on generating categories and defining meaningful themes from the data.

3 FINDINGS

The key technologies used for AI-based elderly healthcare solutions include Machine learning (ML), Natural language processing (NLP), Deep learning models, diagnosis and treatment applications, administrative applications and IOT [8, 9]. ML techniques are used to analyze the structured data such as electrophysiological information, genetic information, and image analysis whereas NLP technology extracts data from unconstrained or unorganized information such as clinical inspections or medical records to not only improve formatted medical screening information but also generating machine-understandable organized files to enhance decision making and simultaneously improving clinical competence [10]. Key themes from the reviewed literature are presented below:

3.1 Smart Homes for Elderly

The fact that the elderly people prefer to live independently, and to take part in their daily activities by themselves is the driving factor behind the design of smart homes for elderly. Daily activities involve a lot of cognitive and physical activities which are supported by data driven, smart and intelligent systems [11–17]. Smart homes are equipped with IOT based intelligent control subsystems, intelligent monitoring subsystems, including sensors, actuators, and biomedical monitors. These devices operate in a totally networked environment which is connected to a remote facility for data collection and processing. Real-time data analysis assists in gathering useful data and make timely decisions for better health support. This entails a lot of things such as:

- Activity recognition
- Smart furniture
- Sensorization in home environments
- Adaptive lighting systems

3.2 AI-based health monitoring technologies

Research shows that the data-driven intelligent information can help the medical practitioners to improve the quality of healthcare for elderly people. Predictive analytics based on health monitoring technologies for elderly is considered very important in this domain [6, 18–21]. This entails:

- Supervised and unsupervised monitoring & learning
- Telecare systems
- Emotion recognition
- Real-time fall monitoring
- Explainable AI
- X-ray film classification and recognition

3.3 Wearable Devices

IOT-based non-invasive wearable devices are becoming more common and popular in the field of elderly healthcare. These wearable devices aids remote monitoring of elderly persons in their natural settings and provide real-time data for effective decision-making [22–24]. These wearable devices come in different forms such as:

- Fitness trackers
- Biometric clothing
- Smart watch
- Cardiovascular measurement units
- Blood oxygen saturation monitoring
- ECG, PPG, GSR and body temperature sensors embedded in wearable devices.

3.4 Gamification technologies in Elderly care

AI-based games are considered useful in supporting elderly to enhance their cognitive, physical, and social life in different contexts. Researchers suggested different game exercises based on various methods including " Virtual reality game-based neurological therapy" and "serious game Farming" with AI based personalized systems [25–32]. These games can be played at different levels with relative scoring mechanism to keep the elderly users engaged and motivated.

3.5 Robotic systems

Robots of various types are also being used in elderly healthcare environments. These robots serve different purposes ranging from providing simple companionship to assisting in complex tasks such as dispensing medicines at specified times, assistance in lifting heavy items, providing assistance to issue reminders and alerts with accompanying healthcare instructions of several different types [2, 33–38]. Robotic systems can be classified as:

- Medication management Robotic systems
- Robot Companion - Pet and entertainment robots
- Interactive and communicative robots
- Humanoid robots

3.6 AI for privacy protection of elderly App users

Information security and privacy are of vital importance for everyone including elderly. Privacy of elderly people's healthcare data is discussed as an important issue. A shared responsibility model based on algorithms is suggested with the claims to support ambient assisted living elderly App users in smart cities through cognitive offloading [39].

3.7 Ethical aspects of AI technologies for elderly and healthcare providers

The issue of ethical aspects of AI technologies for elderly healthcare can affect many users, including elderly, caregivers, care provider's management, and system engineers. Hence, researchers suggest developing artificial morality, to implement moral capacity in artificial systems in general, and to discuss them with respect to an assistive system in geriatric care which is capable of moral learning [8, 40].

