"Artificial Intelligence Enabled Healthcare: Opportunities and challenges for patients with dementia."

Jannat Babar Malik
The Faculty of Medicine, Department of Health Management and Health Economics
University of Oslo
15 November 2023

Supervisor: Jonas Minet Kinge

Artificial intelligence enabled healthcare: Opportunities and challenges for patients with dementia.

Thesis submitted as a part of the Master of Philosophy Degree in Health Economics, Policy and Management

University of Oslo

Abstract

Dementia, often used as an umbrella term, results in the decline of patient's cognitive function and capability to such an extent that it starts to disrupt their daily life. The grave impact this disorder has results in increased isolation as well as frustration for patients. The rising interest in artificial intelligence and robotics shows positive signs of AI elevating the effects of dementia and hence empowering patients with the condition. The research area is rather new therefore little evidence exists on their feasibility and implementation in dementia care.

Which is why the aim of this paper is to review ways in which AI technologies and robotics could improve dementia care as well outline challenges that inevitably exist when dealing with artificial intelligence especially when treating such a vulnerable patient subgroup.

In order to answer the research question, this study employs a scoping review to map out existing data and to further identify the gap in the study area. Multiple databases were used to acquire pre-existing literature hence much of the focus was on evaluating secondary data and journals. A SWOT analysis was further conducted to get a more comprehensive perspective of the topic.

This paper catalogued a total of 38 robotics and AI interventions that assisted patients with dementia and provided descriptions of each robot and AI technology. The results presented highlighted how most of the robots were designed to meet social needs of dementia patients in comparison to those enhancing motor skills, speech assistance and cognitive functions. Amongst the key challenges, cost, access and ethical implications were emphasised on.

Acknowledgments

I would like to express my sincere gratitude for the exceptional guidance and support extended by my supervisor, Jonas Minet Kinge. His insights, constructive feedback, and consistent re-assurances were instrumental in navigating the challenges encountered during the completion of this paper. I feel privileged to have undergone this extensive learning experience.

I would also like to take this moment to thank my father, Muhammad Babar Malik, for enabling me to pursue my studies abroad. His unwavering belief and support in my ability to overcome challenges has been a source of inspiration. None of this would have been possible without his unbreakable support. I wouldn't have been able to come this far in life if it wasn't for you, baba. Thank you for being my anchor and letting me fly.

To my mother who, besides the distance helped me emotionally and mentally throughout my two-year academic programme – you inspire me with your resilience and taught me nothing less. To my brothers, your words of appreciation and motivation have been invaluable. As for my sister, you are a continual source of joy. Words aren't enough to express how grateful I feel for having you all as my strength.

Lastly, to all my close friends that made Oslo home, especially Yoseph, for the constant support and words of affirmation. For guiding me through the writing process and ensuring that I had a smooth journey through this time. I appreciate you and the time you took out of your busy schedule just to make sure I put my greatest effort in writing.

Table of Contents

List of figures

List of tables

Table of Acronyms

Acronyms	
AI	Artificial intelligence
IoMT	Internet of Medical things
NLP	Natural Language Processing
GBD	Global Disease Burden
WHO	World Health Organisation
PwD	Persons with Dementia
DALY	Disability adjusted life year

1 Introduction

The roots of Artificial Intelligence (AI) in healthcare can be traced back to the early 1970s, marking Edward Shortliffe as a seminal figure in the field. Shortliffe introduced MYCIN in 1972, an expert system developed to diagnose bacterial infections and suggest appropriate antibiotic regimens. As Allen Newell notably stated, MYCIN was the system that "launched the field" (Press G, 2020) (Kaul et al., 2020).

Over the years, AI's role in healthcare has been on an upward trajectory, characterized by consistent advancements and breakthroughs. For example, Dxplain, rolled out in 1986, serves as a decision support system that helps healthcare providers diagnose an array of illnesses based on symptomatic input (Barnett et al., 1987) The innovations have been relentless, extending from motor control assistance for quadriplegic patients (Bouton et al., 2016) to early skin cancer detection via image analysis (Esteva et al., 2017).

However, streamlining healthcare is an ongoing predicament that societies find themselves in. Numerous applications of the mechanics of AI have taken place to provide quality, more accessible health care to solve pressing problems that hinder providers from delivering the healthcare patients deserve. AI's expansive influence over the past five decades has revolutionized various facets of medical practice—from medical imaging and drug discovery to chatbots and virtual health assistants. It has augmented diagnostic accuracy, streamlined clinical workflows, enhanced disease monitoring, and generally improved patient outcomes. (Kaul et al., 2020).

The technology facilitates a multitude of applications, including but not limited to, X-ray, MRI, and CT scan analyses, virtual medical wards, and expedited drug discovery processes. (NHS, 2023) (Paul et al., 2021) Furthermore, the shift towards personalized medicine, enabled by 3D printing technologies, allows for customized drug dosages, thus alleviating the need for multiple medications. (Grof and Stepanek, 2021)

The Internet of Medical Things (IoMT) has made remote monitoring possible through AI-powered wearable devices, thereby freeing up hospital beds and aiding chronically ill patients. These devices range from smart medications and cardiac monitors to blood pressure sensors as well as digital biomarkers. (Dwivedi et al., 2022) In surgical settings, real-time tissue condition updates are made possible through IoT surgical instruments.

AI also serves as a robust support system for healthcare providers. Its capabilities include Natural Language Processing (NLP) for data organization, aiding decision-making by extracting relevant information from electronic health records, patient demographics, and clinical notes (Hossain et al., 2023) It is also used in areas such as radiology and pathology analysing reports to diagnose and recommend treatments. (Olthof et al., 2021)
In a nutshell, AI is an opportunity seeking to be explored in a domain like public health and in an era of increased demand and burden of numerous illnesses/diseases.

1.1 Study objectives and structure

This thesis aims to explore the potential of utilizing AI and robotics to assist patients with dementia. To fulfil this objective, the study will research existing data, technologies, and take into account challenges present including ethical considerations. By reviewing pre-existing data and patterns, the primary objective of this paper is to inspect the current landscape of artificial intelligence and robotics potential in supporting patients with dementia. The research is structured around the primary question:
"To what extent can robotics and AI technologies aid in the assistance of individuals with dementia?"
The structure will focus on robotics and AI technology that is currently in use to make the lives of dementia patients easier – aiding them in their daily life and alleviating symptoms of the condition. In order to delve into a deeper understanding of the topic:

- a scoping review would be conducted to build a conceptual framework to outline key theories and extent of research present on the number of robotics and AI in aiding dementia patients. This further helps in categorising and structuring results identified to analyse where research is concentrated and where gaps are present.
- a SWOT analysis will be carried out outlining the strengths, weakness, opportunities and threats of integrating AI into a care domain considered so sensitive yet also highlighting untapped areas of benefits we can procure to enhance welfare of millions that have to live with condition.

2) Background

In a world where medical progress relies heavily on diagnostic and machine-assisted surgical equipment, it comes as no surprise that artificial intelligence (AI) has emerged as a ubiquitous tool for managing, diagnosing, and treating patients in a field predominantly driven by human personnel (Lekadir, 2022). Given its widespread integration into clinical environments, there is a growing anticipation of AI's continued advancement in the realm of detecting and aiding patients with dementia.

While technologies like locator devices and SafelyYou (a wall-mounted camera system that evaluates and detects falls) are already actively in use, alongside telecare equipment, researchers are uncovering promising breakthroughs in the early detection of dementia. (Bayen et al., 2021) These breakthroughs hold the potential to significantly improve the support and care provided to individuals diagnosed with dementia, as well as elevating the burden on their caregivers while enhancing the overall quality of care. Considering our aging global population and the prevalent issue of cognitive impairment among the elderly, the compelling case for considering artificial intelligence as a viable remedy for assisting those with dementia becomes increasingly apparent.

2.1 Disease Burden of dementia

In 2018, the World Health Organization (WHO, 2023) documented 55 million cases of dementia worldwide. This number shot up to 57 million in 2019, setting off alarm bells about the escalating global burden of this condition. (Tran, 2022) (Collaborators, 2022) A study published in Lancet Public Health delved into the ominous predictions for the future. By 2050, they estimated that the global disease burden of dementia would soar to a staggering 153 million cases. (Collaborators, 2022)
Data collected from IHME demonstrated the prevalence of dementia amongst various age groups with the condition being more common in those aged 90 and above. The stats taken were from 2019 but trends and estimates stated above certainly show the neurological disorder to still be very much prevalent amongst the same age group. (IHME, 2019)

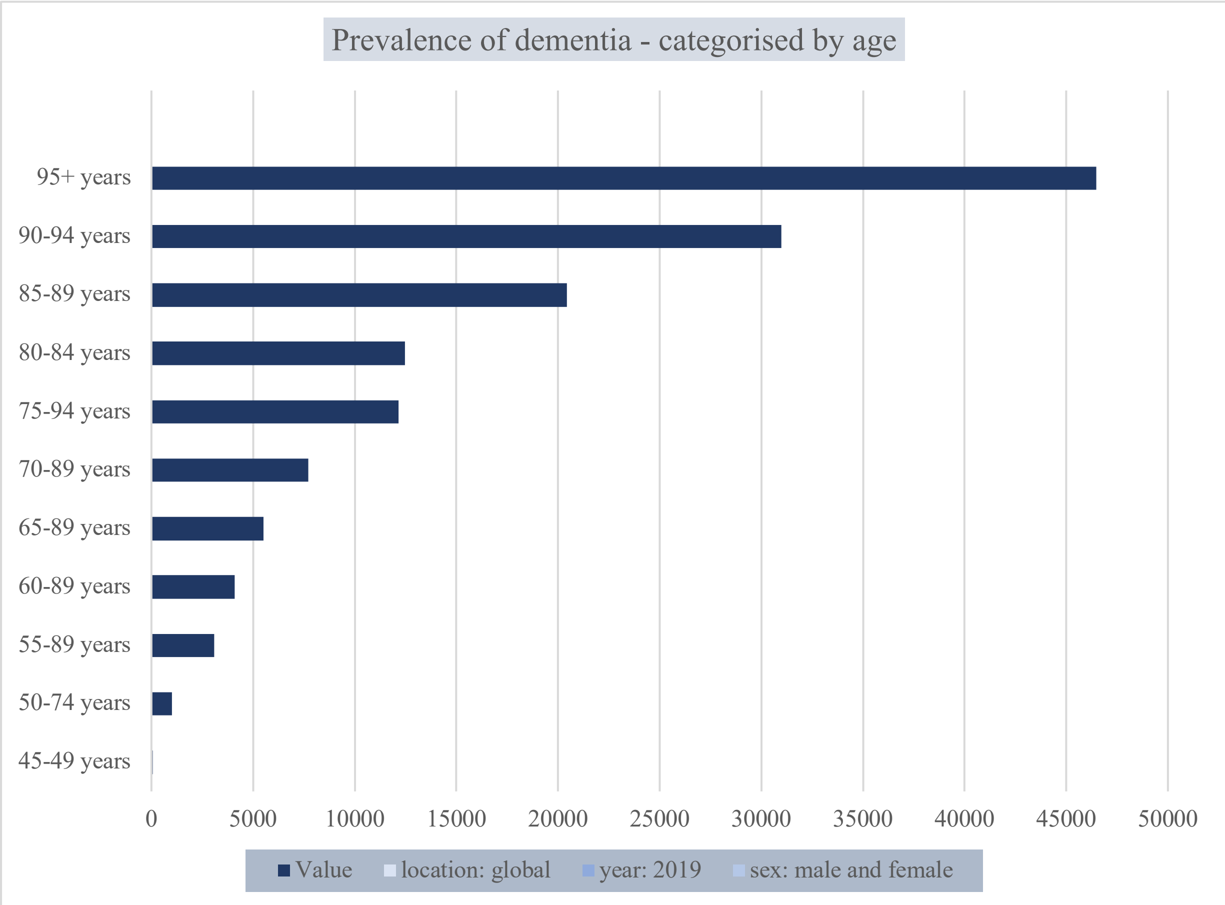


Figure 1 – Prevalence of Alzheimer's disease per 100,000

Source: https://vizhub.healthdata.org/gbd-compare/#0 (IHME, 2019)

The figure below illustrates the prevalence of dementia across different countries, with Japan, Germany, and Finland reporting the highest disability-adjusted life year (DALY'S) per 100,000 individuals. According to the World Health Organization (WHO, 2023) a single DALY represents the loss of a year of optimal or good health. DALY's are a crucial metric in assessing the impact of any health condition, as they quantify the combined years of life lost due to premature mortality and the time spent in a state of reduced health.

