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SMART LIVING TECHNOLOGIES IN THE CONTEXT OF IMPROVING THE QUALITY OF LIFE FOR OLDER PEOPLE: THE CASE OF THE HUMANOID RUDY ROBOT

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Abstract: *Smart living is an essential dimension of an ageing society because one of its measures includes living conditions (health, safety, housing). Many technological solutions are designed to satisfy the needs of older people living in cities. Humanoid robots are one of the technologies that can significantly improve the quality of life in older adults. The Rudy Robot is an example of a robot adapted to the needs of older people. The conducted research aimed to gain knowledge about the potential future use of the humanoid Rudy Robot by older adults in the context of smart living. The study mainly aimed to identify the robot's most important functionalities that could improve older adults' quality of life based on a literature review. In addition, the Rudy Robot was rated according to the most important criteria for evaluating the robot. The paper also examined whether age, sex, education and place of residence affect the assessment of the Rudy Robot technology. It should be noted that this technology is not available in Poland but has become known due to television, the Internet, etc. Respondents received a description of this technology, examples of use, and links to literature and films together with the questionnaire; thus, they knew what the Rudy Robot was and its characteristics, possibilities and potential.*

Keywords: *smart living technologies, ageing society, older people, robot, technology assessment*

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INTRODUCTION

The ubiquitous advancement of technology worldwide is accompanied by the dynamic development of cities. Increasingly progressive technological development and its greater awareness provide people with many opportunities for a safer, healthier and, generally, better life (Bibri & Krogstie, 2017; Nazarko, 2017). Winkowska, Szpilko & Pejic (2019) indicated that the growing migration of people from the countryside to cities is the reason for the perpetual development of the latter. Such development necessitates taking an interest in the smart city concept. It is a relatively new idea that focuses on implementing new technologies in urban space and an intelligent and sustainable way of managing a city to improve functioning and inhabitants' quality of life (Baraniewicz-Kotasińska, 2017). Taking a holistic approach, Szpilko (2020) argued that people and their needs were the most critical elements in the concept of smart cities, whereas technology had a supporting role. A smart city aims to achieve a high quality of life for its inhabitants and sustainable economic growth using social capital, communication and information technologies, human resources, and also the concept of smart management with community participation (Caragliu, Bo, Del, Nijkamp, 2009). At their heart, smart solutions for cities should be designed based on such factors as residents' preferences (regardless of their age), social interactions and cooperation (Szpilko, 2020). Six main smart city areas were distinguished in a report published by the Vienna University of Technology (2007). They are listed in the table below, together with the characterising factors (Table 1).

Table 1. Smart City Areas with Characteristic Factors.

Smart City Area	Characteristic Factors
1. **Smart Economy** (Competitiveness)	entrepreneurship, productivity, labour market flexibility, innovative spirit, international embeddedness
2. **Smart People** (Social and Human Capital)	flexibility, creativity, participation in public life, level of qualification, social and ethnic plurality
3. **Smart Governance** (Participation)	transparent governance, public and social services, participation in decision-making.
4. **Smart Mobility** (Transport and ICT)	local accessibility, availability of ICT infrastructure, (inter)national accessibility
5. **Smart Environment** (Natural Resources)	pollution, environmental protection, attractivity of natural conditions, sustainable resource management
6. **Smart Living** (Quality of Life)	cultural facilities, health conditions, individual safety, housing quality, education facilities, social cohesion, tourist attraction

[Source: Vienna University of Technology, Smart Cities Ranking of European medium-sized cities, 2007.]

As noted by Gudowsky et al. (Gudowsky, Sotoudeha, Caparia, & Wilfing, 2017), cities in the future should be adapted to the needs of an ageing society. In 2019, the world had 703 million persons aged 65 years and more, and the number of older adults is projected to double to 1.5 billion in 2050 (United Nations, 2019; Ejdys, & Halicka, 2018). According to the OECD report on data from the Aging in Cities (OECD, 2015), 43.2% of all older adults lived in cities in the OECD region in 2015. This means that the ageing trend of the population will become more prominent. Therefore, many facilities and technologies will have to be adapted for older adults. In the context of an ageing society, it is important to take a closer look at smart living, which relates to the city's level and quality of life (Stawasz, & Sikora-Fernandez, 2015; 2016). Experts interviewed for The Smart Living Report stated that smart living aims to create a safe, effective, energy efficient, personalised and better-managed living space (for home, work, urban living, and transportation) (Infuture Hatalska, 2019).

Due to age, older adults have various health issues related to mobility, movement and general fitness, memory and others. Smart living can be helpful with technologies supporting their functioning, e.g., technologies supporting daily independent functioning at home (reminder systems, special prams/devices facilitating independent movement, intelligent home building elements). With today's high level of technological development, the so-called smart environments (present in smart living) can be very useful for older people. Such systems can include data-collecting from various sensors designed to record the person's behaviour at home or uninterruptedly monitor their health (Tannou, Lihoreau, Gagnon-Roy, Grondin, Bier, 2022). In addition to intelligent living environments, simple individual solutions, such as smart door locks or an innovative doorbell with a built-in camera (eliminating the need to get up and walk to the door), can be an excellent example of smart living technologies for older adults (Tech-Enhanced Life, 2021). As already mentioned, the health of older adults requires continuous monitoring and medications must be taken regularly. Various devices (e.g., smart pillboxes) are developed to facilitate adherence to the schedule. Such pillboxes may, for example, make a noise when it is time to take medication or even send remote alerts to family members and caregivers (The Senior List, 2022). Technologies that use the IoT (Internet of Things) concept have been emerging in increasing numbers recently and can also be used in the care of older adults. Chan et al. proposed an activity monitoring system studying older people's behaviours and alerting caregivers in case of a fall (Chan, Campo, Bourennane, Bettahar, & Charlon, 2014). The smart bracelet proposed by Angelini et al. (Angelini, Nyffeler, Caon, Jean-Mairet, Carrino, Mugellini, & Bergeron, 2013) tracks the wearer's health status and reminds them of scheduled tasks or medications.