4 DISCUSSION

Elderly healthcare is a crucial issue for healthcare providers due to the increase in ageing population globally. AI based technologies are mainly used as intelligent systems to simulate human intelligence and to consistently improve their performance based on the data collected from elderly patients in different contexts. The concept of

AI was proposed by Alan Turing in 1950's. Since, then AI technology has experienced evolution, "Non-intelligent Dialogue Robot (1950-1960), Speech Recognition (1980-1990), and Deep Learning & Big Data (2000-2010). AI also covers areas such as Image Recognition, Virtual Agents, Decision Management, Text Analytics and Natural Language Processing (NLP), Emotion Recognition and Marketing Automation" [9].

The research findings suggest that the AI can enable a predictive, personalized, preventive, inspiring and participatory elderly healthcare environment. This research work puts forth the important themes for elderly healthcare applications derived from reviewed literature such as Smart homes for elderly, AI-based health monitoring technologies, Wearable devices, Gamification technologies in elderly care, Robotic systems, AI for privacy protection of elderly app users and Ethical aspects of AI technologies for elderly. The empirical evidence shows positive health outcomes of using AI-based health solutions for elderly. For instance, A smart home system comprising hardware and software system includes intelligent control subsystem, intelligent monitoring subsystem, and intelligent protection subsystem [17]. A Smart home equipped with smart furniture and other assistive sensor-based technologies empowers the elderly resident to live an independent and autonomous life for longer time-period with guided supervision. However, some researchers also show concern regarding the risks of AI in elderly care which comprise, "the depersonalization of care through algorithm-based standardization, the discrimination of minority groups through generalization, the dehumanization of the care relationship through automatization, and the disciplination of users through monitoring and surveillance" [8].

Remote health monitoring, solutions allow elderly to continue to live in their home environment while allowing healthcare personnel to monitor important physiological signs of their patients in real time, assess health conditions and provide feedback from distant facilities [24]. For instance, ML, NLP, and sensor-based assistive technologies have enabled the development of applications for activity recognition, fall detection, and remote health monitoring to facilitate disease prevention, diagnosis, and health management for elderly persons. Data received from accelerometers and gyroscopes embedded in user devices, and bio signals like heartbeat or brain activity can be also processed to detect and signal cognitive states of elderly, such as being stressed. Healthcare workers can use this information to provide quick feedback to elderly users [41].

The combination of non-invasive IoT-wearable devices enabled by AI are recommended to handle ever increasing ageing population's problems by monitoring elderly people remotely while performing their routine activities [22]. These devices include but are not limited to wearable sensors, actuators and modern communication and information technologies such as smart watches, fitness trackers, biometric clothing, and cardiovascular measurement units. These sensor based devices are capable of measuring physiological signs such as electrocardiogram (ECG), electromyogram (EMG), heart rate (HR), body temperature, electrodermal activity (EDA), arterial oxygen saturation (SpO2), blood pressure (BP) and respiration rate (RR) [18, 19]. These efficient and cost-effective devices assist the elderly in self health management activities and at the same time healthcare workers can gather useful health data for analytical and clinical purposes. This data can be analyzed to make timely diagnosis and treatment suggestions for fitness and other medical procedures.

Generally, Robotics is considered as an innovative technology to redesign the elderly healthcare utilizing the AI-based automation. Robots are used in elderly care for different purposes. Different categories of robotic systems include the medication management robotic systems, the interactive and communicative robots, pet robots and entertainment game playing robots. Robotic assistive technologies are even proposed for elderly gait training. However, these robotic systems are still far from acting as full fledge assistive healthcare workers due to several technical challenges. AI-based games are also becoming popular among elderly community. These games are developed for several purposes including assisting elderly to enhance their cognitive skills, to conduct physical exercises and reduce loneliness. Commercial companies such as Neuro Rehab VR [32] provides a virtual reality based game. This game-based experience assists elderly patients undergoing physical therapy following a stroke, brain injury or spinal cord injury or patients who suffer from neurodegenerative diseases [1].