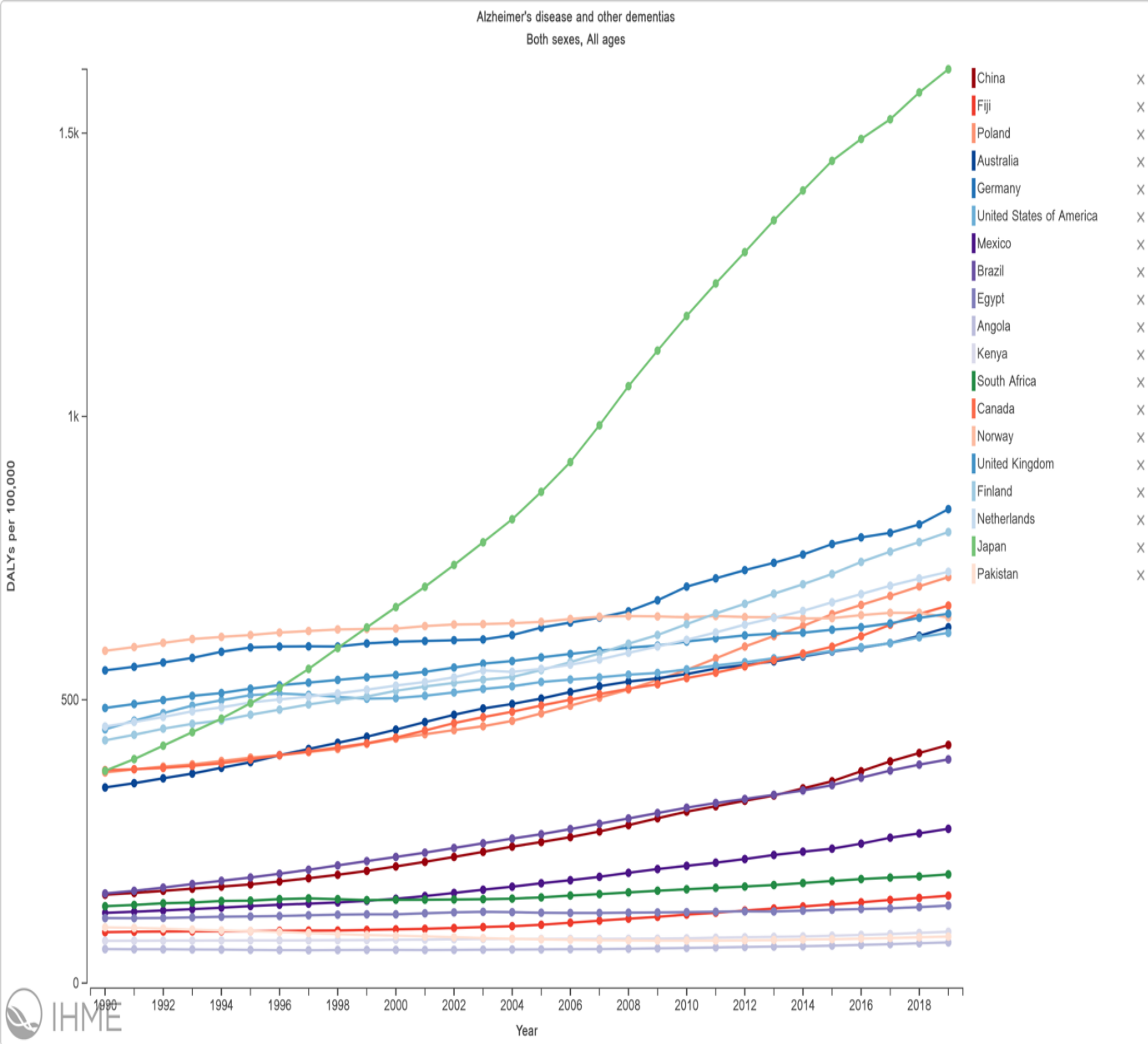


Figure 2 – DALY'S per 100,000 for dementia

(Source: IHEM https://vizhub.healthdata.org/gbd-compare/#0) (IHME, 2019)

2.2 Economic impact of dementia

The current and projected surge in the prevalence of dementia carries with it an inevitable toll, affecting both the economy and society at large. This cost extends beyond the patients receiving care and treatment, impacting caregivers, healthcare systems, and the overall economic landscape. In 2021 alone, the World Health Organization (WHO, 2023) reported that economies worldwide collectively spent 1.3 trillion US dollars in response to this challenge. Notably, 50% of this expenditure was attributed to informal care, provided by devoted close family members and friends who, on average, dedicated five hours each day to offering care and supervision. By 2050, its estimated that the global cost would increase to a soaring 1.6 trillion. (Velandia et al., 2022)

2.3 Social isolation

Health conditions like dementia trigger a cascading impact, affecting both the patient and their caregivers. This often results in feelings of loneliness and profound social isolation. Although there is no known cure for dementia, efforts focus on symptom management to enhance patient's quality of life and foster a greater sense of social security.

A study conducted on this matter found signs of declining cognitive function in 53.0% of patients diagnosed with dementia. Additionally, 31.2 % were reported to have felt unhappy and 37.4% had symptoms of severe anxiety. Worsening cognitive impairment is only the tip of the iceberg – dementia disrupts the daily life of patients, unable to carry out day to day tasks, results in decreasing appetite, hallucinations and continuous forgetfulness making patients as well as those caring for them feeling frustrated and extremely stressed. (Azevedo et al., 2021)

Caregivers are often diagnosed with depression and alcohol use compared to non-caregivers. (Perel, 1998) According to a survey carried out by the NHS, 36% of carers give more than a hundred-hour p/week to their family member diagnosed with dementia. (NHS, 2022) This highlights the gaps where artificial intelligence can more efficiently assist remote patient healthcare for those with dementia, improve quality of their daily lives and even detect the condition years before in order to lift and shift the burden from carers who dedicate so much of their time to informal and unpaid care. More crucially, this technological advancement aims to restore a semblance of normalcy and foster greater independence in the lives of dementia patients.

3 Methodology

Study design and data

Commonly, to any successful research paper, the methodology forms the essence of it. We know there exists numerous types of literature review namely narrative, systematic, scoping literature review or a meta-analysis and the type a researcher chooses to conduct relies heavily on the research question. The purpose of any literature review certainly reflects basic properties: accumulating, assessing and presenting data or theories that already exist. The review may serve the purpose of either encompassing a broader scope of study or delving into specific details.

3.1 Narrative literature review

Conducting a narrative literature review is a process that, while intellectually enriching, can appear somewhat disorganized. It involves the amalgamation and analysis of existing theories and information from a multitude of sources. (Jahan et al., 2016) Unlike systematic and scoping reviews, which have predefined criteria for information inclusion or exclusion, a narrative review tends to encompass a wide range of topics.

Commonly referred to as an "iterative process," it gradually builds toward the formation of a theoretical framework. (Juntunen and Lehenkari, 2021) As described by Baumeister, a narrative review offers a qualitative and interpretive exploration of the literature, providing a descriptive summary of existing knowledge on a specific subject. It is especially valuable in situations where the available data is disparate or too limited to facilitate a systematic review, or when the research question is broad and complex, making it challenging to establish clear-cut inclusion and exclusion criteria. (Baumeister and Leary, 1997)

Baumeister (Baumeister and Leary, 1997) further emphasized that traditional literature reviews, including narrative reviews, do not necessarily aim to canvass novel theories or ideas or arrive at profound conclusions. Instead, they primarily serve the purpose of evaluating existing theories within a research topic and identifying gaps in the literature. These gaps can, in turn, stimulate the generation of new hypotheses, thus informing future research.

3.2 Systematic review

Systematic literature review, on the other hand, is a more exhaustive, focused and rigorous way of compiling, assessing and filtering data that pre-exists. It does not take a holistic approach when appraising data rather really sieves studies to specifics. It compiles data that is eligible according to the defined quality protocol in order to respond to a particular research topic. By applying systematic techniques, they seek to reduce preconceptions. (Munn et al., 2018) It is wise to note that at times meta-analysis and systematic reviews are confused to be the same yet aren't. Meta analysis is merely a tool/method used to synthesise estimates of effects from each study included in a systematic review. (Paul and Leibovici, 2014) Labelling studies as a "meta-analysis" is considered misleading as the reliability and strength of a meta-analysis lies in the tool being able to synthesise and analyse studies a systematic review provides through its transparent and rigorous process of identifying and evaluating relevant literature. Undertaking a meta-analysis in isolation, without a predefined protocol, increases the risk of omitting important studies. (Egger et al., 1997)

Before systematic literature reviews, it was convenient for authors to select papers that maintained the same view as they did. Naturally, this led to the problem of personal bias (Munn et al., 2018) where the study was far from impartial and did not produce the same results if carried out again i.e., poor reliability. Since systematic review is considered a meticulous tool for erasing bias, producing transparent and reproducible evidence, it guides many clinical as well as healthcare decisions, policy formulation and future studies. (Liberati et al., 2009)

Hence when systematic review was produced, it aimed to counteract partialness of the researcher himself by the filtering process and sticking to the protocol defined. (White and Schmidt, 2005) Systematic reviews comply with a pre-established methodology and practice a stringent inclusion and exclusion criteria in order to root out pertinent research, assess their quality, and synthesize their findings using meta-analysis or narrative synthesis. Systematic reviews seek to discover the best possible research pertaining to their topic - authors strive to screen potent studies which use randomized controlled trials following a strict inclusion exclusion criteria. (Levac et al., 2010b, Arksey and O'Malley, 2005) Systematic and scoping review have much in common but the motivation and objective behind each review varies.

3.3 Scoping review

As mentioned before, evidence-based methodologies and research have seen to be essential in assisting decision makers in many sectors but more so within the healthcare field. Unlike other literature reviews, scoping review is one that was first methodologically presented by Hilary Arskey and Lisa O'Malley (Arksey and O'Malley, 2005) which went on to be further refined by Colquhoun et al. (Colquhoun et al., 2014a) The lack of standardization between these two published methods made authors aware that answers to the same hypothesis could differ due to the lack of a streamlined process when conducting scoping review. In order to solve this, Joanna Briggs Institute issued an updated guidance in 2015 but this was superseded by Tricco et al in 2016 and 2018. (Tricco et al., 2018)

Recent trends mirror the rise in the popularity of researchers employing scoping reviews to synthesize evidence of present literature. Figure 3 provides support for this statement illustrating the number of hits on the word "scoping review" itself had on google search. From being a predominately newer concept, many researchers have now established it to be transparent and meticulous in its methods. (Arksey and O'Malley, 2005)

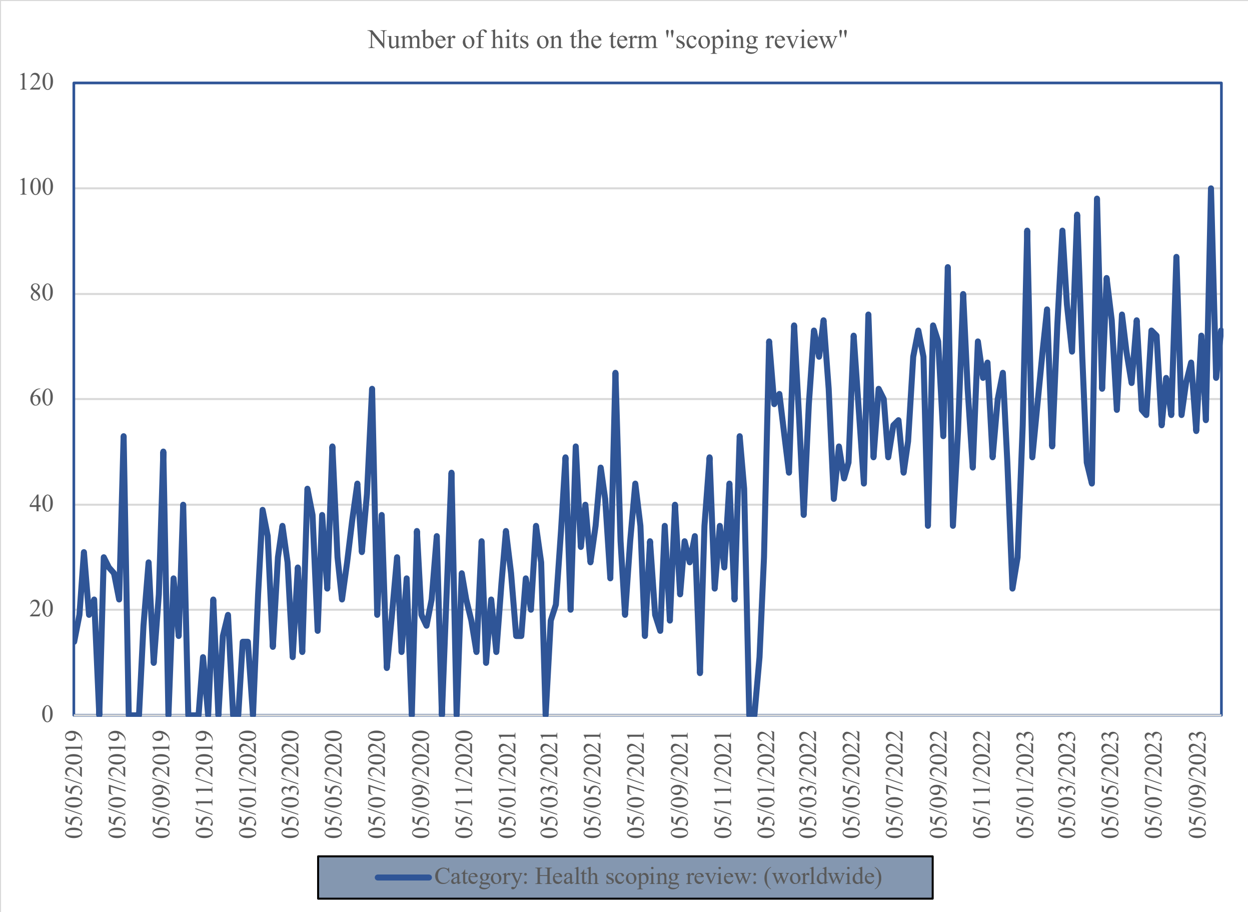


Figure 3: Number of hits on "scoping review" searched from 2019 – 2023 [Worldwide]

Source: (Google trends, 2023)

Known to map out knowledge and findings, it is considered quite flexible as it allows greater freedom to include extensive and diverse data in its study search and selection.

This gets interesting as when researchers begin to search and lay out the evidence pertaining to their research, they're also in a position of identifying and determining emerging trends or what the current key findings make apparent. This becomes a guiding light for other authors. Most known for discovering gaps in literature, scoping review assists in guiding future research in areas where data or findings are insufficient. Research scarcity can lead to authors focusing on study areas that can lead to ground-breaking theories or discoveries. (Pham et al., 2014)

Due to the nature of scoping review to cover broader research questions, the substantial literature reflects and communicates a comprehensive overview of the theory informing its readers adequately. (Arksey and O'Malley, 2005) (Pham et al., 2014) Lastly, as there exists a defined protocol to follow when conducting a scoping review namely the steps it serves as a checklist for researchers to make sure they align their methods of research with the protocol to allow for transparency and the criteria they used to boil down the studies synthesized and discussed. (Pham et al., 2014) Figure 4 reflects its popularity amongst authors and scientists who published studies using scoping reviews.