As many older adults require assistance, their growing numbers mean an increase in the demand for caretakers (Brooke & Jackson, 2020; Cajita, Hodgson, Lam, Yoo, Han, 2018). Humanoid robots can be a useful technology substituting humans. Furthermore, as living conditions (health, safety, housing) are a measure of smart living, robots can be an excellent example of smart living technology. Nowadays, there are several different humanoid robots on the market that are designed to care for people. One example is the Pepper Robot (Softbank Robotics, 2021), which is 120 cm tall and is designed to interact with humans. It can establish contact with a human being through conversation and using a touch screen. The robot is equipped with several touch sensors, microphones and diodes. It also has perception modules necessary for recognition and interaction.

Another good example of a robot designed to care for and interact with people is Care-O-Bot 3 (Fraunhofer IPA, 2022). This humanoid robot can be used for various purposes, such as help and support in caring for older adults at home and in nursing homes, cleaning, or general help. It has an arm and a gripper for manipulating objects, a tray to carry and transfer objects, and a flexible torso allowing butler-like gestures (Joseph, Christian, Abiodun, & Oyawale, 2018).

Thirdly, a Cody Robot (Robots, 2022) is a humanoid nurse tasked with helping people with a disability. It was designed to support research into human–robot interaction. Cody is equipped with an omnidirectional mobile base and compliant arms and can lift its torso using a linear actuator.

The Rudy Robot is yet another example of a humanoid robot that can support older adults in their daily life due to its structure, functions and possibilities. The main goal of the article and the research was to obtain knowledge on the future potential use of an exemplary robot — the Rudy Robot — by older adults in the context of smart living. The Rudy Robot for the care of older adults can be an extremely useful technology that fits smart living and smart homes. The robot can make older adult's life easier and more enjoyable as it has many different uses for daily functioning. This robot provides 24/7 access to emergency services. The Rudy Robot may remind a person to take their medicine and dispense and dose them (Robotics Business Review, 2017). Additionally, Rudy Robot offers Remote Patient Monitoring (RPM), enables social interactions, can call for help, help find lost items and even move things that an older adult cannot carry (Martinez-Martin, Escalona, Cazorla, 2020; INF Robotics, 2022). It can encourage older people to engage in activities, such as games, music and dancing, to keep them physically and mentally active. Overall, the Rudy Robot can also be a good companion and friend, helping to lessen the feeling of loneliness (Martinez-Martin, Escalona, Cazorla, 2020).

Therefore, the Rudy Robot can be extremely helpful for older adults. The constant and dynamic technological development results in a greater supply of advanced robots offering even more possibilities and innovative solutions. A significant contribution can be made by the advancement of artificial intelligence used in robots designed to care for older adults. Technologies for smart living and smart homes are to facilitate daily functioning. Such technologies can offer greater comfort and increase the living standard in general, while for older adults, such solutions can significantly facilitate everyday life at home (e.g., for those living independently). Therefore, robots can be an ideal technology for smart living and smart homes. A literature review found some work describing the potential of exemplary robots in improving the quality of urban life for older people (Martinez-Martin, Pobil, 2017; Görer, Salah, Akin, 2016; Martinez-Martin, Costa, Cazorla, 2019; Wilson, Pereyda, Raghunath, de la Cruz, Goel, Nesaei, Minor, Schmitter-Edgecombe, Taylor, Cook, 2019; RAMCIP Project, 2022). The existing robotic technologies for elderly care were reviewed, analysing their benefits for older people (Martinez-Martin, Pobil, 2017), e.g., an autonomous robotic exercise teacher for older people (Görer, Salah, Akin, 2016) or a robot that suggests and monitors physical activity (Martinez-Martin, Costa, Cazorla, 2019). One article (Wilson, Pereyda, Raghunath, de la Cruz, Goel, Nesaei, Minor, Schmitter-Edgecombe, Taylor, Cook, 2019) describes the integration of robots into intelligent environments to provide more interactive support for older adults with functional limitations and the RAMCIP project aims to research and develop real solutions for assistive robotics for older people (RAMCIP Project, 2022). Also, research is also emerging on public acceptance of these technologies (Beer, Prakash, Mitzner, Roger, 2011; Cajita, Hodgson, Budhathoki, Han, 2017; Ezer, Fisk, Rogers, 2009; Langer, Ronit Feingold-Polaka, Mueller, Kellmeyer, Levy-Tzedek, 2019). E.g., a literature review (Beer, Prakash, Mitzner, Rogers) identified various features of the robot that may influence acceptance. In contrast, another article conducted a survey to explore older people's expectations of domestic robots and their relationship to robot acceptance (Ezer, Fisk, Rogers, 2009). Furthermore, guidelines for trust-building and a method for measuring trust in human-robot interactions in rehabilitation were proposed (Langer, Ronit Feingold-Polaka, Mueller, Kellmeyer, Levy-Tzedek, 2019). However, it is also necessary to investigate how these technologies are viewed by the public to determine the most important features/functions of robots (Ejdys, Halicka, 2018). It is also worth investigating whether the age, sex, education and place of residence of the respondent impact the result of the technology assessment.

