [19]).

3.5.2. Online solutions for aphasia treatment

Online digital solutions for the treatments of people with aphasia is another popular research area. These digital solutions are designed to help people with aphasia through online means of technology, which facilitate them to use such solutions anywhere and at any time.

Vithea (Virtual Therapist for Aphasia Treatment) is an online system developed for people with aphasia, and it can act as their virtual therapist. Vithea can guide the people with aphasia to carry out their training exercises through simple instructions. The Vithea uses Automatic Speech Recognition (ASR) technology that helps it to verify the words spoken by the people with aphasia as either correct or wrong. This allows people with aphasia to train naming things while staying in the comfort of their own homes. Resultantly, the number of hours spent on training can increase, and it can provide more opportunities for their rehabilitation (Pompili et al. [37]).

A multiuser online virtual platform called EVA Park has been popularly used for speech therapy. The people with aphasia can use this platform from their own home and can practice speech repeatedly. A personalized avatar represents the user, as users can choose their conversation environment, including shops, bars, restaurants etc. and can communicate through their headphones (Galliers et al. [24]).

Virtual Clinician is another system used for people with aphasia to practice their communication in everyday situations while staying in their homes. A virtual-clinician avatar is used for this purpose, which acts just like a real clinician. This is a cost-effective and user-friendly solution that people with aphasia can use to practice their speech (Teodoro et al. [46]).

3.5.3. Self-management of Aphasia treatments

The introduction of digital solutions to treatments can not only provide the choice of place whether treatments can be done but also enable the people with aphasia to self-administer their treatments

(Marshall et al. [34]). The speech therapists can remotely monitor the progress of people with aphasia through recorded sessions against standardized performance metrics (Glykas and Chytas [25]). A recent study investigated the use of a smart tablet to self-administer the treatments of people with aphasia. The smart tablet helped to perform and record the performance of the users in word recollection exercises. The exercises showed substantial improvements through a series of trials (Lavoie et al. [32]).

3.5.4. Augmented and virtual reality

Everyday Life Activities (ELA) House is a non-immersive virtual house designed for people with aphasia. The ELA uses real pictures, extract their features and create object texture in the animation and modelling software called Maya. The people with aphasia can train through discovery, structured discovery and memory tasks with the use of a mouse in the virtual environment (Stark et al. [43]). Web-ORLA is another telerehabilitation application, which uses a virtual 3D animated character to talk to people with aphasia through the help of pre-recorded messages. This application has helped in delivering language and speech therapies (Cherney and Van Vuuren [16]).

AphasiaScripts is a specialized tool that allows people with aphasia practising, specially scripted dialogues. An avatar acts as a dialogue partner or a virtual speech therapist. The system offers two views, first for the people with aphasia and second for the speech therapist for controlling and allocating materials for speech relevant to individual needs (Lee and Cherney [33]). Another similar tool called AphasiaRx helps in speech therapy through script-based dialogues. The additional feature of this tool is the instant feedback that users can receive, which highlights the words that users need to practice more (Van Vuuren and Cherney [49]).

4. Open research areas

After detailed data analysis and looking at the current state of the art in digital solutions research for people with aphasia, the following research areas are identified as potential research directions for future research investigations. This section covers the fifth research objective, i.e. “Exploring open areas that need further research efforts”.

4.1. Global view of aphasia

As discussed in the previous section, almost 91% of the digital solutions research came from 10 leading countries. Looking closely on the demographics of these countries, China is the only non-western country that made it to the top 10 countries list with just 31 publications that constitute only 3% of the global research in this field. This situation highlights that current digital solutions research for people with aphasia mainly presents a western view of academic research. The global view of this research field is still missing and demands more efforts from the rest of the world, especially the developing countries. Therefore, there is need on the part of other countries from Asia, Africa and South America. The governments of these countries should also start investing in this research field as ageing is going to increase the number of people with aphasia in all these countries as well. Additionally, this will help to come up with a global view of digital solution research for the targeted population.

4.2. National strategies for aphasia

Strong national strategies related to aphasia can play an important role in both research and practical practices for the wellbeing of the people with aphasia. We tried to investigate which of the top 10 leading research countries for the current study have national aphasia strategies in place. Surprisingly, none of the countries has such strategies at the government level. The USA has an aphasia strategy in place developed by a charity known as “National Aphasia Association” running since

1987. Most of the board members, including the president for this association are the people with aphasia. This association supports the services like research, education and rehabilitation of the people with aphasia (Association [6]). Similarly, “UK Connect” is a charity that supports people with aphasia in the UK (Connect [17]). Both these charities have helped considerably in research and education activities at the USA and UK, which is a contributing factor for these countries to be world leaders in digital solutions research for the people with aphasia. Charity organizations in other countries should learn from the experiences of the National Aphasia Association and UK Connect to support the wellbeing of the people with aphasia in their countries. World Governments should also establish their national aphasia strategies to help in their rehabilitation. National strategies from other research areas like heart disease Arthur et al. [4] and dementia Fortinsky and Downs, [23]; Asghar et al., [5] can be taken as a roadmap to develop national strategies for aphasia.