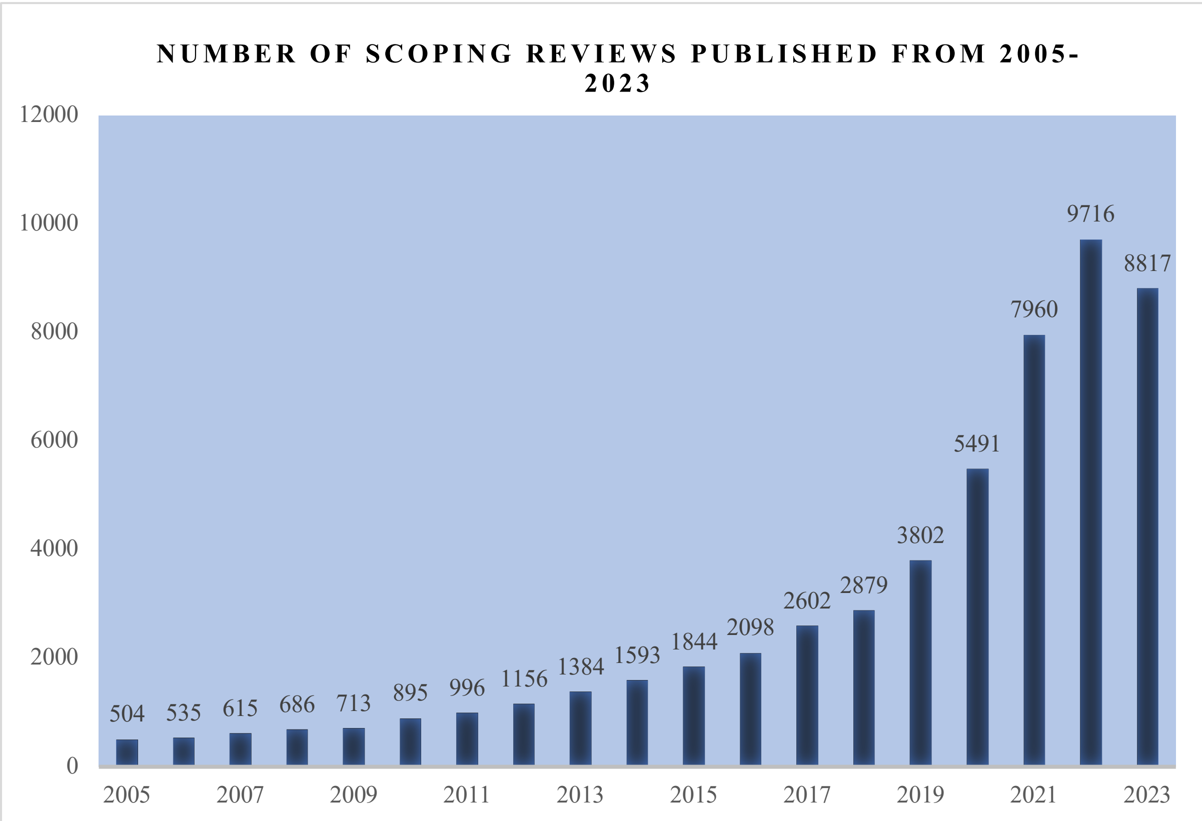


Figure 4:: Number of scoping reviews published from 2005-2023

(Pubmed, 2023)

Seen as this paper aims to study the landscape of robotic and AI interventions, motivated by its capability of capturing the depth of the field, a scoping review is instrumental in answering the research question. Hence the methodology of this research paper will be guided by the standards set by pioneers of scoping review, Arksey and O'Malley who defined scoping review as: "aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available and can be undertaken as standalone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before." O'Malley (Arksey and O'Malley, 2005)

Practically applicable depending on the depth of the study design, a scoping review is a flexible review that aims to assess broader research questions and are frequently carried out to study the scope and nature of research carried out within a specific field. It's designed in a way that ultimately, by the end of the study, communicates what is known about the topic under question.

It further acts as a stepping stone for systematic review in considering costs as well as the practicality of a study. (Levac et al., 2010b, Arksey and O'Malley, 2005) To be more precise, Arksey and O'Malley put forth an iterative five step framework which will explain more thoroughly the steps this paper will employ.

3.4 Protocol

Identifying the research question

The research question is as follows: "To what extent can robotics and AI technologies aid in the assistance of individuals with dementia?" A scoping review will assist in mapping out and inspecting the current landscape of robots and AI's application to this patient subgroup. As it is a study area that has a lot more potential of being explored, a scoping review will also help me in highlighting the gap that is present which must be further investigated and researched into. To answer this question, the review will outline the steps taken in detail to arrive at the literature included in this research paper.

To study the 'extent' of how far these two interventions help in supporting and relieving symptoms of dementia, a SWOT analysis will be carried out to reflect in depth the strengths, weaknesses, opportunities and threats of using robotics and AI. In a nutshell, this will highlight advantages, disadvantages, opportunities that can be played on and maximised and threats that can be minimised and further researched on. What this essentially does is provide a nuanced view of the interventions and current position of robots and artificial intelligence while highlighting gaps and grey areas to guide policy and decision making. (Helms and Nixon, 2010) When outlining weakness and threats, user safety is pivotal as it becomes a roadmap for future research and innovation to safeguard patients and ensure maximum benefit from using AI in healthcare.

Step 2 - Recognising relevant articles

Literature search when carrying out a scoping review aims to targets data that is relevant and helpful in answering the research question. Electronic databases such as PubMed and Web of science were used to identify existing journal articles studies carried out on the topic. The MeSH terms organised in Table 1 were used to guide the scoping review and acquire literature that answered the question and data I wanted to obtain. The results identified through this search strategy have been categorised and presented under chapter 4 – results. A structured literature search consisting of comprehensive secondary data was carried out to extract facts and statistics surrounding dementia published by World Health Organisation and IHME. Grey literature was acquired through websites such as https://www.nhs.uk/conditions/dementia/ , https://www.alzint.org/about/dementia-facts-figures/dementia-statistics/ , https://research.google/outreach/ and numerous other highlighted under the section discussing results.

MeSH terms utilised	
Artificial intelligence	((artificial intelligence[Title/Abstract]) OR (deep learning[Title/Abstract])) OR (machine learning[Title/Abstract])
Dementia	((dementia[Title/Abstract]) OR (alzheimers[Title/Abstract])) OR (cognitive decline[Title/Abstract])
Robotics	((robotics) OR (socially assistive robotics)) OR (companion robots)

Table 1 - Literature Search Strategy

Step 3 - Study Selection

The articles selected were specific to the population of dementia patients and the context focused on the way artificial intelligence or robotics has helped this patient group in assisting them. Several articles reviewed proof of robotics and AI in helping elevate the impacts of dementia on patients and indicated the extent of its feasibility. Only studies ranging from

1997 – 2023 were selected - no particular country was specifically targeted for inclusion, and no restrictions were imposed on the selection of papers discussing these countries.

It is important to note that data on detection of dementia was excluded from the research as the paper wanted to throw light on how artificial intelligence can aid and support patients with dementia. Evidence with the focus of robotics, artificial intelligence and dementia was key. In addition, it's also important to state that intelligent assistive technology was also excluded.

From the databases included in the study, literature was screened to fit and answer the research question. Duplicates from the two main databases (PubMed and Web of Science) were then removed and utilised in the paper. The PRISMA flowchart offers visuals of the number of journals and papers that came up after using the key terms and themes listed in Table 1.

Inclusion criteria	Exclusion criteria
Literature published only in English.	Printed books were excluded from the research.
Studies only from 1997 – 2023.	Assistive devices that are not intelligent.
Evidence that aimed to study patients only with dementia.	Records not in English.
All countries and regions included.	Patients not diagnosed with any neurological disease.
Evidence that focused on robotics and AI technologies.	AI to support caregivers of dementia.
Evidence on cost and feasibility.	Assistive technology was not included.
AI to elevate dementia care.	AI to detect of dementia.

Table 2 – Eligibility criteria

Step 4 - Charting the data

Table 3 presents the findings extracted from the reviewed articles and websites. It outlines the use of robotic and AI technology in addressing specific symptoms of dementia and meeting the care needs of patients. Additionally, it provides descriptions and details about the functions of these technologies. The "features" column is particularly pertinent as it elucidates how the implementation of AI technology offers effective solutions to mitigate the symptoms experienced by dementia patients.

Table 4 offers a qualitative analysis of the results found in table 3. This helps in drawing up a more evidence-based evaluation to come to more sound and factual conclusions. Not only this but it identifies trends and offers a comparative analysis. In this case showcasing that there exists more robotics and AI technology to counter isolation, symptoms of depression and anxiety, followed by those helping to revive memory functions and other cognitive abilities. By enabling us to see numbers, we can compare and analyse which areas require more research and investment for technology to keep aiding patients with dementia.

Step 5 - Accumulating, summarizing and reporting results

Content analysis and a detailed discussion would then be carried out. Step 5 would be summarizing and reporting the results that relate to the purpose of the research question and provide dialogue on how and if the results hold implications for the future.

There are numerous reasons as to why a scoping review is fitting for this research paper. These have been elaborated upon under Chapter 3, particularly 3.3 however its useful to briefly touch upon them. The research question as identified is rather broad and one that requires an exploratory approach. The existing database of literature can help map out current findings and key theories to answer the research question. An overview and review of several articles will assist in presenting a summary of evidence available.

Secondly, the use of robotics and artificial intelligence particularly for assisting dementia patients is a relatively fresh topic. After analysing and eliminating articles and studies, it appeared to be a field that hasn't progressed beyond its early stages. Hence, a scoping review was employed to analyse the scope of existing literature as well as to see the magnitude of studies that have been published on this specific topic. Being an emerging study, research allowed for this paper to reveal what is known about the hypothesis and hence identify concepts and the gap in the research area in order to shed light on the need for further research on the topic. (Munn et al., 2018)

3.5 Limitations in methodology

The upward trend of scoping review is one that reflects researchers actively embracing the methodology due to its employability in both newer as well as established fields. However, with various authors refining the definition, protocol, and presentation of results, prevents the review from utilizing its full potential to give solid results and hence influence policy and healthcare practices. The lack of agreement between authors and minute additions to how a scoping review should be conducted make it difficult to stick to uniformity and hence this can mean lack of uniformity when reproducing results too. (Colquhoun et al., 2014b)

In addition, there exists a blur between systematic and scoping literature review as there's only a very thin line that separates the two. The protocol and stages in carrying out either of the reviews can lead to confusion and lack of clarity makes it difficult to differentiate between the two. (Munn et al., 2018)

Secondly, as the review is designed to address broader questions there is lack of an in-depth analysis into the relevant literature - the detail with which a systematic review is carried out would be absent under a scoping review. Building on this, the broader the question or examination of data, the higher the chances for a researcher to be incapable of capturing pertinent studies especially when reviews such as these are meant to be guiding policies and important decisions. (Levac et al., 2010a)

The major purpose of this type of review is not quality compared to systematic reviews where quality is kept as a priority by setting a criterion. This can be far less reliable as when quality of the data isn't of paramount importance, evidence-based research would be an understatement as well as risky to use to make key decisions. (Arksey and O'Malley, 2005) Whereas systematic reviews are gold standard for erasing biases, scoping reviews may face trouble as it is up to the researcher to decide which studies to include and which to exclude after the question, context and population to study have been decided. Hence, there is a chance for potential biases. (Sucharew and Macaluso, 2019)

4 Scoping review results

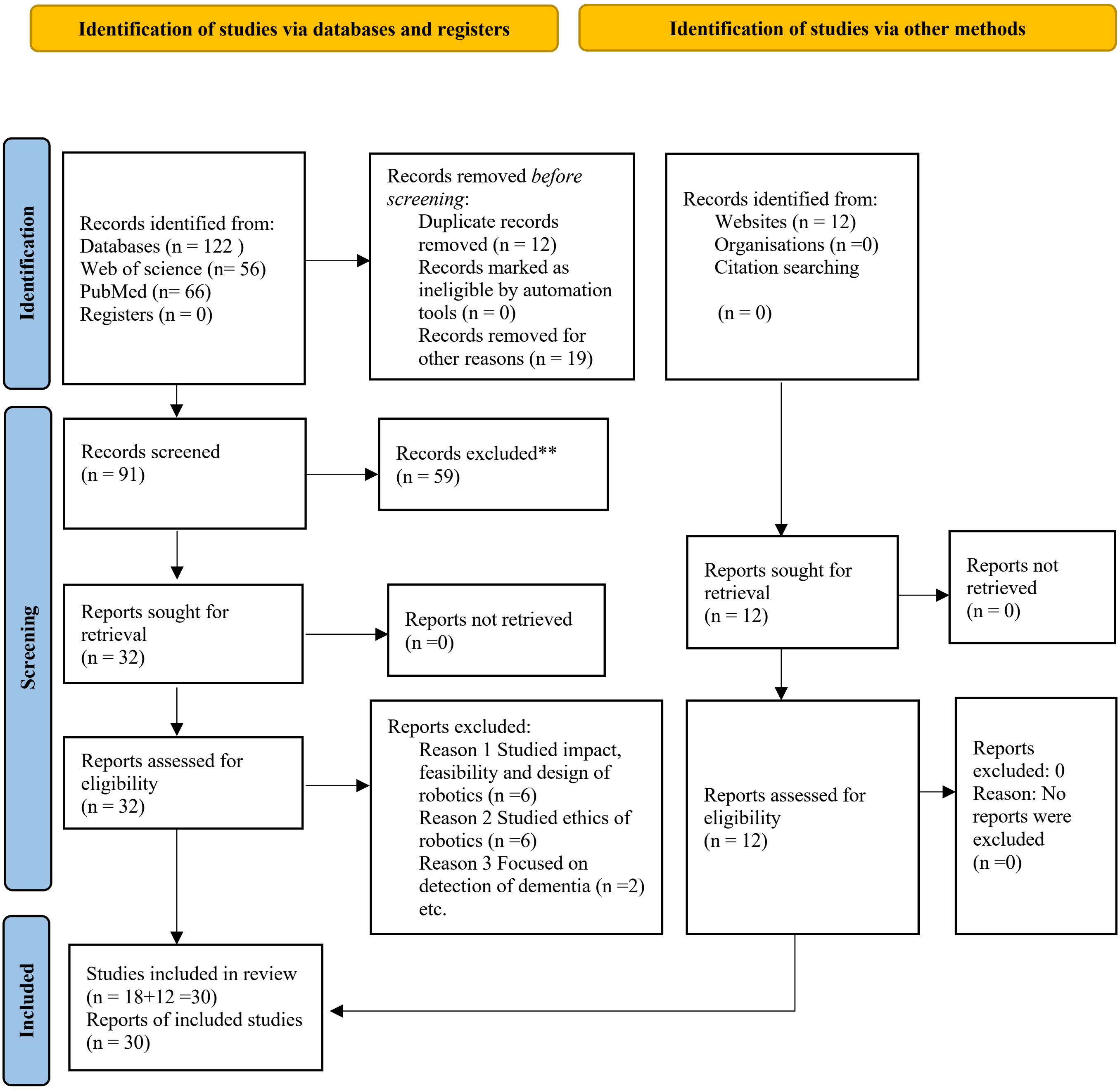
The protocol, as defined by Arksey and O'Malley for conducting a scoping review, extensively detailed in Chapter 3, was employed to derive the results presented in this paper, at illustrated through a PRISMA flowchart. A clear eligibility criterion was set at the start of this paper to guide the research hence the inclusion and exclusion criteria were diligently applied at all stages to sift through secondary data.