The article and research aimed to understand the potential future use of a robot by older people in the context of smart living. Additionally, the article also aimed to learn the public's evaluation of this technology in the context of various criteria. To date, no such studies have been conducted. As respondents find it easier to comment on a specific technology, the Rudy Robot was chosen as an example, and the questionnaire referred to it specifically. Together with the questionnaire, the respondents received a few photos of this robot, a description of its functionality, examples of its use, links to literature, etc. Therefore, respondents knew what the Rudy Robot was and understood its capabilities. However, it should be emphasised that most robots in the context of smart living have very similar properties. Thus, the study results can be generalised to all humanoid robots.

Humanoid robots are not yet widely used at the moment. In Poland, such robots are not yet available because of the price and fear of using new technologies. However, knowledge is spread through television, the Internet, etc. (INF Robotics, 2022; Robotics Business Review, 2017). In general, people do not trust new, unfamiliar technologies. However, it is a technology that has a great potential for further development, and given the demographic situation, it could be one of the key solutions to improve the quality of life of older people in the city (Arthanat, Wilcox, Macuch, 2019; Oh, Oh, Ju, 2019; Luxton & Riek, 2019). A paper (Arthanat, Wilcox, Macuch, 2019) has already explored the ownership of smart home technology among older people, their willingness to adopt SH (Smart Home) technology, and identified customer factors associated with technology adoption. Another article developed five robot design concepts and conducted interviews to assess preferences for the developed design concepts (Oh, Oh, Ju, 2019). Some researchers overviewed the applications of smart technologies in contemporary rehabilitation practice and research and presented trends and future opportunities in smart environments and smart mobile devices used by older people (Luxton & Riek, 2019).

In their previous research, the authors of this paper identified and described nine groups of technologies that improve the quality of life of older people (Halicka & Surel, 2021) and prepared a ranking of these technologies (Halicka & Kacprzak, 2021). The authors identified the most desirable group of technologies improving the quality of life of older people (Halicka, 2019) among current and future users, described humanoid robots in detail (Ejdys, Halicka, 2018), and identified the factors and their interrelationships that determine the attitude and future use of humanoids by older people in Polish society (Ejdys, Halicka, 2018).

METHODOLOGY

This research focused on obtaining information on the future use of the selected technology — the humanoid Rudy Robot — that facilitates urban life for older adults in the context of smart living. The article's main objective was to answer the following research questions: (1) What are the most important expected robot functionalities that facilitate the quality of life of older people in the context of smart living? (2) What are the most important criteria for evaluating a robot? (3) How was the Rudy Robot rated according to different criteria? (4) Does age affect the assessment of the analysed technology? (5) Does sex affect the assessment of the Rudy Robot technology? (6) Does education affect the assessment of the analysed technology? (7) Does the place of residence affect the assessment of the Rudy Robot? The respondents have not used this technology so far. Therefore, their answers were not based on experience but the information taken from the description attached to the questionnaire, literature, films, etc. The research process consisted of four main tasks presented in Fig. 1.