Information security and privacy are very important concerns regarding use of digital tools and online applications for everyone and elderly healthcare is not an exception [39, 42, 43]. Findings suggest that a significant amount of personal information and behavioral data is collected through data driven smart applications. However, majority of reviewed articles did not discuss anything specifically regarding privacy concerns of elderly while being a subject of above-mentioned technologies. Only one article by Elahi et al [39] proposed a shared responsibility model based on algorithms to support ambient assisted living elderly App users in smart cities. This situation shows that there is a general lack of studies regarding the AI-based solutions to alleviate information security and privacy concerns of elderly. Another area largely ignored is the discussion of ethical aspects of AI technologies for elderly, healthcare workers, system engineers, and health managers. The collection of huge volumes of behavioral data, continuous monitoring of elderly through different devices and assistive technologies requires that special attention should be given to the development of ethical guidelines in every context e.g. developing artificial morality [8, 40].

5 CONCLUSION AND FURTHER RESEARCH

The outcomes in this study suggest that the traditional healthcare systems are falling short to provide solutions for sharply increasing elderly community globally. The current geriatric care scenarios demand AI based automated monitoring systems and comprehensive data capturing and analytical systems to promote health assessment, safety, and health management. The role of AI based tools and applications for elderly healthcare systems could be a game changer to improve the quality of life for elderly people. However, this will require that great attention is paid to the development of both clinical geriatric systems and the associated ethical factors for the AI based technologies. While the disruptive AI technologies aim to enhance the independent living by promoting empowerment and well-being, it is of utmost importance to consider the impact of AI based technologies on the changing relationships between elderly and caregivers. Future research should focus on exploring

initiatives to address information security, privacy, and ethical concerns of AI-based healthcare technologies for supporting elderly community.

REFERENCES

[1] S. Iqbal and P. Jokela, "Innovative Approaches in Health Care: Observational Study at an Elderly Care Unit in Japan," 2019.

[2] S. Iqbal, P. Jokela, T. Hammar, and A.-L. Nilsson, "Sustainable Healthcare Systems. A holistic perspective on the use and impact of medication management robots in home healthcare," *Scandinavian Journal of Information Systems*, vol. 33, no. 2, p. 6, 2021.

[3] A. Ho, "Are we ready for artificial intelligence health monitoring in elder care?," *BMC geriatrics*, vol. 20, no. 1, pp. 1–7, 2020.

[4] G. Vial, "Understanding digital transformation: A review and a research agenda," *Managing Digital Transformation*, pp. 13–66, 2021.

[5] S. Kraus, F. Schiavone, A. Pluzhnikova, and A. C. Invernizzi, "Digital transformation in healthcare: Analyzing the current state-of-research," *Journal of Business Research*, vol. 123, pp. 557–567, 2021.

[6] S. Vyas *et al.*, "Investigation of Diabetes Care in Elder Individuals Using Artificial Intelligence," *Journal of Food Quality*, vol. 2022, 2022.

[7] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative research in psychology*, vol. 3, no. 2, pp. 77–101, 2006.

[8] G. Rubeis, "The disruptive power of artificial intelligence. Ethical aspects of gerontechnology in elderly care," *Archives of Gerontology and Geriatrics*, vol. 91, p. 104186, 2020.

[9] C. Qi and J. Lyu, "Applications of artificial intelligence in children and elderly care and short video industries: cases from Cubo Ai and Tiktok," in *International Conference on Computer Application and Information Security (ICCAIS 2021)*, SPIE, 2022, pp. 501–505.

[10] J. Rong, X. Ji, X. Fang, and M.-H. Jee, "Research on Material Design of Medical Products for Elderly Families Based on Artificial Intelligence," *Applied Bionics and Biomechanics*, vol. 2022, 2022.

[11] D. D. Onthoni and P. K. Sahoo, "Artificial-Intelligence-Assisted Activities of Daily Living Recognition for Elderly in Smart Home," *Electronics*, vol. 11, no. 24, p. 4129, 2022.