The primary databases accessed were Web of Science and PubMed. Web of Science yielded a total of n= 56 studies, while PubMed contributed n=66, making a cumulative total of n= 122 studies. Some of the data was uncovered through alternative methods, such as websites, and this tally has been incorporated into the PRISMA flowchart. 12 duplicate entries were subsequently eliminated to filter out journal articles that appeared more than once. In addition, 19 articles were further removed as they did not meet the eligibility criteria indicated in table 2.

The journals were excluded because they did not provide relevant answers to the research question. A number of these papers focused on Parkinson’s, intelligent assistive technology, digital healthcare and studied impacts of artificial intelligence and robotics on caregivers rather than the patients. Hence, they couldn’t be included in the review. These articles were further scrutinized and cross-referenced against the eligibility criteria, both inclusion and exclusion, as well as against the title/abstract. The total number of retrieved articles, including those inaccessible, is depicted in the flowchart.

After conducting a thorough search for relevant papers, a total of n=32 were subjected to full-text screening. Following this screening, n=14 papers were excluded, resulting in n=18 studies being included in the final assessment. The revised PRISMA flowchart, which encompasses the inclusion of grey literature retrieved from various websites, was employed for enhanced clarity. Some data presented in the results table were derived from these web-based sources. An examination of n=12 distinct websites contributed to the overall dataset.

In total, n=30 records were incorporated into this paper, with their findings discussed in the subsequent chapter. This comprehensive approach ensures a nuanced exploration of the subject matter, drawing from numerous sources to strengthen the overall validity and depth of the study.



(Page et al., 2021)

30 reports were used to extract results that have been charted and more elaborately discussed in section 4.1.

Figure 5: PRISMA flowchart

4.1 Results identified

Dementia, often utilized as a broad term, encompasses a syndrome characterized by a substantial decline in cognitive function, significantly disrupting everyday life. Before we delve deeper into this condition, it's essential to clarify that while dementia is a general concept and not a specific disease, both the World Health Organization (WHO) and the NHS define it as a syndrome, comprising of a cluster of interconnected symptoms. Alzheimer's is just one subtype of dementia. (WHO, 2023) (NHS, 2023) This paper will exclusively concentrate on the described terms and won't delve into other dementia variations.

That being noted, it is enlightening to explore the symptoms encountered during various stages of dementia. Such an examination enhances our comprehension of the specific challenges that robotics and AI technology aim to address, and in doing so, strive to alleviate the accompanying feelings of frustration and agitation associated with these symptoms.

Diseases falling under the dementia umbrella progressively kill nerve cells and inflict damage to the brain, typically resulting in *cognitive impairment*. This cognitive decline is frequently accompanied by alterations in mood and motivation, leading individuals to struggle with emotional regulation and behaviour management (WHO, 2023) (NHS, 2023).

The impact of this condition on patients themselves and their caregivers holds profound importance due to its psychological and economic implications. Specifically known to isolate a person, it can remove a personal from activities within the general society making them *less social* and more *anxious* and agitated. (WHO, 2023) Dementia advances through distinct stages, with symptoms intensifying as patients transition from the initial to the later phases. Indications of dementia encompass *memory loss* as the primary sign, *speech difficulties,* challenges in daily tasks, and difficulties in making sound judgments. (Banovic et al., 2018)

In the advanced stages of dementia, *psychomotor skills*, which rely on the active cognitive processes for activities such as walking, driving, or engaging in games like throwing a ball or sewing, deteriorate significantly. At this juncture, the brain loses its ability to transmit signals to the body for movement, and reflexes become rigid. (Morais et al., 2017) (Hanson et al., 2016)

The principal impairments have been set forth in the table below and can facilitate a clearer comprehension of how robotics or AI technology can assist and bolster these symptoms.

Dementia symptoms and care needs	Name of AI or robotics technology	Description of AI technology and robotics identified
Declined cognitive function – memory loss	**Egocentric Live 4D Perception (Meta, 2021)**	**3D virtual reality headset, powered by AI, is designed to enhance the understanding of how individuals with dementia (PwD) interact with their environment. This technology aids in tasks such as locating misplaced items and preventing overmedication by intelligently informing the patient that they've already taken their prescribed medication.**
	Rfusion (Zewe, 2021)	**Robotic arm with a camera and a radio frequency antenna clamped to that – waves from the antenna and visuals from the camera help track and retrieve lost item even from under a pile of things. This is done by using AI algorithm.**
	Google Home and Amazon Alexa (Topsfield, 2022)	**A smart device provides prompts to remind patients to take their medications, engage in stretching exercises, and stay hydrated. It also offers answers to questions and provides**

		comprehensive information. These prompts are like the guidance provided by care workers and are designed to assist individuals with dementia (PwD) in memory retention and maintaining cognitive function.
	Gerontechnology (Leroi et al., 2018)	**Wearable devices such as those that help with reminders and GPS tracking, applications that help with cognitive stimulation, smart home technology that can assist with automatic lights, controlled temperature and security alarms. Gerontechnology can also include communication aids along with monitoring systems.**
	Sil-Bot (Park et al., 2021) (Robocare, 2019)	**A robot equipped with a training program designed to stimulate and refine cognitive skills. This program focuses on improving memory, concentration, decision-making, speech, and spatial abilities.**
Isolation and lack of social connections, anxiety and depression	**Paro; eBear (Su et al., 2022, Lee et al., 2022) (Petersen et al., 2017) (Hung et al., 2019)**	**Therapeutic interactive robots engage patients in social interactions, promoting positive emotions, reducing stress, regulating behavior, and alleviating distress. These sensor-based robots assist individuals with dementia (PwD) through cognitive, sensory, and social**

		engagement, as well as physical exercise. Equipped with tactile sensors, they respond to patients' touch and adjust their interactions accordingly.
	Lovot robot (Dinesen et al., 2022)	**A companion robot designed to provide company and emotional support, reducing feelings of loneliness. Equipped with sensors to detect changes in emotions, it offers users a tactile experience through petting.**
	Telenoid (Sorbello et al., 2014)	**Allows for remote communication and conveys more than just the voice of the user to the other end by imitating head movements and basic expressions.**
	Robear/ Riba 2 (Wilkinson, 2015) (Acker man, 2011)	**Projects that included a sturdy robot assisting PwD by lifting them from their bed to their wheelchair and even provide assistance in helping them stand.**
	Kabochan and Silver Care Robot (Sasagawa,	**Social robot that helps maintains conversations with the elderly to mitigate**

	2017) (Lee et al., 2022) (Oh et al., 2015)	**effects of loneliness while stimulating cognitive abilities and thought.**
	Fukuoka (Mori, 2023)	**A robotic boy companion designed to alleviate stress and reduce symptoms of depression by engaging in therapeutic conversations with patients.**
	NAO robot (Lee et al., 2022) (Valentí Soler et al., 2015)	**An AI powered robotic fitted with sensors, a microphone and cameras capable of navigating its environment, understand what its being told through voice commands to better interact with patients and provide them with a more real-life experience of being social.**
	AIBO (Koutentakis et al., 2020)	**Robotic dog that detects the face of its users, their smiles and does tricks to keep patients engaged along with users having the opportunity to pet the dog to gain a real-life pet experience.**

	Necoro robotic cat (Koutentakis et al., 2020)	**Robotic pet designed to resemble and mimic a real cat through purring, swinging its tail, stretching as well as responding to touch and motion – aims to give its users a therapeutic and comforting experience, one that real pet owners feel.**
	Ryan (Abdollahi et al., 2023)	**A social bot crafted to provide companionship to individuals with dementia (PwD) by engaging patients in meaningful conversations with the goal of alleviating feelings of depression.**
	TinyBot (Amabili et al., 2022)	**Social robot that initiates PwD in conversations, gives out suggestions and plays music of the patient's choice stimulating their cognitive function.**
	Pepper (Woods et al., 2021)	**A companion robot that combats isolation and depression by helping patients stay connected with family and friends through calls, making them feel a part of the broader society by reading news headlines to them, and assisting**

		them in selecting hobbies such as watching movies or listening to music.
	Mario(Kouroupetroglou et al., 2017)	**A companion and social robot that provides company and engages patients with social applications, including games and activities, keeps them informed with news and headlines, and facilitates connections with family and friends through calls.**
	JustToCat; ; FurReal Cat (Thunberg et al., 2020)	**Plush robotic cats that offer social interactions and help improve physical and social wellbeing by keeping the elderly company.**
	iCat (Thunberg et al., 2020)	**A plug and play interactive robot cat capable of making various real-life expressions in an aim to engage patients.**
	Joy for All Dog and Joy for All Cat (Thunberg et al., 2020)	**AI powered lifelike robotic dogs and cats that aim to give real life experience of keeping a pet to PwD by imitating behaviours such as purring or lifting paws when caressed.**

	iRobiQ (Huang et al., 2023)	**Interactive robot to primarily provide companionship but also expresses various expressions that enables users to feel understood and helps to emotionally connect with them too. Aids with daily routines such as medicine reminders as well as the quantity to take.**
	LudWig the robot (Pou-Prom et al., 2020)	**Humanoid to keep the elderly occupied and company by making conversation with them and responding to their cues.**
	Giraff (Márquez-Sánchez et al., 2020)	**Telepresence robot controlled by caregivers of patients through sensors and wearable devices that help to keep a check on the patients by connecting them with their family members as well as health care personnel from the comfort of their home.**
	Bonoid (Magyar et al., 2019)	**A humanoid baby robot designed to engage dementia patients in conversations by actively responding to their cues and exhibiting lifelike movements of its mouth and head, creating a more human-like interaction.**

	Hector (Wang et al., 2017)	**An 'in home" carer robot that has functions of a smart phone except can walk, talk and give reminders to patients to take medicines, to call family and friends – provides home based support and ultimately helps alleviate effects of loneliness and isolation.**
Declining psychomotor skills	**AAL (ambient assisted living) (Orejel Bustos et al., 2023)**	**Smart devices, medical sensors and wireless networks that amplify patient safety by monitoring health at home and detecting falls at the same time.**
	Mister Bah (Getahun, 2022)	**A mobile robot balance assistant equipped with sensors to detect and prevent falls before they happen. It can also support patients' balance by using sensors and a wearable strap.**
	Sensors (Topsfield, 2022)	**Wall-mounted sensors designed to detect movement, especially falls, and in the absence of a response, send alerts to the authorities.**
	Avatar Robot Café (OriHime-D robot) (Takeuchi et al., 2020) (Thornhill, 2023)	**By functioning as remote humanoid waiters, this AI driven robotic café employs people with disabilities and even people with dementia to feel more**

		inclusive in the general society by working from the comfort of their homes and beds.
	Project Activate (Lillilllian and Nikka, 2021)	**An AI-powered algorithm that empowers individuals with limited psychomotor skills to use their facial expressions, as directed by a smartphone, for successful interaction.**
Language impairment	**Project relate (Cattiau, 2021)**	**An updated and trained AI algorithm that can understand people with speech impairments and through the 'repeat' function translate what they say in a clearer and more coherent way in addition to smaller tasks such as switching the lights off or playing a specific song.**
	Jessica (Ortiz, 2023)	**An AI driven speech therapist.**
	Parrotron (Chen et al., 2021) (Biadsy and Weiss, 2019)	**An AI tool by Google that helps slurred speech to be translated into eloquent conversations.**

Note: Some of the results identified independently were then searched on PubMed to verify their sources. Those journal articles have been referenced. These results are independent of what showed up after typing in the key terms in the two databases used.

Table 3: Qualitative results outlining robotics and AI to aid PwD

4.2 Quantitative analysis of results identified

Symptoms/ care needs	Total number identified for each symptom/care need	Percentage total
Declined cognitive function – memory loss	**6**	**15%**
Isolation and lack of social connections, anxiety and depression	**26**	**65%**
Declining psychomotor skills	**5**	**12.5%**
Language impairment	**3**	**7.5%**
TOTAL	**40**	**100%**

Table 4: Quantitative analysis of results

A total of 40 instances of robotics and AI technologies were identified. The findings revealed that robots designed to mitigate symptoms of social exclusion, desolation, and emotional distress were the most prevalent, followed by those aimed at enhancing cognitive function and assisting with memory loss, which held the second position. The third rank was occupied by robotics primarily intended to improve the psychomotor skills of patients, thereby enhancing their physical dexterity. Notably, the number of robotics developed to address speech impairments, with the goal of enhancing communication abilities, was the lowest among the identified categories.

5 SWOT analysis/feasibility of AI and robotics

The growing body of evidence and the increasing presence of robotics and artificial intelligence in the realm of dementia care stand as compelling indicators of their potential effectiveness. The provided table is an attempt to comprehensively catalogue the various AI-powered companion robots designed to address the needs and provide the care that dementia patients inherently require. While it's important to note that we're still a long way from finding a cure, enhancing the well-being of this patient group has the potential to significantly improve the lives of millions and provide them with the personalized care they rightfully deserve.

Abundant data exists regarding the feasibility of robotics and its impact on dementia patients, their caregivers, and healthcare professionals. This paper, with its focus on examining the extent to which AI and robotics benefit individuals diagnosed with dementia, deems it appropriate to conduct a SWOT analysis. A SWOT analysis is a systematic tool used to assess strengths, weaknesses, opportunities and threats. While strengths and weaknesses explore internal or personal factors, opportunities and threats inspect external factors. (Namugenyi et al., 2019)

The following reasons and factors help justify why a SWOT analysis was carried out instead of discussing advantages and disadvantages:

- Strengths of using robotics and AI to assist and support patients with dementia can give us an elaborate overview of how they can benefit and alleviate symptoms PwD must live with.