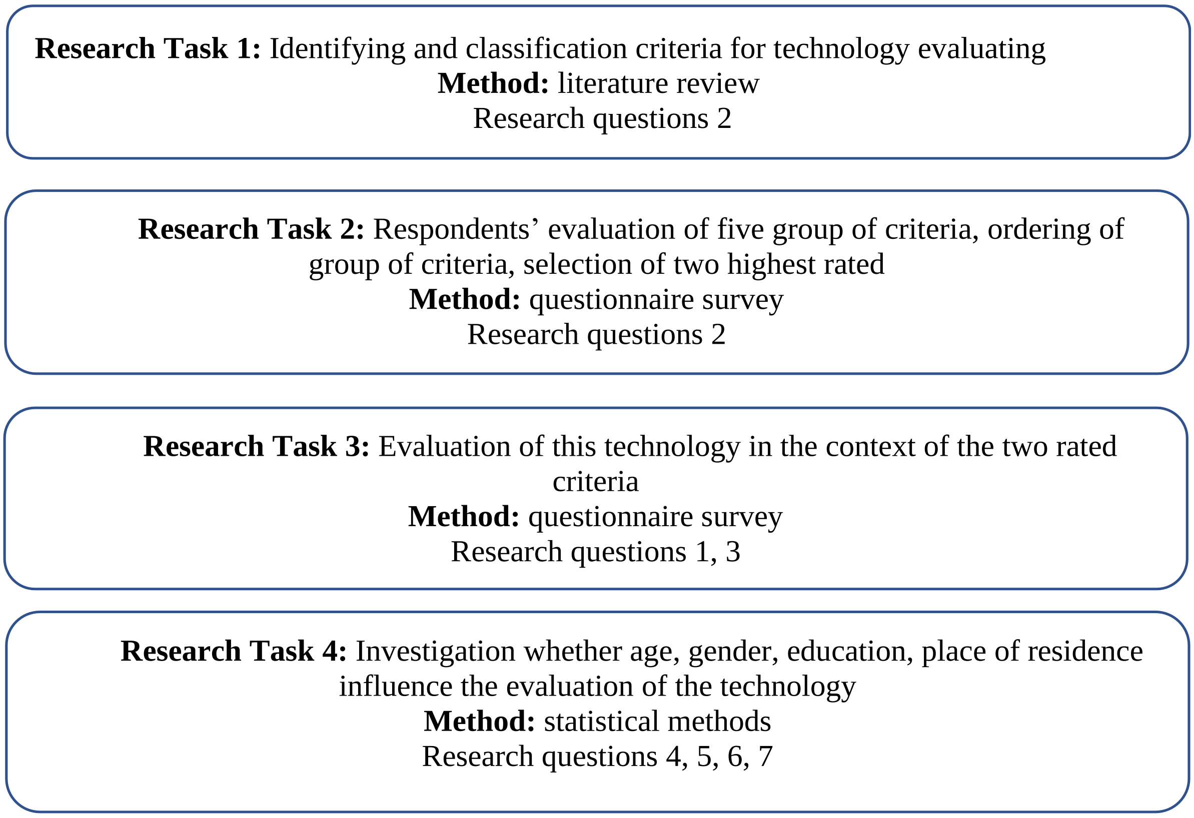

Figure 1. Tasks in the Research Process.
[Source: elaborated by the authors.]

As Fig. 1 demonstrates, the entire research process consists of four main tasks. The first task is to identify the criteria for the evaluation of the Rudy Robot. The set of criteria is taken from the literature and is rather general. This makes it possible to evaluate and compare various technologies, not only the exemplary Rudy Robot.

Research is conducted by the authors to evaluate different technologies (e.g., wheelchairs: Wheelie7, smart bracelet) that can improve older people's quality of life in the context of smart living. In the future, the authors intend to develop a technology ranking and select the best technology that can be used by older adults and improves their quality of life. Additionally, the survey was also sent to potential manufacturers. In the next study, the authors will evaluate the technology from the perspective of a potential future manufacturer. Therefore, the set of criteria is rather general consciously. Also, respondents were asked to evaluate the criteria (the responses of users and producers may differ). The humanoid Rudy Robot has enormous potential for further development and is continuously improved, which necessitates the knowledge of criteria considered by potential technology users as the most significant for producers/technology developers to consider.

Based on the literature review (Halicka, 2020; Ejdys, 2020; Halicka, 2017), five main criteria groups for evaluating the Rudy Robot technology were selected: Competitiveness, Demand Criteria, Technical Criteria, Social and Ethical Criteria, and Ecological Criteria. Each group contains several key statements for respondents to consider. Five to seven criteria were identified in each group, making a total of 31.

Another task (Fig. 1) was to evaluate the individual five groups of criteria by the respondents, organise these groups and select the top two.

The third research step was the evaluation of the technology (the Rudy Robot) in the context of the two highest-rated criteria.

The last task was to investigate whether age, sex, education and place of residence impacted the technology (the Rudy Robot) assessment in the context of two criteria groups. It was checked how the Rudy Robot would be assessed by older adults in the context of the highest-rated groups of criteria. In the study, the research method was a diagnostic survey using the CAWI (*Computer-Assisted Web Interview*) survey technique. As the assessed technology was not widely used, the conducted research mainly concerned the robot's functionality, assessed based on information from the description attached to the questionnaire, literature, films, etc.

RESULTS

The survey was conducted in Poland at the turn of 2020 and 202, targeting people over 40. The representative research sample comprised 1152 respondents (citizens of all Polish voivodships).

The first assessed criterion was the competitiveness of the Rudy Robot. Over 22 % of respondents considered this criterion very important, and almost 13 % — important. More than 8 % assessed this criterion as very irrelevant. Detailed data on the assessment of the "Competitiveness" criterion are shown in Fig. 2.

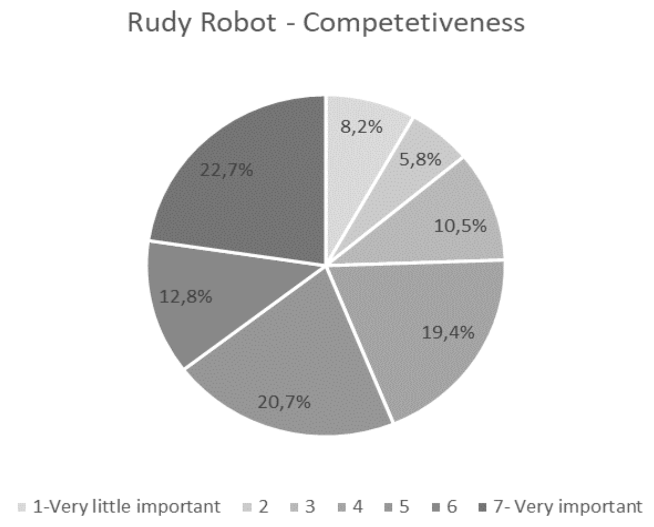

Figure 2. Assessment of the Competitiveness criterion for the Rudy Robot.
[Source: elaborated by the authors.]

Another criterion was “Demand”. More than half of the survey participants indicated it was important. Only 3.7 % of the respondents assessed it as of very little importance. Detailed information on the evaluation of the “Demand” criterion is shown in Fig. 3.