[12] J. I. Méndez, O. Mata, P. Ponce, A. Meier, T. Peffer, and A. Molina, "Multi-sensor system, gamification, and artificial intelligence for benefit elderly people," in *Challenges and trends in multimodal fall detection for healthcare*, Springer, 2020, pp. 207–235.

[13] D. Ganesh, G. Seshadri, S. Sokkanarayanan, S. Rajan, and M. Sathiyanarayanan, "Iot-based google duplex artificial intelligence solution for elderly care," in *2019 International Conference on contemporary Computing and Informatics (IC3I)*, IEEE, 2019, pp. 234–240.

[14] N. K. Suryadevara, S. C. Mukhopadhyay, R. Wang, and R. K. Rayudu, "Forecasting the behavior of an elderly using wireless sensors data in a smart home," *Engineering Applications of Artificial Intelligence*, vol. 26, no. 10, pp. 2641–2652, 2013.

[15] A. Hazzam *et al.*, "Implementing ambient assisting technologies in elder-care: Results of a pilot study," *Synesis: A Journal of Science, Technology, Ethics, and Policy*, vol. 2, no. 1, pp. G27–G38, 2011.

[16] M. Chan, E. Campo, D. Estève, and J.-Y. Fourniols, "Smart homes—current features and future perspectives," *Maturitas*, vol. 64, no. 2, pp. 90–97, 2009.

[17] Q. Ji, "The design of the lightweight smart home system and interaction experience of products for middle-aged and elderly users in smart cities," *Computational intelligence and neuroscience*, vol. 2022, 2022.

[18] M. Elbattah and O. Molloy, "Clustering-aided approach for predicting patient outcomes with application to elderly healthcare in Ireland," in *Workshops at the Thirty-First AAAI Conference on Artificial Intelligence*, 2017.

[19] M. Nahian, T. Ghosh, M. N. Uddin, M. Islam, M. Mahmud, and M. S. Kaiser, "Towards artificial intelligence driven emotion aware fall monitoring framework suitable for elderly people with neurological disorder," in *International Conference on Brain Informatics*, Springer, 2020, pp. 275–286.

[20] H. Raza, "An IoMT enabled smart healthcare model to monitor elderly people using Explainable Artificial Intelligence (EAI)," *Journal of NCBAE*, vol. 1, no. 2, pp. 16–22, 2022.

[21] Y. Wang, X. Wang, L. Jin, and X. Wei, "X-ray film under artificial intelligence algorithm in the evaluation for nursing effect of gamma nail internal fixation in elderly patients with intertrochanteric fracture of femur," *Computational and Mathematical Methods in Medicine*, vol. 2021, 2021.

[22] J. B. Awotunde, S. A. Ajagbe, and H. Florez, "Internet of Things with Wearable Devices and Artificial Intelligence for Elderly Uninterrupted Healthcare Monitoring Systems," in *International Conference on Applied Informatics*, Springer, 2022, pp. 278–291.

[23] S. Iqbal and P. Jokela, "Exploring Smart Watch Ecosystem Value Co-creation Experience: A Qualitative Case Study," in *SPWID 2022: The Eighth International Conference on Smart Portable, Wearable, Implantable and Disability-oriented Devices and Systems*, 2022, pp. 1–7.

[24] S. Majumder, T. Mondal, and M. J. Deen, "Wearable sensors for remote health monitoring," *Sensors*, vol. 17, no. 1, p. 130, 2017.

[25] S.-J. Eun, E. J. Kim, and J. Kim, "Artificial intelligence-based personalized serious game for enhancing the physical and cognitive abilities of the elderly," *Future Generation Computer Systems*, 2022.

[26] J. Li, X. Xu, T. P. Pham, Y.-L. Theng, N. Katajapuu, and M. Luimula, "Exergames designed for older adults: a pilot evaluation on psychosocial well-being," *Games for health journal*, vol. 6, no. 6, pp. 371–378, 2017.