4.3. Combination of human care and digital solutions

Usually, technology-based digital solutions are used for assisting people with special needs (likewise for the people with aphasia), and such solutions often prove useful for them to be part of the social circle. It is commonly believed that such solutions help to reduce social isolation of the people with special needs Khosravi et al. [29]. However, a few studies have also reported that in some cases the overuse and dependence on such solutions can increase social isolation of these people, as their family members and caregivers can reduce their interaction with them (Seelye et al. [42]). This highlights the need for balancing the use of digital solutions with proper human care. This combination can yield maximum benefits for people with aphasia as well and can contribute positively towards their rehabilitation.

Additionally, it is believed that digital solutions for speech therapies produce the best results when used under the guidance and support of language and speech therapists. As therapists can easily understand the strengths and weaknesses of the person using the digital solution and can tailor the exercises as per specific needs of that person (Association [8]).

4.4. Virtual reality as a potential rehabilitation tool

As discussed in the previous section, some researchers tried to develop VR based digital solutions for treating people with aphasia. However, most of these represent non-immersive virtual environments. To the best of the authors’ knowledge, none of the present digital solutions has used fully immersive VR tools for treating the people with aphasia. Fully immersive VR therapies have been effectively applied in other research areas like; social phobia therapy (Klinger et al. [31]), cognitive-behaviour therapy (Anderson et al. [3]), fear of flying therapy (North et al. [36]), physical rehabilitation therapy (Bailenson and Yee [10]) and anxiety disorder therapy (Powers and Emmelkamp [38]).

The fully immersive VR solutions will offer close to real-life interaction experience for the people with aphasia and their surroundings inside the virtual space. This will resultantly increase their chances of integrating back into real-life, which is a basic goal of every digital solution. This claim is supported by (Brundage and Hancock [15]), as they developed a VR system for people who stutter. The experiments showed that users’ confidence increased over time after practising their speeches with this system. Therefore, a fully immersive VR application along with an appropriate automated speech recognition model for treating people with aphasia can go a long way in their rehabilitation.

A previous review paper by (Egaji et al. [20]), outlined the challenges, opportunities and potential solutions for the adoption of digital speech therapy for treating people with aphasia. The authors found that previously adopted non-immersive VR therapy for people with mild aphasia showed promising results in the recovery process during the trials. With the ever-increasing workload of speech therapists, the authors hoped that the use of fully immersive VR with an appropriate AI-

powered voice recognition model with ease the workload of speech therapists and aid the long-term recovering process for people with aphasia.

5. Limitations of the study

The authors did their best to make this study comprehensive and meaningful. However, there are a few limitations associated with this study, as well:

- The digital solution-based studies are considered only for the period 2000 to 2019.
- Although seven major databases are used for searching relevant studies, there are still many un-indexed journals and publications from such journals might have been missed.
- No search string can be 100% perfect; therefore, false positive and false negative results are always possible.
- Only English language papers are considered for the study, which may have biased results towards English speaking countries to some extent.

6. Conclusions

The research activities within the first few years of this millennium have established the importance of aphasia as one of the leading medical challenges. Many therapies, including digital solutions, are now being developed and used for promoting wellbeing among the people with aphasia. Therefore, this study analysed global digital solutions research for people with aphasia. Data was gathered from the major databases including Scopus, ACM, IEEE, ScienceDirect, Web of Science, EMBASE/MEDLINE and PubMed. The research parameters considered in this paper are the number of studies, number of citations, P-Index, major research areas and open research directions for further research. Scopus and Web of Science have outperformed other databases for both numbers of studies and number of citations (which is not surprising as both these databases are the largest academic databases available currently).

Based on the research parameters, the USA, UK, Canada, Australia, Germany, Italy, China, Netherlands, Ireland and Portugal emerged as leading countries for digital solutions research. The USA and UK led this research field in every aspect including the number of studies, number of citations and P-Index. Furthermore, both the USA and the UK are the only countries to have aphasia strategies in place (not at government level though), which could have supported both countries in productive research outputs.

Further analysis showed that current research reveals only the western view of this research field. Therefore, there is a need for developing countries to invest and conduct more research in this field to achieve a global view of digital solutions research for people with aphasia. Digital solutions can yield better results when applied in combination with human care; therefore, the balance between human care and digital solution should be considered. There is great scope for fully immersive VR based digital solutions to aid rehabilitation among the people with aphasia. The associated limitation to this study are that inclusion of paper was limited to only from the years 2000–2019, seven major databases and English language studies.

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