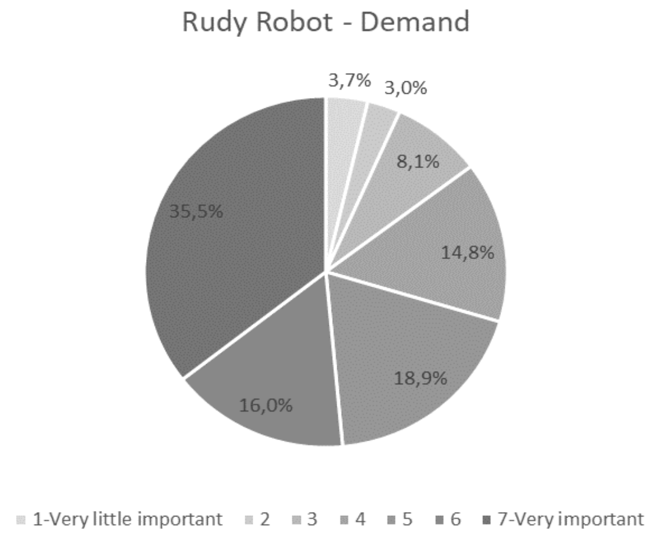

Figure 3. Assessment of the Demand criterion for Rudy Robot.
[Source: elaborated by the authors.]

The next important criterion was related to the. Almost 37 % of the respondents answered that the “Technical Criteria” of the Rudy Robot were very important, 18.1 % believed they were an important aspect, and a small proportion (4.8 %) of respondents thought this criterion was of very little or little importance. Detailed information on the technical criteria for the Rudy Robot technology is shown in Fig. 4.

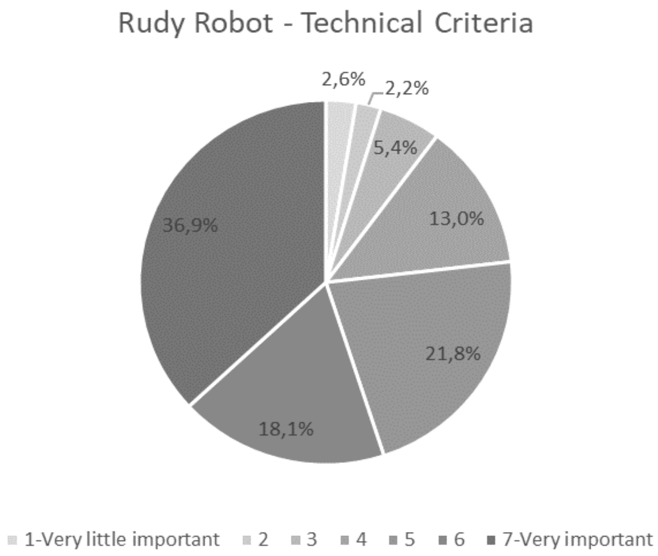

Figure 4. Assessment of the Technical Criteria for the Rudy Robot.
[Source: elaborated by the authors.]

The fourth criterion is related to social and ethical issues. A decidedly larger part of the respondents replied that social and ethical criteria were important for the technology of the Rudy Robot. About 16 % of the respondents considered this criterion to be of little importance, and 15.5 % had no opinion on this subject. Detailed information on the evaluation of this criterion can be found in Fig. 5.

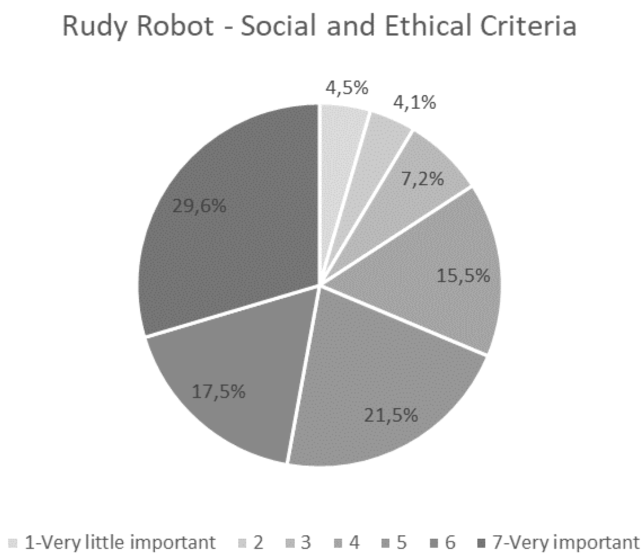

Figure 5. Assessment of the Social and Ethical Criteria for the Rudy Robot.
[Source: elaborated by the authors.]

The last criterion was related to ecological issues. More than 60 % of the respondents believed that ecological criteria were an important aspect of this technology. About 18 % decided that these issues were not important, and more than 15 % of the respondents did not have an opinion on the issue. More detailed data related to the assessment of this criterion are shown in Fig. 6.

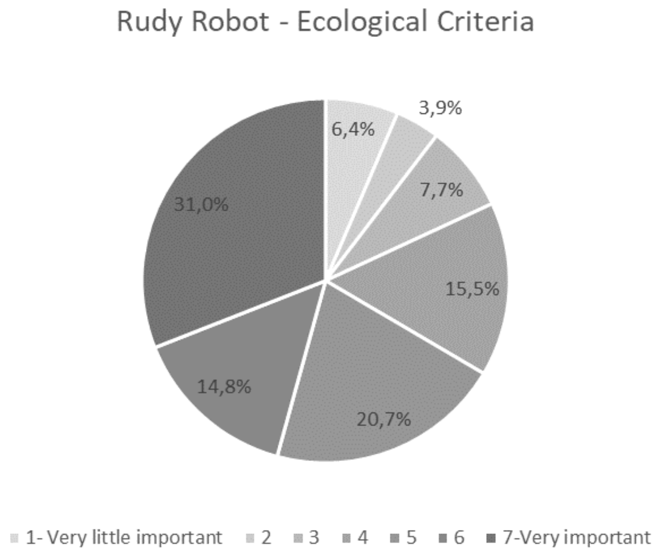

Figure 6. Assessment of the Ecological Criteria for the Rudy Robot.
[Source: elaborated by the authors.]