- Weaknesses note and outline constraints and performance capabilities of robotics and AI as well as reflect when it starts lacking in its purpose to deliver relief and assistance.

- Opportunities more interestingly give us both a building platform to improve on roadblocks we experience in employing robotics and unveil hidden opportunities that can be seized to make improvements in dementia care and technological research. (Namugenyi et al., 2019)

- Threats, lastly and most importantly when highlighted (e.g General Data Protection Regulation) can be minimised, erased and create ease in achieving goals – they are of paramount importance when making future laws, in guiding research and compelling the change needed to make the integration of robotics and AI more smooth. (Namugenyi et al., 2019)

Commended for its simplicity and holistic approach, it gives an overview of its practical application as well as relevance, particularly in guiding research and policy. Becoming a popular tool within healthcare research and published papers, it is a common analysis carried out to This approach is instrumental in gaining a more comprehensive understanding of what robotics and AI technology can bring to the field of dementia care. By analysing the strengths, weaknesses, opportunities, and threats inherent in the infusion of robotic technology into dementia care, we aim to arrive at a more informed perspective on its potential. (Nwosu et al., 2019)

STRENGTHS	**WEAKNESSES**
○ Not on salaries like care workers. ○ Do not feel human emotions and so are rational and focused on what they are designed to do. ○ Training is not required. ○ Free up healthcare personnel. ○ Meet social needs of PwD, give them reminders and have proven to diminish effects of anxiety and depression. ○ Monitor patients and send alerts. ○ Exhaustion does not occur and continue to operate on a daily. ○ Provide companionship and stimulate autonomy and independence. ○ Has the ability to better acquaint itself with the patients needs and personalise care it provides – quick to adapt. ○ AI algorithm means no errors as performance is standardised	○ Lack of emotional intelligence and capacity to sincerely feel for the patient. ○ Extortionate prices. ○ Price can limit access people have to efficient care to a large extent. ○ Standardisation means no progress beyond what they're designed to do. ○ High maintenance and can be costly if broken or stop working. ○ Ethical implications involved treating such a vulnerable patient group. ○ User acceptability and acceptance can vary hence does not ensure effectiveness and positive results. ○ May not successfully be able to replace human contact which is dire for some people
OPPORTUNITIES	**THREATS**
○ Advancements in technology and creating pathways for better care for the present and future. ○ Access to improved quality of life and better healthcare ○ Patients get to stay in the comfort of their homes for longer given the autonomy that comes with the use of AI and robotics. ○ Can supplement care provided by humans. ○ Frees up bed space in care homes for those in later stages of dementia.	○ May result in loss of jobs within care workers. ○ Can replace reliance and interaction with family and friends. ○ Can replace patient doctor relationship and contact. ○ Irony of increased social isolation if there is complete and enhanced reliance on robots. ○ Data privacy issues ○ Data protection ○ User consent ○ Vulnerability of patients

(Nwosu et al., 2019)

Table 5: SWOT analysis

5.1 Strengths

When assessing the performance of robotics in terms of consistency, standardization, and the potential for errors, it's indisputable that they are ideal for providing care that demands meticulous attention. Standardization ensures error-free operation and eliminates the impact of human emotions, exhaustion, and hunger. (Beasley, 2012) The sensitivity of patient care, especially for individuals with specific needs like those with dementia (PwD), demands recognition. There are aspects of this care that necessitate privacy, and this is where robotic assistance truly excels, especially in personal care. (Nwosu et al., 2019)

From more intimate tasks to lighter responsibilities such as monitoring blood pressure, heart rates, and detecting falls to promptly alert healthcare providers, robotics empower countless dependent patients to lead more self-reliant lives, ultimately enhancing their quality of life. (Topsfield, 2022) When we discuss artificially intelligent robots, it means they can swiftly adapt to software updates and refine their algorithms, often tailored to meet the unique needs of their patients, providing personalized care and attention. (Nwosu et al., 2019)

Before incorporating human caregivers, comprehensive training and education are essential, including diversity training to ensure effective interactions with patients from diverse racial and cultural backgrounds. Moreover, the implementation of novel practices and techniques requires time for testing and adaptation to identify the most suitable approaches. In contrast, robotic systems, designed to target specific tasks, offer an efficient means to deliver rapid and precise care.

The continuous and consistent adoption of AI technology and robotics encourages ongoing technological research and development, potentially leading to improved functionalities, extended battery life, and areas that require further refinement (Nwosu et al., 2019)

5.2 Weaknesses

Perhaps the most significant drawback of robots and AI technology is the exorbitant cost, which limits access for millions of people with dementia. While the benefits are undeniable and rather compelling, the issue of affordability poses a considerable challenge to their widespread adoption in the care of this vulnerable patient group. The extensive features, the need for battery maintenance, power supply, and internet connectivity all contribute to the high cost and can affect continuous use of robotics in patient care. (Nwosu et al., 2019) In addition, personnel has to be trained and retrained for progressive and updated technology every time and hospital or care spaces have to be redesigned to adjust to such technology and robots.

Furthermore, there is insufficient evidence to guarantee the presence of effective infection prevention and control measures. (Dodds et al., 2018) Standardization, while an appealing feature for task execution, also implies limited versatility. The program or software typically restricts a specific robot to a defined set of designated tasks, hindering its ability to adapt to unforeseen situations. For example, certain robots may struggle to transport a patient from point A to point B in an emergency or address needs beyond their designated functions, thus limiting problem-solving capabilities. (Ceccarelli, 2011b)

Furthermore, robots tend to perform tasks in a mechanical manner, lacking the sophisticated motor skills required for essential daily activities like dressing, cooking, or even opening doors successfully. (Hendrich et al., 2015)

While robots excel in precision and meticulousness, they lack emotional intelligence. (Ceccarelli, 2011a)Their incapacity to experience or genuinely convey concern or emotion can instil fear and distrust in users, especially within this vulnerable patient subgroup. (Hall et al., 2019, Broadbent et al., 2009a) (Cresswell et al., 2018) Another often underestimated challenge is user acceptability. Many patients may prefer human care with a personal one to one touch over that provided by a robot. Acceptance and expectations vary among caregivers, patients, and policy makers, underlining the need for a comprehensive assessment of the extent and ease of their acceptance. (Flandorfer, 2012, Tobis et al., 2017)

5.3 Opportunities

The incorporation of robotic care instigates a discernible shift in the allocation of responsibilities, effectively transferring the burden from healthcare services and personnel to AI-powered robots. In light of the escalating prevalence and the financial implications linked to the care of individuals with dementia (PwD), a distinctive opportunity cost arises. Healthcare resources can be channelled towards meeting the specific needs of this patient group or redirected to address other pressing medical conditions and diseases. This strategic redistribution of care services and resources not only streamlines care for PwD but also presents avenues for bolstering healthcare in various domains.

Naturally, as we grow older, the comfort of our homes becomes a feeling we yearn for and feel that the place we're familiar with is our safe haven – especially when talking about people with dementia and the value they place to be cared for in their safe space - often people find discomfort in places alien to them and having to shift in between care homes agitates and aggravates their symptoms further. Robotics and AI give birth to an opportunity where millions can be treated in the comfort of their homes without having personnel tend to them twenty-four seven. Companion bots like Telenoid, Robobear/Riba 2 and Mister Bah amongst the many reflect the opportunity of at-home care again attempting to diminish the fear that exists globally of the isolation that comes with the condition. (Van Patten et al., 2020)

Furthermore, a multitude of studies demonstrates the positive impact of utilizing robot pets like PARO and other social or companion robots. (Shibata and Wada, 2011, Moyle et al., 2017) They proved to serve a rather therapeutic purpose haven proven effective in mitigating depression, alleviating symptoms of anxiety, and utilizing sensors to detect and subsequently reduce the occurrence of falls. (Riches et al., 2022) These robots also serve as medication reminders, contributing to the overall well-being of patients while aiding in the enhancement of their psychomotor skills and physical activity. These findings not only confirm past successes but also signify untapped potential for advancing palliative care for the elderly. Such advancements hold significant promise in addressing the growing number of PwD cases.

5.4 Threats

As much as we try and make healthcare accessible and equitable for all, this isn't the case with robotics and AI as they are not the most cost-effective option when it comes to caring for the elderly. This could mean instigating inequality in the extent of access patients have as an average person would not be able to comfortable afford a companion robot or humanoid to tend to all their needs. (Nwosu et al., 2019)

More interestingly there is likelihood of unconscious bias present in the integration of robotics in care. Ultimately, algorithm design and data driven AI technologies and softwares are drawn up and tested by a group of homogenous individuals who may not best represent the wider society or the target patient group they solutions these technologies for. They may tackle and aim to support certain hurdles that PwD face but truly there is more to the complications they face than what we observe. (Cath, 2018)

Furthermore, there exists great fear that complete reliance on robotics my replace real family contact and even health personnel leading to losses of jobs and increased isolation of the elderly. More importantly is how the focus on integrating robotics in care system might demotivate other societal efforts – progress made in medicine and that from care personnel. (Broadbent et al., 2009) (Cresswell et al., 2018)

Lastly, considerable concerns stand for the ethics in using robotics for such a vulnerable subgroup. It is essential to check for their agility and effectuality to guarantee safety of patients and users. Much of the domain of ethics has to do with data privacy and breach of confidentiality and researchers as well as designers need to be diligent with prevention of such a breach. (Mansouri et al., 2017) (Sharkey and Sharkey, 2012)

Robots and AI can access, record and save excessive amount of patient data that can be further shared without the consent of users. (Nwosu et al., 2018) In addition, there exists a conundrum of whether robots should indeed follow every instruction given to them even if the requested actions are unlawful or pose a danger to the user such as assisting in taking certain harmful substances, consumption of alcohol and even euthanasia. A request denied in order to protect the patient might lead to the operator ceasing to trust and rely on the humanoid or pet robot. (Nwosu et al., 2019)

This puts the moral agency of robotics in question especially with patients considered extremely vulnerable thus there is a need for a robust evaluation and research in whether robot-pets or humanoids can be relied on solely for alleviating symptoms of the condition in question. (Stahl and Coeckelbergh, 2016) Ethical implications of employing robotics and AI are of paramount importance and hence will be explored in further depth under the discussion section.

6 Discussion

6.1 Summary of findings

The aim of this paper was to identify robotics and AI technology designed to assist patients diagnosed with dementia - specifically investigating their effectiveness in alleviating symptoms associated with the condition – symptoms that have been highlighted in table 3 under results.

Table 3 consolidates and categorizes the overall number of robotics identified through two key databases, namely PubMed and Web of Science. Additionally, grey literature sourced from independent websites specializing in healthcare robotics, particularly in dementia care, has been integrated into the synthesis. In total, the study identified 40 instances of AI technology and robots, encompassing both humanoid and pet robot categories. These technologies have been implemented to assist and enhance the daily lives of Persons with Dementia (PwD), showcasing their potential to alleviate the challenges associated with the condition.

From the identified robots, 15% were designed with the purpose of actively enhancing the cognitive abilities of Persons with Dementia (PwD), contributing to a pause and delay in the progression of memory and cognitive function decline. 65% of robots and AI technologies were recognized for their significant impact in reducing feelings of desolation, depression, and social isolation among patients. Among these technologies, many were designed to keep

PwD occupied and engaged in conversations, providing companionship that played a crucial role in reminders and sending alerts to healthcare personnel or the police. Additionally, they contributed to the provision of entertainment through games, media, and interactive activities, all geared towards offering comfort and normalizing life for individuals with dementia. This was particularly evident when integrating robot pets, aiming to evoke the same affection and warmth associated with keeping a real-life pet.

While relatively few, 12.5% (of the total) robotics and AI technologies functioned to enhance psychomotor skills and promote increased functionality in patients—whether pertaining to body movement or facial expressions—made a significant contribution to the overall findings. Within this category, the use of sensors emerged as a common feature, serving the purposes of fall detection, patient lifting, and maintaining balance. Particularly noteworthy was the revelation of remote working solutions for patients experiencing social isolation, wherein cafes employed humanoids as workers on salaries, facilitating engagement with customers.

In comparison, robots and AI technology with the lowest percentage of 7.5%, addressed language and speech impairments in dementia patients. Nevertheless, the three instances highlighted are of paramount importance. These technologies play a critical role in translating slurred speech into coherent phrases, enabling better understanding of patients, whether by their family and friends, care personnel, or the broader society.

Table 4 - quantitative analysis of the results provides evidence-based support in inspecting the current landscape of existing robotics and AI technology as well as guiding research into symptoms of dementia that need alleviation and assistance. Not only this but we identified a trend that translated into how much more resources and research has and can go into companion humanoids and social robotic pets that deter the symptoms outlined.

From the expansive list of robotics and AI found, it can be seen that there is literature on the numerous robotics that exist to enhance quality of life of PwD. Not only this but numerous studies, as discussed below, reflect positive attitudes and acceptance of users when it comes to integrating them in their care. As highlight, these robotics and AI technology all aim to target and alleviate symptoms of dementia in one way or the other and can certainly be a guiding light for future research.

6.2 Comparative analysis of AI technology and robotics intervention in dementia care

There has been significant research in employing robotics and artificial intelligence within the domain of dementia – however only a handful list robotics and AI technologies that PwD can and have integrated in their daily lives in an aim to alleviate symptoms that come with the symptoms of dementia. Most of the journal articles lay emphasis on the extent of their effectiveness to study whether these social robots had any positive impact on the patient's moods and social wellbeing. Conclusions from most studies did indeed prove that the use of social bots and technologies saw improved moods, regulated emotions and happier patients. (Kang et al., 2020) (Jøranson et al., 2016)

While existing journal articles have strengthened the case for the effectiveness of robotics and AI in aiding people with dementia, this paper stands out as one of the few systematically categorizing these technologies based on the evolving needs of dementia patients, aligning with the progression of their symptoms into later stages of the condition. Observed from the reports that appeared in databases, many studies in this field tend to focus on a limited number of robots or AI technologies, limiting their capacity to make broad generalizations.