[27] J. Li, M. Erdt, J. C. B. Lee, H. Vijayakumar, C. Robert, and Y.-L. Theng, "Designing a digital fitness game system for older adults in community settings," in *2018 international conference on cyberworlds (CW)*, IEEE, 2018, pp. 296–299.

[28] M.-H. Lu, W. Lin, and H.-P. Yueh, "Development and evaluation of a cognitive training game for older people: a design-based approach," *Frontiers in psychology*, vol. 8, p. 1837, 2017.

[29] O. Korn, L. Buchweitz, A. Rees, G. Bieber, C. Werner, and K. Hauer, "Using augmented reality and gamification to empower rehabilitation activities and elderly persons. a study applying design thinking," in *International Conference on Applied Human Factors and Ergonomics*, Springer, 2018, pp. 219–229.

[30] D. O'Connor, L. Brennan, and B. Caulfield, "The use of neuromuscular electrical stimulation (NMES) for managing the complications of ageing related to reduced exercise participation," *Maturitas*, vol. 113, pp. 13–20, 2018.

[31] M. C. Shake, K. J. Crandall, R. P. Mathews, D. G. Falls, and A. K. Dispennette, "Efficacy of Bingocize®: A game-centered mobile application to improve physical and cognitive performance in older adults," *Games for health journal*, vol. 7, no. 4, pp. 253–261, 2018.

[32] "Physical Therapy Virtual Reality System," *Neuro Rehab VR*, 2019. https://www.neurorehabvr.com (accessed Oct. 10, 2019).

[33] P. Rantanen, T. Parkkari, S. Leikola, M. Airaksinen, and A. Lyles, "An in-home advanced robotic system to manage elderly home-care patients' medications: A pilot safety and usability study," *Clinical therapeutics*, vol. 39, no. 5, pp. 1054–1061, 2017.

[34] A. S. Gessl, S. Schlögl, and N. Mevenkamp, "On the perceptions and acceptance of artificially intelligent robotics and the psychology of the future elderly," *Behaviour & Information Technology*, vol. 38, no. 11, pp. 1068–1087, 2019.

[35] A. Vercelli, I. Rainero, L. Ciferri, M. Boido, and F. Pirri, "Robots in elderly care," *DigitCult-Scientific Journal on Digital Cultures*, vol. 2, no. 2, pp. 37–50, 2018.

[36] M. E. Pollack *et al.*, "Pearl: A mobile robotic assistant for the elderly," in *AAAI workshop on automation as eldercare*, AAAI, 2002, Edmonton, Alberta, Canada, 2002.

[37] A. Tapus, M. J. Mataric, and B. Scassellati, "Socially assistive robotics [grand challenges of robotics]," *IEEE robotics & automation magazine*, vol. 14, no. 1, pp. 35–42, 2007.

[38] "Intuition Robotics - Cognitive AI Agents," *Intuition Robotics*, 2019. https://intuitionrobotics.com/ (accessed Oct. 10, 2019).

[39] H. Elahi, A. Castiglione, G. Wang, and O. Geman, "A human-centered artificial intelligence approach for privacy protection of elderly App users in smart cities," *Neurocomputing*, vol. 444, pp. 189–202, 2021.

[40] C. Misselhorn, "Artificial systems with moral capacities? A research design and its implementation in a geriatric care system," *Artificial Intelligence*, vol. 278, p. 103179, 2020.

[41] S. Hanisch, P. Arias-Cabarcos, J. Parra-Arnau, and T. Strufe, "Privacy-Protecting Techniques for Behavioral Data: A Survey," *arXiv preprint arXiv:2109.04120*, 2021.

[42] J. Ostheimer and S. Iqbal, "Privacy in online dating: does it matter?," *ICCSP 2019, January 19–21, 2019, Kuala Lumpur, Malaysia*, Jan. 2019.

[43] S. Iqbal, "Design and Emergence of a Pedagogical Online InfoSec Laboratory as an Ensemble Artefact," *Journal of Information Systems Education*, vol. 27, no. 1, p. 17, 2016.