The following are the ratings of the five most important groups of the Rudy Robot technology criteria. Based on the above analyses and criteria evaluations, two groups of criteria with the highest scores can be distinguished: Technical Criteria (76.8 %) and Demand for Technology (70.4 %). The listed groups have been identified based on the analysis of the ratings given by the respondents. The highest rating was given to criteria which received the highest number of answers: 5 — rather important, 6 — important, 7 — very important. This indicated the high importance of a criterion.

Referring to the above analyses and conclusions, the most important criteria for the Rudy Robot gerontechnology were technical, demand, and social and ethical criteria. Indeed, technical criteria are a vital element when it comes to such advanced technology as the Rudy Robot. The technology is primarily designed for older adults, so it is not complicated to use or prone to failure. The demand for this technology is also an important factor, mainly because the use of such a robot could replace humans. People unable to take care of their parents/grandparents would thus be relieved of the duty. Therefore, for further analysis, the Rudy Robot technologies were considered in the context of the two most important criteria groups: technical (T) and demand (D). Five evaluation criteria were identified in the technical group (T1–T5) and eight — in the demand group (D1–D8) (Table 2).

According to the respondents, the Rudy Robot was rated the highest in terms of T5, which means a very large potential for further improvement of this technology (the average rating of the respondents was 5.20, with a rating scale from 1 to 7) (Fig. 7).

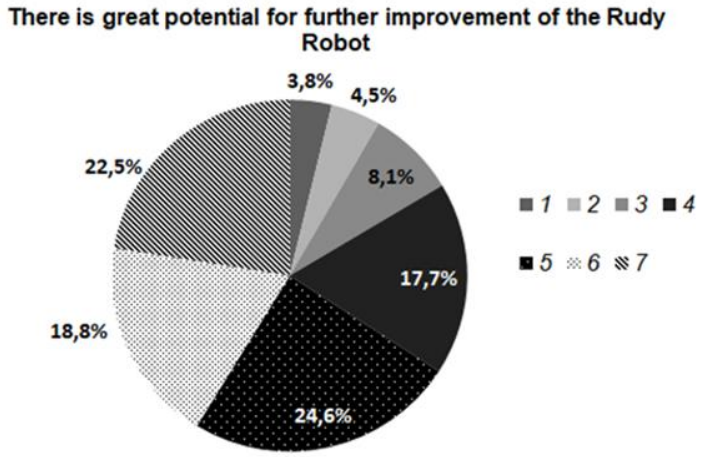

Figure 7. Evaluation of the Rudy Robot in the context of criterion T5 ("There is great potential for further improvement of the Rudy Robot").
[Source: elaborated by the authors.]

This technology was also highly rated in terms of D2 ("The use of the Rudy Robot will be a source of additional benefits for its potential users, which is unavailable in the case of using other solutions") and D3 ("The popularisation of the Rudy Robot is in line with the forecasts concerning the directions of technology development and the expectations of older adults"). Therefore, according to the respondents, the Rudy Robot will be a source of additional benefits for potential future users, unavailable in the case of using other solutions (the average rating of the respondents of 5.03, a rating scale from 1 to 7). Furthermore, the dissemination of the analysed technology is in line with the forecasts concerning the directions of technology development and the expectations of older adults (the average rating of the respondents was 5.05, with a rating scale from 1 to 7). The Rudy Robot was rated the lowest in terms of T2 and T3, indicating a high probability of serious technical problems during the development of this technology (the average grade of 3.65, with a rating scale from 1 to 7). According to the respondents, the use of the Rudy Robot depended on the use of hard-to-reach and expensive materials (the average grade of 3.80, with a rating scale from 1 to 7).

Respondents had not used the Rudy Robot technology but had ideas about humanoid robots. They also knew their expectations for an improved quality of life. Therefore, based on their expectations and knowledge taken from the Internet and films about humanoid robots, they were able to assess whether that technology would be able to meet their potential requirements and, thus, be a source of additional benefits for them. Based on this information, they could also determine the potential of the technology.

The next part of the study checked whether sex influenced the evaluation of the Rudy Robot technology. The critical level of significance was assumed at the level of $p = 0.05$. The non-parametric Mann-Whitney U test (Wilcoxon 1945; Mann, Whitney, 1947) was used to examine the influence of sex on the assessment of this technology in the context of dementia and technological criteria (Table 2).

When analysing Table 2, it can be noticed that significant differences depending on sex in the assessment of the Rudy Robot technology ($p < 0.05$) occur in the case of the criteria D1, D2, D3, D6 and T3. In the case of the remaining criteria, no significant differences were found between technology and sex assessment.

Table 2. Statistics of the Mann-Whitney U test for assessment of the Rudy Robot.