By collecting and systematically categorising robots and AI technology, acquired through my research and by conducting a comprehensive SWOT analysis, makes a distinctive contribution to the present body of work on AI and dementia. While numerous studies reports and aim to investigate the extent of the effectiveness of robotics and AI in alleviating symptoms of dementia, this study goes a step further by effectively outlining the strengths, weaknesses, opportunities, and threats associated with the integration of such technology within dementia care.

By conducting a SWOT analysis, we move past the traditional evaluation of their effectuality and provide a more refined and nuanced conception of the broader field. This strategy can enrich and guide research, helping in optimisation of viable interventions. At the same time, realising that weaknesses and threats assist in drawing up policy and strategy to tackle those challenges and hindrance.

Furthermore, an elaborate discussion of challenges in this paper sheds light in pointing out what limitations patients and researchers face in fully integrating robotics in dementia care. These are prospective areas that serve as a foundation for the much-needed intervention, paving the way to unlock the potential stemmed within artificial intelligence. The end purpose being to take advantage of the potentiality AI has in order to meet the needs of those with declining cognitive abilities and to ensure the best quality of care possible. In contributing to the ongoing discourse on the effectiveness of robotics and AI in dementia care, these results also offer a comprehensive framework for maximizing the impact of these technologies, ultimately enhancing the lives of PwD.

Gaps identified and further research

During the composition of this thesis, several gaps were examined, and they will be discussed in the paragraph below. While the research focus and study objectives have been discussed above, the constraints of time have necessitated the identification of the following gaps:

- user experience and acceptance of the robotics.
- the potential and extent of how these technologies integrate with traditional care and how the synergy between robotic care and human care can coexist. There is growing literature on perspectives of healthcare personnel when it comes to incorporating AI robotics in healthcare revealing varying acceptance rates.
- ethical implications were touched upon but researching into the legal aspects concerning the protection of patients could constitute another facet to explore within this wide research topic.
- lastly, while this paper aimed to inspect the current landscape of robotics and AI being employed in dementia care, studying the future of these technologies within dementia could become a guiding roadmap for updated and better inventions and policies.

Through studying the identified gap, we can study perspective areas to obtain a more comprehensive understanding of the field. Hence these gaps as well as my research paper does hold implications for further research.

The domain of robotics and AI is one that requires drastic investment. Before we advocate for full integration of this advanced AI into healthcare, it would be very useful to conduct a cost-effectiveness analysis of employing robotics as well as resource allocation. Not only does will this allow for a comparative analysis with other forms of technology that can help dementia patients but also study patient outcomes, deciding whether its use made any improvements in the quality of life of PwD.

Secondly, ethical implications is a rather widely discussed topic and field whenever artificial intelligence or robotics is brought up. The grave issues of user privacy, shared and leaked data, GDPR and user consent have not been studied to an extent where a solid legal framework has been drawn up to protect users and patients. This is extremely important seen as the patient group is highly vulnerable and sensitive and a strong sense of trust and protection needs to be instilled in buyers before making such an investment.

Lastly, future research can be guided into looking at practical implications of integrating robots in healthcare. We know that there is proof of robotics and AI in healthcare and specifically in dementia care but the need to study data on evaluating the barriers and facilitations that are present in the real-world healthcare settings. This is essential so as to analyse the real applicability of such technology and if needed to remove those barriers and fund required facilitations to make the transition much smoother.

Not only will these study areas examine and guide policy but identify existing gaps currently present in laws and legal frameworks. Together, recommendations and taking steps towards more strengthened future of robotics in healthcare, particularly dementia can be achieved by evaluating these fields.

6.3 Challenges present in integrating robotics and AI

In any form of support or treatment, cost determines access. Exorbitant prices of these robotics deter equity of access and ultimately a better quality of life. While proven to be effective, PARO, the most researched pet robot costs about $6000. AIBO costs $3000. Prices of humanoids are sky high with buyers paying somewhere around $22000 to $35000 for Pepper bot. (Fracasso et al., 2022) Expected to replace human care workers and reduce costs of hiring them, for an average person, robotics or advanced AI technology might not be the first solution they can benefit from. Even if smaller pet robots are only relatively cheaper, they most likely lack features to meet all the needs of patients and might not prove as effective. Some studies even identified cost being a big limitation for families of PwD even if the features seemed attractive. (Moyle et al., 2019, Young et al., 2009)

Another challenge this integration faces is user acceptability. Patient acceptance of social robots has been reported to be decreasing with age. (Baisch et al., 2017, Broadbent et al., 2009b) (Flandorfer, 2012) Regardless of age, acceptability varies across multiple factors – one of them being the fear of growing reliant on AI technology and robotics and second how it may replace contact with family and caretakers. (Wang et al., 2017) When it came to evaluating whether the elderly could form a connection with robots, in a study published those aged between 65-86 years said they did not want to build a friendship with their social robot. (Frennert et al., 2013) However, a heap of recent studies showcase increasing interest and acceptance of Pepper, Nao as well as Aibo by dementia patients as well as their families – reporting how inquisitive and captivated they all felt during the trial of using these robots and how well they evoked emotions. (Tamura et al., 2004, Paletta et al., 2019)

Additionally, safety risks, privacy concerns and etc are amongst some of the challenges that care homes and at home patients face. Some studies reported the risk of employing robotics with patients who have cognitive and physical impairments for there can be collisions and robots drifting into unwanted places such as bathrooms. Workers further fear dementia patients feeling more agitated and confusing robots with people and so in efforts to assist them might just make it worst for them. (Hung et al., 2022)

The concern of ethics is rather cardinal when disusing AI and robotics. When dealing with such a vulnerable patient group, privacy concerns come to mind which quite frankly are justified. Most of these social or pet robots come fitted with cameras creating a 'Big Brother' culture. Considered intrusive, the older population may consider it alienating unable to adapt as quickly or be eager to learn how to operate it. This inability may trigger feelings of frustration particularly when it comes to confusion of when and when they aren't being monitored or recorded. (Portacolone et al., 2020) While that these humanoids and pet bots fill in social gaps and keep the elderly engaged, video calls that help put them in contact with their family may be displaying other members of care homes without their consent to whole families who may be conversing in public areas. Reports also highlighted the presence of these robots to make care workers feel under constant surveillance. Numerous frontline workers hence advocate for patients consent, discretion to reject and autonomy must be respected before integrating robotics into care homes and their lives. (Hung et al., 2022)

Although numerous guidelines and legal frameworks exist to ensure ethical practices when it comes to data privacy and protection, (Saqr, 2022) there "is little evidence of good practice in ethical governance." (Winfield and Jirotka, 2018) Perhaps what is of concern is the deception it creates in the minds of patients into believing they do have a genuine emotional connection with the robots when in reality its one sided and not real. (Coeckelbergh, 2011) Lastly, on the issue of taking informed consent from users, there is no steady guidance on how to actually take informed consent from patients as well as when and how a proxy can voice their consent on behalf of somebody whose cognitively challenged. (Portacolone et al., 2020)

Bias and moral agency have been discussed under the SWOT analysis but its worth emphasising and investigating the ethical quality of decisions made by an autonomous robot designed to perform tasks and take decisions without human interference.(Stahl and Coeckelbergh, 2016) Hence it is crucial to gain the trust of users as well as healthcare personnel for robotics and AI to be fully integrated into care homes and those of patients. Clarity on liability, legal actions and insurance, if errors or technological malfunctions occur need to be stated and established as to avoid patient injury and in order to implement a safe and legally secure integration of artificial intelligence and robotics into clinical care. (Maliha et al., 2021)

6.4 Limitations of the study

Due to the time restrictions, this paper could not explore all the types of robotics and AI technology. Intelligent assistive technology had to be excluded from the research as there was not enough time to include all forms of intelligent devices in the paper. The data sources were indeed limited and had they been used, there is a possibility that more results could have been obtained.

A scoping review was carried out to map out the current or emerging data on the topic of this paper but more importantly to help establish and identify the gap that exists in the research area. However, because a scoping review allows you to select studies that you may feel are relevant to your research question, the results or process of research may not quite have been objective. In addition, non-English articles were excluded too. As China and Japan are pioneers in the field of manufacturing and designing AI and robotics, there is a big likelihood of important data having been missed out due to the language barriers Having said that, a systematic review was not carried out and hence there is possibility of relevant and cardinal data being excluded from the paper.

Third, even though a SWOT analysis provided an extensive overview it can only aim to read and give an evaluation pertaining to the current strengths, opportunities, weaknesses and threats. It is not a future forecasting tool and as progress is made, a swot analysis made now would not be applicable then. It unfortunately oversimplifies complicated issues, lacks objectivity and does not aim to reflect or work on any solution. Perhaps one of the tests of using a SWOT analysis is trying to avoid subjectivity and assumptions that may well skew the results – for example underestimating strengths, overestimating weaknesses and choosing to consider external factors that can affect opportunities and threats.

Lastly, technology always has the risk of going obsolete and some of the results identified may have been replaced by updated algorithms or been taken off of the market to be replaced by newer robotics and AI technology. Hence there may be chance that this paper did not capture new and emerging technologies and some of the robotics identified under results may not at best reflect their purpose.

7 Conclusion

The primary objective of this paper was to understand and explore how and if there were robotics and AI technology that were in use to mitigate symptoms of dementia. To study the extent to which they did fulfil this purpose. After research and browsing databases as well as independent website, an extensive list of robotics and AI devices appeared which indeed confirm their existence and whether they played a part in relieving symptoms that dementia patients experienced.

The findings were further analysed in relation to the symptoms PwD experience. Robotics and AI technology were systematically categorised according to the symptoms they operated to mitigate and assist with. This reflected the presence and their purpose which made it easier to understand their function. By doing so, this paper reveals the potential stemmed in artificial intelligence to promote wellbeing of millions of patients by ameliorating symptoms they experience and making them more capable of feeling a part of the general society.

Categorising the results and conducting a SWOT analysis more pertinently highlights that there is need for further research in areas that are considered a threat and act as a hindrance to its full integration. Additionally, on how suitable AI is to assist patients in their daily lives, to consider concerns of direct patients and frontline workers to ensure a balanced, ethical and safe practice.

Studying how acute dementia as a condition can be for the person going through it as well as for their family, I was inspired to research on solutions that could, to some extent, make their lives easier. The forecasted predictions of statistics revolving around how many more people can be detected with it is indeed appalling.

The faith that stems from the competency of artificial intelligence and robotics to make our lives easier is quite promising. For us to miss out on the opportunity to unlock its power would be wasted potential and an untapped solution for millions.

References

ABDOLLAHI, H., MAHOOR, M. H., ZANDIE, R., SIEWIERSKI, J. & QUALLS, S. H. 2023. Artificial Emotional Intelligence in Socially Assistive Robots for Older Adults: A Pilot Study. *IEEE Trans Affect Comput,* 14**,** 2020-2032.

ACKERMAN, E. (2011) RIBA II Healthcare Robot Gets Bigger Muscles, Cuter Ears, *IEE Spectrum,* 3 August. Available from: riba-ii-healthcare-robot-gets-bigger-muscles-cuter-ears [Accessed 5 October 2023].

AMABILI, G., CUCCHIERI, G., MARGARITINI, A., BENADDUCI, M., BARBAROSSA, F., LUZI, R., RICCARDI, G. R., PELLICCIONI, G., MARANESI, E. & BEVILACQUA, R. 2022. Social Robotics and Dementia: Results from the eWare Project in Supporting Older People and Their Informal Caregivers. *Int J Environ Res Public Health,* 19.

ARKSEY, H. & O'MALLEY, L. 2005. Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology,* 8**,** 19-32.

AZEVEDO, L., CALANDRI, I. L., SLACHEVSKY, A., GRAVIOTTO, H. G., VIEIRA, M. C. S., ANDRADE, C. B., ROSSETTI, A. P., GENEROSO, A. B., CARMONA, K. C., PINTO, L. A. C., SORBARA, M., PINTO, A., GUAJARDO, T., OLAVARRIA, L., THUMALA, D., CRIVELLI, L., VIVAS, L., ALLEGRI, R. F., BARBOSA, M. T., SERRANO, C. M., MIRANDA-CASTILLO, C. & CARAMELLI, P. 2021. Impact of Social Isolation on People with Dementia and Their Family Caregivers. *J Alzheimers Dis,* 81**,** 607-617.

BAISCH, S., KOLLING, T., SCHALL, A., RÜHL, S., SELIC, S., KIM, Z., ROSSBERG, H., KLEIN, B., PANTEL, J. & OSWALD, F. 2017. Acceptance of social robots by elder people: does psychosocial functioning matter? *International Journal of Social Robotics,* 9**,** 293-307.

BANOVIC, S., ZUNIC, L. J. & SINANOVIC, O. 2018. Communication Difficulties as a Result of Dementia. *Mater Sociomed,* 30**,** 221-224.

BARNETT, G. O., CIMINO, J. J., HUPP, J. A. & HOFFER, E. P. 1987. DXplain. An evolving diagnostic decision-support system. *Jama,* 258**,** 67-74.

BAUMEISTER, R. F. & LEARY, M. R. 1997. Writing Narrative Literature Reviews. *Review of General Psychology,* 1**,** 311-320.

BAYEN, E., NICKELS, S., XIONG, G., JACQUEMOT, J., SUBRAMANIAM, R., AGRAWAL, P., HEMRAJ, R., BAYEN, A., MILLER, B. L. & NETSCHER, G. 2021. Reduction of Time on the Ground Related to Real-Time Video Detection of Falls in Memory Care Facilities: Observational Study. *J Med Internet Res,* 23**,** e17551.

BEASLEY, R. A. 2012. Medical robots: current systems and research directions. *Journal of Robotics,* 2012.

BIADSEY, F and WEISS R. (2019) 'Parrotron:New Research into Improving Verbal Communication for People with Speech Impairments.' *Google Research.* 17 July. Available at: https://blog.research.google/2019/07/parrotron-new-research-into-improving.html?m=1 [Accessed 20 October 2023].