Acronym and the name of the criterion	Statistics of the Mann-Whitney U test		
	U	Z	p
D1: There is a need for the Rudy Robot on the part of institutions responsible for the care of older adults (e.g., nursing homes)	149718,5	2,61717	**0,008867**
D2: The use of the Rudy Robot will be a source of additional benefits for their users, which are unavailable through other solutions;	150871,5	2,41196	**0,015868**
D3: The popularisation of the Rudy Robot is in line with the forecasts concerning the directions of technology development and the expectations of older adults.	151300,5	2,33561	**0,019512**
D4: The Rudy Robot is characterised by higher ease of use and simplicity of operation compared to the technologies used so far	158312,5	1,08762	0,276762
D5: The use of the Rudy Robot is consistent with the previous habits of older adults	156965,0	1,32745	0,184361
D6: Changes in the environment make the Rudy Robot more attractive for older adults (e.g. due to new legal regulations, consumption trends, or technological standards)	150177,5	2,53548	**0,011230**
D7: The infrastructure necessary for the efficient use of the Rudy Robot is available.	164407,0	0,00294	0,997657
D8: Potential users are ready to pay the Rudy Robot in relation to the prices of the technologies used so far	162538,0	0,33558	0,737189
T1: The Rudy Robot is implemented and successfully used by older adults.	156430,5	1,42258	0,154859
T2: Serious technical problems are likely to occur during the development of the Rudy Robot	155349,5	-1,65982	0,096951
T3: The widespread use of the Rudy Robot depends on the use of hard-to-reach materials.	150382,0	-2,54284	**0,010996**
T4: The Rudy Robot can complement the solutions currently available on the market.	155358,5	1,61337	0,106665
T5: There is great potential for further improvement of the Rudy Robot.	157286,5	1,27023	0,204004

[Source: elaborated by the authors.]

It was then checked whether age, education and place of residence impacted the assessment of the analysed technology. The ANOVA Kruskal-Walls test was used to examine the influence of age, education, and place of residence on the evaluation of the Rudy Robot technology in terms of technological and demand-related criteria (Table 3).

Table 3. Statistics of the ANOVA Kruskal-Walls test for assessment of the Rudy Robot.

Acronym	Age		Education		Residence	
	T	p	T	p	T	p
D1	1.559	0.458	8.491	0.369	2.647	0.754
D2	7.867	**0.019**	1.779	0.619	10.155	0.071
D3	5.523	0.063	2.686	0.443	6.113	0.295
D4	6.434	**0.040**	5.997	0.1127	7.100	0.213
D5	0.55	0.759	8.901	0.306	5.820	0.324
D6	8.052	**0.018**	14.590	**0.002**	3.433	0.634
D7	1.652	0.438	8.369	0.385	6.861	0.231
D8	0.497	0.780	8.641	0.345	10.989	0.052
T1	0.809	0.667	14.906	**0.002**	13.900	**0.016**
T2	2.039	0.361	4.867	0.187	3.548	0.616
T3	1.666	0.435	2.886	0.409	6.856	0.231
T4	1.212	0.546	7.247	0.644	12.027	**0.034**
T5	2.515	0.284	2.684	0.443	9.759	0.082

[Source: elaborated by the authors.]

Based on Table 3, a 95% probability exists that age does not affect the assessment of the analysed technology ($p > 0.05$) in the context of all technological criteria (T1–T5) and the following demand criteria D1, D3, D5, D7 and D8. Fig. 8 shows the values of the acceptance responses for selected statements (statistically significant: D2, D4, and D6) regarding the evaluation of the Rudy Robot technology in terms of demand in three age groups. The analysis of Fig. 8 showed that the lowest acceptance of D2 was found among respondents aged 40–49 (the average grade of 4.8). On the other hand, the average rating was 5.05 among respondents over 60 years of age. Thus, people over 60 estimated that the use of the Rudy Robots would be a source of additional benefits unavailable from other solutions. Statements D4 ("The Rudy Robot is characterised by higher ease of use and simplicity of operation compared to the technologies used so far") obtained an average rating of 5.0 from people over 60 years of age. In turn, statement D6 was assessed by people over 60 at about 4.7. Thus, people in this age group assessed changes in the environment that made the Rudy Robot more attractive to older adults on average at 4.7 (on a scale of 1 to 7).