BOUTON, C. E., SHAIKHOUNI, A., ANNETTA, N. V., BOCKBRADER, M. A., FRIEDENBERG, D. A., NIELSON, D. M., SHARMA, G., SEDERBERG, P. B., GLENN, B. C., MYSIW, W. J., MORGAN, A. G., DEOGAONKAR, M. & REZAI, A. R. 2016. Restoring cortical control of functional movement in a human with quadriplegia. *Nature,* 533**,** 247-50.

BROADBENT, E., STAFFORD, R. & MACDONALD, B. 2009a. Acceptance of Healthcare Robots for the Older Population: Review and Future Directions. *International Journal of Social Robotics,* 1**,** 319-330.
BROADBENT, E., STAFFORD, R. & MACDONALD, B. 2009b. Acceptance of healthcare robots for the older population: Review and future directions. *International journal of social robotics,* 1**,** 319-330.
CATH, C. 2018. Governing artificial intelligence: ethical, legal and technical opportunities and challenges. *Philos Trans A Math Phys Eng Sci,* 376.
CATTIAU, J. (2021) *A communication tool for people with non-standard speech.* Available from:
https://blog.google/outreach-initiatives/accessibility/project-relate/ [Accessed 5 October 2023].
CECCARELLI, M. 2011a. Problems and issues for service robots in new applications. *International Journal of Social Robotics,* 3**,** 299-312.
CECCARELLI, M. 2011b. Problems and Issues for Service Robots in New Applications. *International Journal of Social Robotics,* 3**,** 299-312.
CHEN, Z., RAMABHADRAN, B., BIADSY, F., ZHANG, X., CHEN, Y., JIANG, L., CHU, A., DOSHI, R. & MENGIBAR, P. J. M. 2021. Conformer Parrotron: a Faster and Stronger End-to-end SpeechConversion and Recognition Model for Atypical Speech.
COECKELBERGH, M. 2011. Are emotional robots deceptive? *IEEE transactions on affective computing,* 3**,** 388-393.
COLLABORATORS, G. B. D. D. F. 2022. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. *Lancet Public Health,* 7**,** e105-e125.
COLQUHOUN, H. L., LEVAC, D., O'BRIEN, K. K., STRAUS, S., TRICCO, A. C., PERRIER, L., KASTNER, M. & MOHER, D. 2014a. Scoping reviews: time for clarity in definition, methods, and reporting. *Journal of Clinical Epidemiology,* 67**,** 1291-1294.
COLQUHOUN, H. L., LEVAC, D., O'BRIEN, K. K., STRAUS, S., TRICCO, A. C., PERRIER, L., KASTNER, M. & MOHER, D. 2014b. Scoping reviews: time for clarity in definition, methods, and reporting. *J Clin Epidemiol,* 67**,** 1291-4.
CRESSWELL, K., CUNNINGHAM-BURLEY, S. & SHEIKH, A. 2018. Health Care Robotics: Qualitative Exploration of Key Challenges and Future Directions. *J Med Internet Res,* 20**,** e10410.
DINESEN, B., HANSEN, H. K., GRØNBORG, G. B., DYRVIG, A. K., LEISTED, S. D., STENSTRUP, H., SKOV SCHACKSEN, C. & OESTERGAARD, C. 2022. Use of a Social Robot (LOVOT) for Persons With Dementia: Exploratory Study. *JMIR Rehabil Assist Technol,* 9**,** e36505.
DODDS, P., MARTYN, K. & BROWN, M. 2018. Infection prevention and control challenges of using a therapeutic robot. *Nurs Older People,* 30**,** 34-40.
DWIVEDI, R., MEHROTRA, D. & CHANDRA, S. 2022. Potential of Internet of Medical Things (IoMT) applications in building a smart healthcare system: A systematic review. *J Oral Biol Craniofac Res,* 12**,** 302-318.
EGGER, M., SMITH, G. D. & PHILLIPS, A. N. 1997. Meta-analysis: principles and procedures. *Bmj,* 315**,** 1533-7.
ESTEVA, A., KUPREL, B., NOVOA, R. A., KO, J., SWETTER, S. M., BLAU, H. M. & THRUN, S. 2017. Corrigendum: Dermatologist-level classification of skin cancer with deep neural networks. *Nature,* 546**,** 686.

FLANDORFER, P. 2012. Population ageing and socially assistive robots for elderly persons: the importance of sociodemographic factors for user acceptance. *International Journal of Population Research,* 2012.

FRACASSO, F., BUCHWEITZ, L., THEIL, A., CESTA, A. & KORN, O. 2022. Social Robots Acceptance and Marketability in Italy and Germany: A Cross-National Study Focusing on Assisted Living for Older Adults. *International Journal of Social Robotics,* 14**,** 1463-1480.

FRENNERT, S., EFTRING, H. & ÖSTLUND, B. What Older People Expect of Robots: A Mixed Methods Approach. *In:* HERRMANN, G., PEARSON, M. J., LENZ, A., BREMNER, P., SPIERS, A. & LEONARDS, U., eds. Social Robotics, 2013// 2013 Cham. Springer International Publishing, 19-29.

GETAHUN, H. (2022) *A robot named Mr. Bah can sense when the elderly are about to lose their balance — and catch them before they fall.* Available from: https://www.insider.com/robot-mr-bah-can-catch-older-people-about-to-fall-2022-9 [Accessed 5 October 2023].

GOOGLE TRENDS. (2023) 'Scoping review'. Available at: https://trends.google.com/trends/explore?date=2019-01-01%202023-10-17&q=scoping%20review&hl=en. [Accessed 17 October 2023].

GROF, Z. & STEPANEK, F. 2021. Artificial intelligence based design of 3D-printed tablets for personalise d me dicine. *Computers & Chemical Engineering,* 154.

HALL, A. K., BACKONJA, U., PAINTER, I., CAKMAK, M., SUNG, M., LAU, T., THOMPSON, H. J. & DEMIRIS, G. 2019. Acceptance and perceived usefulness of robots to assist with activities of daily living and healthcare tasks. *Assist Technol,* 31**,** 133-140.

HANSON, E., HELLSTRÖM, A., SANDVIDE, Å., JACKSON, G. A., MACRAE, R., WAUGH, A., ABREU, W. & TOLSON, D. 2016. The extended palliative phase of dementia – An integrative literature review. *Dementia,* 18**,** 108-134.

HELMS, M. M. & NIXON, J. 2010. Exploring SWOT analysis–where are we now? A review of academic research from the last decade. *Journal of strategy and management,* 3**,** 215-251.

HENDRICH, N., BISTRY, H. & ZHANG, J. 2015. Architecture and Software Design for a Service Robot in an Elderly-Care Scenario. *Engineering,* 1**,** 027-035.

HOSSAIN, E., RANA, R., HIGGINS, N., SOAR, J., BARUA, P. D., PISANI, A. R. & TURNER, K. 2023. Natural Language Processing in Electronic Health Records in relation to healthcare decision-making: A systematic review. *Comput Biol Med,* 155**,** 106649.

HUANG, R., LI, H. X., SUOMI, R., LI, C. L. & PELTONIEMI, T. 2023. Intelligent Physical Robots in Health Care: Systematic Literature Review. *JOURNAL OF MEDICAL INTERNET RESEARCH,* 25.

HUNG, L., LIU, C., WOLDUM, E., AU-YEUNG, A., BERNDT, A., WALLSWORTH, C., HORNE, N., GREGORIO, M., MANN, J. & CHAUDHURY, H. 2019. The benefits of and barriers to using a social robot PARO in care settings: a scoping review. *BMC Geriatr,* 19**,** 232.

HUNG, L., MANN, J., PERRY, J., BERNDT, A. & WONG, J. 2022. Technological risks and ethical implications of using robots in long-term care. *J Rehabil Assist Technol Eng,* 9**,** 20556683221106917.

JAHAN, N., NAVEED, S., ZESHAN, M. & TAHIR, M. A. 2016. How to Conduct a Systematic Review: A Narrative Literature Review. *Cureus,* 8**,** e864.

JØRANSON, N., PEDERSEN, I., ROKSTAD, A. M. & IHLEBAEK, C. 2016. Change in quality of life in older people with dementia participating in Paro-activity: a cluster-randomized controlled trial. *J Adv Nurs,* 72**,** 3020-3033.
JUNTUNEN, M. & LEHENKARI, M. 2021. A narrative literature review process for an academic business research thesis. *Studies in Higher Education,* 46**,** 330-342.
KANG, H. S., MAKIMOTO, K., KONNO, R. & KOH, I. S. 2020. Review of outcome measures in PARO robot intervention studies for dementia care. *Geriatr Nurs,* 41**,** 207-214.
KAUL, V., ENSLIN, S. & GROSS, S. A. 2020. History of artificial intelligence in medicine. *Gastrointest Endosc,* 92**,** 807-812.
KOUROUPETROGLOU, C., CASEY, D., RACITI, M., BARRETT, E., D'ONOFRIO, G., RICCIARDI, F., GIULIANI, F., GRECO, A., SANCARLO, D., MANNION, A., WHELAN, S., PEGMAN, G., KOUMPIS, A., REFORGIATO RECUPERO, D., KOUROUPETROGLOU, A. & SANTORELLI, A. 2017. Interacting with Dementia: The MARIO Approach. *Stud Health Technol Inform,* 242**,** 38-47.
KOUTENTAKIS, D., PILOZZI, A. & HUANG, X. 2020. Designing Socially Assistive Robots for Alzheimer's Disease and Related Dementia Patients and Their Caregivers: Where We are and Where We are Headed. *Healthcare (Basel),* 8.
LEE, H., CHUNG, M. A., KIM, H. & NAM, E. W. 2022. The Effect of Cognitive Function Health Care Using Artificial Intelligence Robots for Older Adults: Systematic Review and Meta-analysis. *JMIR Aging,* 5**,** e38896.
LEKADIR, K. (2022) Artificial intelligence in healthcare - Applications, risks, and ethical and societal impacts. *EPRS*. Available from: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/729512/EPRS_STU(2022)729512_EN.pdf [Accessed 1st September 2022].
LEROI, I., KITAGAWA, K., VATTER, S. & SUGIHARA, T. 2018. Dementia in 'super-aged' Japan: challenges and solutions. *Neurodegener Dis Manag,* 8**,** 257-266.
LEVAC, D., COLQUHOUN, H. & O'BRIEN, K. K. 2010a. Scoping studies: advancing the methodology. *Implement Sci,* 5**,** 69.
LEVAC, D., COLQUHOUN, H. & O'BRIEN, K. 2010b. Scoping Studies: Advancing the Methodology. *Implementation science : IS,* 5**,** 69.
LIBERATI, A., ALTMAN, D., TETZLAFF, J., MULROW, C., GOTZSCHE, P. & IOANNIDIS, J. 2009. PA, Clarke M., Devereaux PJ, Kleijnen J., Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Bmj,* 339**,** b2700-b2700.
LILLIANFIELD, L & NIKKA, A. (2021) *Two new tools that make your phone even more accessible.* Available from: https://blog.google/outreach-initiatives/accessibility/making-android-more-accessible/ [Accessed 5 October 2023].
MAGYAR, J., KOBAYASHI, M., NISHIO, S., SINCÁK, P., ISHIGURO, H. & IEEE 2019. Autonomous Robotic Dialogue System with Reinforcement Learning for Elderlies with Dementia. *2019 IEEE INTERNATIONAL CONFERENCE ON SYSTEMS, MAN AND CYBERNETICS (SMC).*
MALIHA, G., GERKE, S., COHEN, I. G. & PARIKH, R. B. 2021. Artificial Intelligence and Liability in Medicine: Balancing Safety and Innovation. *Milbank Q,* 99**,** 629-647.
MANSOURI, N., GOHER, K. & HOSSEINI, S. E. 2017. Ethical framework of assistive devices: review and reflection. *Robotics Biomim,* 4**,** 19.
MÁRQUEZ-SÁNCHEZ, S., MORA-SIMON, S., HERRERA-SANTOS, J., RONCERO, A. O. & CORCHADO, J. M. 2020. Intelligent Dolls and robots for the treatment of

elderly people with dementia. *ADCAIJ-ADVANCES IN DISTRIBUTED COMPUTING AND ARTIFICIAL INTELLIGENCE JOURNAL,* 9**,** 99-112.
META. (2021) 'Teaching AI to perceive the world through your eyes.' *Meta.* 14 October. Available at: https://ai.meta.com/blog/teaching-ai-to-perceive-the-world-through-your-eyes/ [Accessed 15 October 2022].
MORAIS, A., SANTOS, S. & LEBRE, P. 2017. Psychomotor, Functional, and Cognitive Profiles in Older People with and without Dementia:What Connections? *Dementia,* 18**,** 1538-1553.
MOYLE, W., BRAMBLE, M., JONES, C. J. & MURFIELD, J. E. 2019. "She had a smile on her face as wide as the great Australian bite": a qualitative examination of family perceptions of a therapeutic robot and a plush toy. *The Gerontologist,* 59**,** 177-185.
MOYLE, W., JONES, C. J., MURFIELD, J. E., THALIB, L., BEATTIE, E. R. A., SHUM, D. K. H., O'DWYER, S. T., MERVIN, M. C. & DRAPER, B. M. 2017. Use of a Robotic Seal as a Therapeutic Tool to Improve Dementia Symptoms: A Cluster-Randomized Controlled Trial. *J Am Med Dir Assoc,* 18**,** 766-773.
MUNN, Z., PETERS, M. D. J., STERN, C., TUFANARU, C., MCARTHUR, A. & AROMATARIS, E. 2018. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology,* 18**,** 143.
NAMUGENYI, C., NIMMAGADDA, S. L. & REINERS, T. 2019. Design of a SWOT Analysis Model and its Evaluation in Diverse Digital Business Ecosystem Contexts. *Procedia Computer Science,* 159**,** 1145-1154.
NHS. (2022) *Personal Social Services Survey of Adult Carers in England.* NHS. UK. NHS Digital. Available from: https://files.digital.nhs.uk/28/2342AD/PSS_SACE_Report_2021-22.pdf [Accessed 1st October 2022].
NHS (2023) *What is dementia.* Available from: https://www.nhs.uk/conditions/dementia/about-dementia/what-is-dementia/ [Accessed 5 August 2023].
NWOSU, A. C., COLLINS, B. & MASON, S. 2018. Big Data analysis to improve care for people living with serious illness: The potential to use new emerging technology in palliative care. *Palliat Med,* 32**,** 164-166.
NWOSU, A. C., STURGEON, B., MCGLINCHEY, T., GOODWIN, C. D., BEHERA, A., MASON, S., STANLEY, S. & PAYNE, T. R. 2019. Robotic technology for palliative and supportive care: Strengths, weaknesses, opportunities and threats. *Palliat Med,* 33**,** 1106-1113.
OH, J. H., YI, Y. J., SHIN, C. J., PARK, C., KANG, S., KIM, J. & KIM, I. S. 2015. [Effects of Silver-Care-Robot Program on Cognitive Function, Depression, and Activities of Daily Living for Institutionalized Elderly People]. *J Korean Acad Nurs,* 45**,** 388-96.
OLTHOF, A. W., VAN OOIJEN, P. M. A. & CORNELISSEN, L. J. 2021. Deep Learning-Based Natural Language Processing in Radiology: The Impact of Report Complexity, Disease Prevalence, Dataset Size, and Algorithm Type on Model Performance. *J Med Syst,* 45**,** 91.
OREJEL BUSTOS, A. S., TRAMONTANO, M., MORONE, G., CIANCARELLI, I., PANZA, G., MINNETTI, A., PICELLI, A., SMANIA, N., IOSA, M. & VANNOZZI, G. 2023. Ambient assisted living systems for falls monitoring at home. *Expert Rev Med Devices,* 20**,** 821-828.
ORTIZ, S. (2023) *Do you need a speech therapist? Now you can consult AI.* Available from: https://www.zdnet.com/article/do-you-need-a-speech-therapist-now-you-can-consult-ai/ [Accessed 5 October 2023].