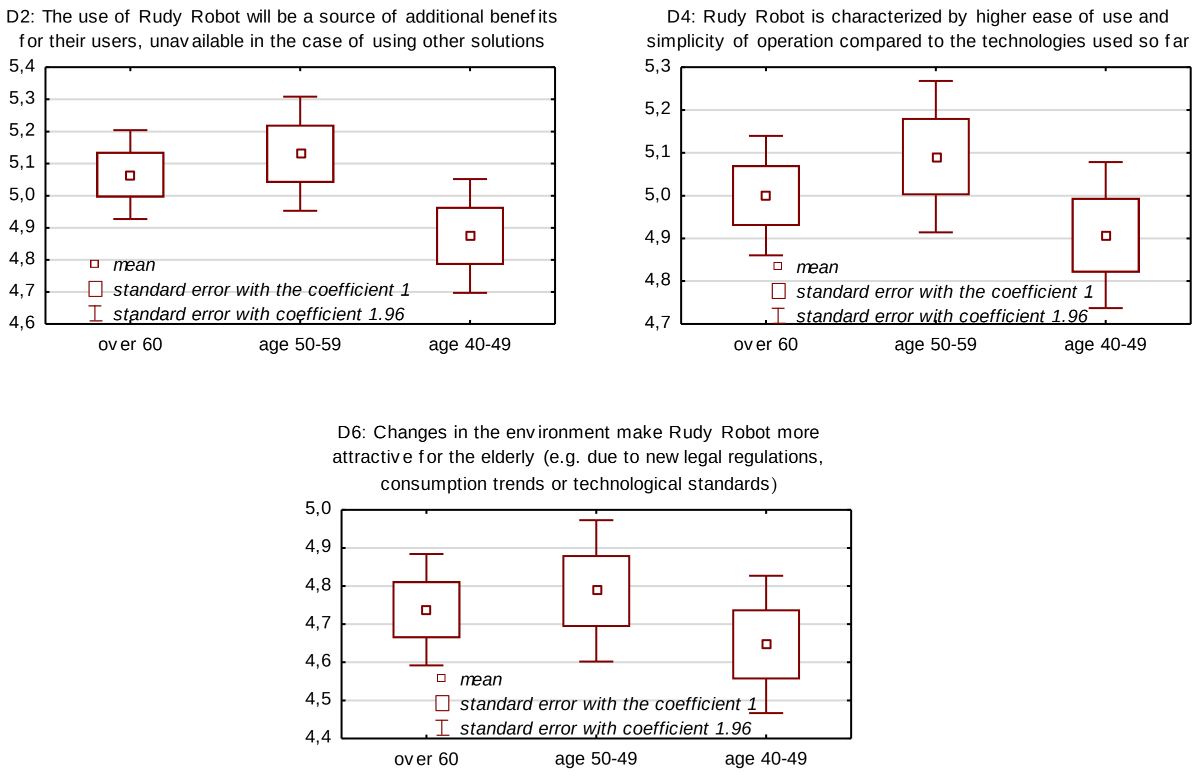

Figure 8. Technology Assessment of the Rudy Robot in terms of Demand in Three Age Groups.
[Source: elaborated by the authors.]

Based on Table 3, statistically significant differences ($p < 0.05$) were found depending on education in the case of the Rudy Robot technology assessment only in the context of the D6 and T1 criteria. However, it should be stated with a probability of 95% that the place of residence affects the assessment of the technology in terms of the criteria T1 and T4.

DISCUSSION OF THE RESULTS

The conducted research aimed to gain knowledge about the future use of robots by older adults in the context of smart living. The main assumption of the study was to look for answers to the following questions: (1) What are the most important expected robot functionalities that facilitate the quality of life of older people in the context of smart living? (2) What are the most important criteria for evaluating a robot? (3) How was the Rudy Robot rated according to different criteria? (4) Does age affect the assessment of the analysed technology? (5) Does sex affect the assessment of the Rudy Robot technology? (6) Does education affect the assessment of the analysed technology? (7) Does the place of residence affect the assessment of the Rudy Robot? As the assessed technology is not widely used, the research is mainly concerned with the robot's functionality, which is assessed on the basis of information taken from the description attached to the questionnaire, literature, films, etc. Robots that care for older people can be a very useful and life-changing technology. Technologies for smart living and smart homes are designed to simplify lives in a simple and smart way. Older people may have age-related challenges with independent everyday functioning at home, which can be resolved using technologies. It should be noted that the use of this type of technology should be simple and intuitive, especially for older adults. The research results demonstrated that the most important functionalities of the Rudy Robot that make life easier for older adults in the context of smart living are (Joseph, Christian, Abiodun, Oyawale, 2018):

- notification of family members about threats to the health or life of the older adult,
- the Remote Patient Monitoring (RPM) capability,
- remote monitoring of the situation at home,
- prevention of falls,
- detection of falls,
- non-contact emergency response,
- entertainment (telling jokes, dancing),
- interaction.

The Rudy Robot provides key information based on trends in the health and activity of older people. This information can help optimise treatment, improve performance indicators, and save costs.

Moreover, based on the conducted analyses, the respondents indicated that demand and technical were the most important criteria in assessing the Rudy Robot technology. The robot was rated the highest in the context of the potential for further improvement of this technology (an average of 5.20 on a scale from 1 to 7). On the other hand, the Rudy Robot was rated the lowest in terms of T2, indicating a high probability of serious technical problems occurring during the development of this technology (the average grade of 3.65 on a scale from 1 to 7).

Based on the analysis, a probability of 95 % exists that the respondent's sex does not affect the assessment of the Rudy Robot technology in the context of most demand and technical criteria, such as D4, D5, D7, D8, T1, T2, T4 and T5. The same 95% probability also exists that the respondent's age does not affect the evaluation of the technology in the technical aspect. Age affects the evaluation of the Rudy Robot technology only in terms of the following demand criteria D2, D4 and D6. Furthermore, it was found that the education of the respondent did not affect the assessment of most technical criteria. Education affects the assessment of this technology only in the context of the D6 and T1 criteria. In turn, the place of residence affects the assessment of the analysed technology in terms of the criteria T1 and T4.

In their future research, the authors intend to extend the research to a larger sample and other EU countries. They also intend to consider other technology assessment criteria, such as Technology Readiness Levels (TRL) or Life Cycle Analysis (S-LCA). The authors also plan to evaluate other life-enhancing technologies for older people (Wheelie7, smart bracelets) and would like to evaluate technologies from the perspective of a potential future manufacturer and develop a ranking of life-enhancing technologies for older people.

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