PAGE, M. J., MCKENZIE, J. E., BOSSUYT, P. M., BOUTRON, I., HOFFMANN, T. C., MULROW, C. D., SHAMSEER, L., TETZLAFF, J. M., AKL, E. A., BRENNAN, S. E., CHOU, R., GLANVILLE, J., GRIMSHAW, J. M., HRÓBJARTSSON, A., LALU, M. M., LI, T., LODER, E. W., MAYO-WILSON, E., MCDONALD, S., MCGUINNESS, L. A., STEWART, L. A., THOMAS, J., TRICCO, A. C., WELCH, V. A., WHITING, P. & MOHER, D. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery,* 88**,** 105906.

PALETTA, L., SCHÜSSLER, S., ZUSCHNEGG, J., STEINER, J., PANSY-RESCH, S., LAMMER, L., PRODROMOU, D., BRUNSCH, S., LODRON, G. & FELLNER, M. 2019. AMIGO—A Socially Assistive Robot for Coaching Multimodal Training of Persons with Dementia. *In:* KORN, O. (ed.) *Social Robots: Technological, Societal and Ethical Aspects of Human-Robot Interaction.* Cham: Springer International Publishing.

PARK, E. A., JUNG, A. R. & LEE, K. A. 2021. The Humanoid Robot Sil-Bot in a Cognitive Training Program for Community-Dwelling Elderly People with Mild Cognitive Impairment during the COVID-19 Pandemic: A Randomized Controlled Trial. *Int J Environ Res Public Health,* 18.

PAUL, D., SANAP, G., SHENOY, S., KALYANE, D., KALIA, K. & TEKADE, R. K. 2021. Artificial intelligence in drug discovery and development. *Drug Discov Today,* 26**,** 80-93.

PAUL, M. & LEIBOVICI, L. 2014. Systematic review or meta-analysis? Their place in the evidence hierarchy. *Clin Microbiol Infect,* 20**,** 97-100.

PEREL, V. D. 1998. Psychosocial Impact of Alzheimer Disease. *JAMA,* 279**,** 1038-1039.

PETERSEN, S., HOUSTON, S., QIN, H., TAGUE, C. & STUDLEY, J. 2017. The Utilization of Robotic Pets in Dementia Care. *J Alzheimers Dis,* 55**,** 569-574.

PHAM, M. T., RAJIĆ, A., GREIG, J. D., SARGEANT, J. M., PAPADOPOULOS, A. & MCEWEN, S. A. 2014. A scoping review of scoping reviews: advancing the approach and enhancing the consistency. *Res Synth Methods,* 5**,** 371-85.

PORTACOLONE, E., HALPERN, J., LUXENBERG, J., HARRISON, K. L. & COVINSKY, K. E. 2020. Ethical Issues Raised by the Introduction of Artificial Companions to Older Adults with Cognitive Impairment: A Call for Interdisciplinary Collaborations. *J Alzheimers Dis,* 76**,** 445-455.

POU-PROM, C., RAIMONDO, S. & RUDZICZ, F. 2020. A Conversational Robot for Older Adults with Alzheimer's Disease. *ACM TRANSACTIONS ON HUMAN-ROBOT INTERACTION,* 9.

PRESS, G. (2020) 12 *AI Milestones: 4. MYCIN, An Expert System For Infectious Disease Therapy.* Available from: https://www.forbes.com/sites/gilpress/2020/04/27/12-ai-milestones-4-mycin-an-expert-system-for-infectious-disease-therapy/?sh=badbb2076e51 [Accessed 15 September].

PUBMED. (2023) 'Scoping Reviews'. Available at: https://pubmed.ncbi.nlm.nih.gov/?term=scoping%20review&filter=years.2005-2024 [Accessed 15 August 2023].

ROBOCARE. (2019). *SILBOT.* Available from:http://www.robocare.co.kr/pages/product03_en.php [Accessed 2 November 2023].

RICHES, S., AZEVEDO, L., VORA, A., KALEVA, I., TAYLOR, L., GUAN, P., JEYARAJAGURU, P., MCINTOSH, H., PETROU, C., PISANI, S. & HAMMOND, N. 2022. Therapeutic engagement in robot-assisted psychological interventions: A systematic review. *Clin Psychol Psychother,* 29**,** 857-873.

SASAGAWA, E. (2017) *You're going to want to thank your grandmother's robot.* Available from: https://www.cbc.ca/radio/outintheopen/can-robots-be-human-1.4363742/you-re-going-to-want-to-thank-your-grandmother-s-robot-1.4364140 [Accessed 5 October 2023].
SAQR, M. 2022. Is GDPR failing? a tale of the many challenges in interpretations, applications, and enforcement. *Int J Health Sci (Qassim),* 16**,** 1-2.
SHARKEY, A. & SHARKEY, N. 2012. Granny and the robots: ethical issues in robot care for the elderly. *Ethics and information technology,* 14**,** 27-40.
SHIBATA, T. & WADA, K. 2011. Robot therapy: a new approach for mental healthcare of the elderly - a mini-review. *Gerontology,* 57**,** 378-86.
SORBELLO, R., CHELLA, A., CALÍ, C., GIARDINA, M., NISHIO, S. & ISHIGURO, H. 2014. Telenoid android robot as an embodied perceptual social regulation medium engaging natural human–humanoid interaction. *Robotics and Autonomous Systems,* 62**,** 1329-1341.
STAHL, B. C. & COECKELBERGH, M. 2016. Ethics of healthcare robotics: Towards responsible research and innovation. *Robotics and Autonomous Systems,* 86**,** 152-161.
SU, Z., BENTLEY, B. L., MCDONNELL, D., AHMAD, J., HE, J., SHI, F., TAKEUCHI, K., CHESHMEHZANGI, A. & DA VEIGA, C. P. 2022. 6G and Artificial Intelligence Technologies for Dementia Care: Literature Review and Practical Analysis. *J Med Internet Res,* 24**,** e30503.
SUCHAREW, H. & MACALUSO, M. 2019. Progress Notes: Methods for Research Evidence Synthesis: The Scoping Review Approach. *J Hosp Med,* 14**,** 416-418.
TAKEUCHI, K., YAMAZAKI, Y. & YOSHIFUJI, K. Avatar work: Telework for disabled people unable to go outside by using avatar robots. Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction, 2020. 53-60.
TAMURA, T., YONEMITSU, S., ITOH, A., OIKAWA, D., KAWAKAMI, A., HIGASHI, Y., FUJIMOOTO, T. & NAKAJIMA, K. 2004. Is an entertainment robot useful in the care of elderly people with severe dementia? *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences,* 59**,** M83-M85.
THORNHILL, T. (2023) *Inside the incredible Tokyo Cafe where the food and drinks are served to customers by Robots.* Available from: https://www.dailymail.co.uk/travel/article-12557317/Inside-incredible-Tokyo-cafe-food-drinks-served-customers-ROBOTS.html [Accessed 1 November 2023].
THE INSTITUTE OF HEALTH METRICS AND EVALUATION. (2019) 'Prevalence of Dementia 2019'.Available at: gbd-compare. [Accessed: 17th October 2023].
THE INSTITUTE OF HEALTH METRICS AND EVALUATION (2019) 'DALY's per 100,000.' Available at: https://vizhub.healthdata.org/gbd-compare/ [Accessed 17 October 2023].
Topsfield, J. (2022) *Robot dogs and Google reminders: How AI helps people with dementia stay independent.* Available from: https://www.smh.com.au/lifestyle/health-and-wellness/robot-dogs-and-google-reminders-how-ai-helps-dementia-patients-stay-independent-20220828-p5bdar.html [Accessed 5 October 2023].
THUNBERG, S., RÖNNQVIST, L. & ZIEMKE, T. 2020. Do Robot Pets Decrease Agitation in Dementia Patients? An Ethnographic Approach. *SOCIAL ROBOTICS, ICSR 2020.*
TRAN, Q. (2022) *Worldwide dementia cases to triple by 2050 to over 150 million people.* Available from: https://www.alzheimersresearchuk.org/worldwide-dementia-cases-to-triple-by-2050-to-over-150-million/#:~:text=The%20researchers%20suggest%20that%20the,Africa%20and%20the%20Middle%20East.[Accessed 10 August 2023.]

TOBIS, S., CYLKOWSKA-NOWAK, M., WIECZOROWSKA-TOBIS, K., PAWLACZYK, M. & SUWALSKA, A. 2017. Occupational Therapy Students' Perceptions of the Role of Robots in the Care for Older People Living in the Community. *Occup Ther Int,* 2017**,** 9592405.
TRICCO, A. C., LILLIE, E., ZARIN, W., O'BRIEN, K. K., COLQUHOUN, H., LEVAC, D., MOHER, D., PETERS, M. D. J., HORSLEY, T., WEEKS, L., HEMPEL, S., AKL, E. A., CHANG, C., MCGOWAN, J., STEWART, L., HARTLING, L., ALDCROFT, A., WILSON, M. G., GARRITTY, C., LEWIN, S., GODFREY, C. M., MACDONALD, M. T., LANGLOIS, E. V., SOARES-WEISER, K., MORIARTY, J., CLIFFORD, T., TUNÇALP, Ö. & STRAUS, S. E. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med,* 169**,** 467-473.
VALENTÍ SOLER, M., AGÜERA-ORTIZ, L., OLAZARÁN RODRÍGUEZ, J., MENDOZA REBOLLEDO, C., PÉREZ MUÑOZ, A., RODRÍGUEZ PÉREZ, I., OSA RUIZ, E., BARRIOS SÁNCHEZ, A., HERRERO CANO, V., CARRASCO CHILLÓN, L., FELIPE RUIZ, S., LÓPEZ ALVAREZ, J., LEÓN SALAS, B., CAÑAS PLAZA, J. M., MARTÍN RICO, F., ABELLA DAGO, G. & MARTÍNEZ MARTÍN, P. 2015. Social robots in advanced dementia. *Front Aging Neurosci,* 7**,** 133.
VAN PATTEN, R., KELLER, A. V., MAYE, J. E., JESTE, D. V., DEPP, C., RIEK, L. D. & TWAMLEY, E. W. 2020. Home-Based Cognitively Assistive Robots: Maximizing Cognitive Functioning and Maintaining Independence in Older Adults Without Dementia. *Clin Interv Aging,* 15**,** 1129-1139.
VELANDIA, P. P., MILLER-PETRIE, M. K., CHEN, C., CHAKRABARTI, S., CHAPIN, A., HAY, S., TSAKALOS, G., WIMO, A. & DIELEMAN, J. L. 2022. Global and regional spending on dementia care from 2000-2019 and expected future health spending scenarios from 2020-2050: An economic modelling exercise. *EClinicalMedicine,* 45**,** 101337.
WANG, R. H., SUDHAMA, A., BEGUM, M., HUQ, R. & MIHAILIDIS, A. 2017. Robots to assist daily activities: views of older adults with Alzheimer's disease and their caregivers. *International psychogeriatrics,* 29**,** 67-79.
WHITE, A. & SCHMIDT, K. 2005. Systematic literature reviews. *Complement Ther Med,* 13**,** 54-60.
WHO. (2023) *Disability-adjusted life years (DALYs).* Available from:https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158 [Accessed 26 September 2023].
WHO. (2023) *Dementia.* Available from: **https://www.who.int/news-room/fact-sheets/detail/dementia#:~:text=In%202019%2C%20dementia%20cost%20economies,care%20and%20supervision%20per%20day.** [Accessed 26 September 2023].
WILKINSON J. (2015) *The strong robot with the gentle touch*. Available from: https://www.riken.jp/en/news_pubs/research_news/pr/2015/20150223_2/ [Accessed 5 October 2023].
WINFIELD, A. F. T. & JIROTKA, M. 2018. Ethical governance is essential to building trust in robotics and artificial intelligence systems. *Philos Trans A Math Phys Eng Sci,* 376.
WOODS, D., YUAN, F. P., JAO, Y. L. & ZHAO, X. P. 2021. Social Robots for Older Adults with Dementia: A Narrative Review on Challenges & Future Directions. *SOCIAL ROBOTICS, ICSR 2021.*
YOUNG, J. E., HAWKINS, R., SHARLIN, E. & IGARASHI, T. 2009. Toward acceptable domestic robots: Applying insights from social psychology. *International Journal of Social Robotics,* 1**,** 95-108.

ZEWE, A. (2021) *A robot that finds lost items.* Available from: https://news.mit.edu/2021/robot-finds-items-camera-antenna-1005 [Accessed 5 October 2023].