Archives of Gerontology and Geriatrics 116 (2024) 105137

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Developing a model to explain users' ethical perceptions regarding the use of care robots in home care: A cross-sectional study in Ireland, Finland, and Japan

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HIGHLIGHTS

- Surveys for home-care robots were conducted in Japan, Ireland, and Finland.
- The study built a model of ethical perceptions regarding the use of home-care robots.
- Our final model had explanatory power across countries with different backgrounds.
- This model can also be applied to explain ethical perceptions by attributes.

ARTICLE INFO

Keywords:
Ethical issues
Caregivers
Robotics
Assistive technology
Psychometric proprieties
Validation

ABSTRACT

To date, research on ethical issues regarding care robots for older adults, family caregivers, and care workers has not progressed sufficiently. This study aimed to build a model that universally explains the relationship between the use of care robots and ethical awareness, such as regarding personal information and privacy protection in home care. We examined data obtained from cross-sectional surveys conducted in Japan (n=528), Ireland (n=296), and Finland (n=180). We performed a confirmatory factor analysis by using responses to 11 items related to the ethical use of care robots. We evaluated the model based on the chi-square to degrees of freedom ratio, the comparative fit index, and the root mean square error of approximation. Subsequently, we compared the model with the Akaike's information criterion. Ten items were adopted in the final model. There were 4 factors in the model: 'acquisition of personal information', 'use of personal information for medical and long-term care', 'secondary use of personal information', and 'participation in research and development'. All factor loadings of the final model ranged between 0.63 and 0.92, which were greater than 0.6, showing that the factors had a high influence on the model. The final model was applied to each country; the fit was relatively good in Finland and poor in Ireland. Although the three countries have different geographies, cultures, demographics, and systems, this study showed that the impact of ethical issues regarding the use of care robots in home care can be universally explained by the same model.

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https://doi.org/10.1016/j.archger.2023.105137
Received 9 December 2022; Received in revised form 20 July 2023; Accepted 22 July 2023
Available online 25 July 2023

1. Introduction

The population of people aged 65 and over worldwide is projected to increase to more than 1.5 billion by 2050. Although the rate of ageing differs between countries, the population is ageing faster particularly in developed countries (Department of Economic and Social Affairs, 2019). Societal ageing causes problems such as an increase in the number of older adults with dementia and increase in the care burden of family caregivers and care staff (European Commission & Department of Economic and Financial Affairs, 2012; Fazio et al., 2020; United Nations Population Fund & HelpAge International, 2012). Japan, for example, is currently facing both a declining birth rate and an ageing population, making it difficult to secure caregivers (Ide et al., 2021).

In addition, it is estimated that by 2040, Japan will face a shortage of 690,000 caregivers (Ministry of Health, Labour and Welfare, 2021). As one of the solutions to the limited caregivers problem, the use of technologies such as robotics, artificial intelligence, and information and communication technology (ICT) is expected to support the older adult population by providing high-quality care. The Japanese government has prioritised caregiving, including assistance with long-term care functions such as transfers, mobility problems, toileting, patient monitoring and communications, bathing, and the collection and aggregation of data associated with those functions for care robots (Ministry of Health, Labour and Welfare, 2017).

Against this background, robots that provide care services are being developed (Abdi et al., 2018; Casey et al., 2020; Jordan, 2016; Inoue et al., 2021; Ismail & Lokman, 2017; Moyle et al., 2020; Wang et al., 2017). There are high expectations regarding the development and social implementation of assistive devices such as care robots that utilise ICT and sensing technologies (Fares et al., 2021; Japan Economic Research Institute, 2020; Qiu et al., 2021). However, thus far, the social implementation of care robots has not been sufficiently achieved (Granja et al., 2018; Schreiweis et al., 2019). The reason why this idea has not been socially implemented is related to not only the function and economic efficiency of care robots but also the presence of ethical issues. For example, when a robot takes care of a person, the person being cared for may experience a lack of warmth that accompanies a human caregiver (Coghlan, 2021; Pirni et al., 2021). Additionally, there is an argument that care robots will take over providing care, which has been performed by humans thus far, consequently taking jobs away from people. There are also problems that exist from the perspectives of privacy protection and security (Coeckelbergh, 2015; Palmerini et al., 2014; Sharkey & Sharkey, 2012; Stahl & Coeckelbergh, 2016).

These important ethical issues have been considered from the perspectives of both developers and users. One early example is the recommendation provided by the Danish Council of Ethics (2010) regarding the use of robots. The council intended that policy makers and stakeholders be aware of the recommendation when they apply regulations regarding protection of privacy and personal information, advertisement, and safety, and develop robots. Furthermore, the Institute of Electrical and Electronics Engineers (IEEE) has formulated a concept termed Ethically Aligned Design (IEEE Standards Association, 2018), which mainly deals with the ethical behaviours of researchers and developers of autonomous and intelligent systems. Ethically Aligned Design uses the concept of Responsible Research and Innovation (RRI) to promote innovation in research and development while addressing ethical issues. RRI has also been adopted by HORIZON 2020, a large research funding programme of the European Union (Horizon 2020, 2013).

While there has been a shift in focus towards co-design and co-production of care robots (Koutentakis et al. 2020), little progress has been made in research on ethical issues regarding care robots for older adults, family caregivers, and care workers. Regarding social implementation, multiple users' (not only older people themselves but also caregivers and family members) perspectives on ethical considerations should be assessed. Thus far, research on acceptance models for care robots has emphasised the importance of raising awareness regarding ethical issues (Rantanen et al., 2018; Stahl & Coeckelbergh, 2016; Vandemeulebroucke et al., 2018). The following models have already been constructed: the Almere model for assessing older adults' acceptance of assistive social agent technology (Heerink et al., 2010), a robot acceptance model for care (RAM-care model) focusing on care workers' individual context-dependent values behind care robot acceptance (Turja et al., 2020), and Alaiad and Zhou's (2014) structural model of determinants (SMD) involved in the introduction of care robots.

Suwa et al. (2020a) reported that care workers' ethical perceptions influenced their willingness to utilise care robots. Other possible factors that influence users' intention to use care robots include their cultural context, ageing rate, health care policy, and the level of development of technology and its social implementation in each country. The existing findings on these factors are conflicting. Some studies demonstrated that emotions towards robots vary by country (Coco et al., 2018; Suwa et al., 2020b), whereas another study suggested that the situations in Europe and Japan may not vary significantly (Nakada et al., 2021). Hence, there is no universal structure to explain the ethical perceptions that affect the willingness to use care robots across countries.

Therefore, this study aimed to build a model that explains the relationship between the use of care robots and ethical awareness, such as regarding personal information protection and privacy protection in home care. With the aim to construct a universal model that can universally explain the impact of ethical issues on the use of home-care robots beyond jurisdictions, we examined data obtained from surveys conducted in Japan, Ireland, and Finland, which have different geographies, cultures, demographics, and systems.

2. Methods

2.1. Survey

We developed a questionnaire examining the ethical issues that could potentially determine the willingness to use a home-care robot by older adults, family caregivers, and care workers. The questionnaire contained questions about respondents' sex, age group, attribute (older adults, family caregivers, and/or care workers), attitude towards homecare robots (I am open to the use of home-care robots; 'yes' or 'no'), and willingness to use home-care robots (Would you like to use a home-care robot at home when providing care for your family? Would you like to use a home-care robot at home when receiving care yourself?; 'yes', 'yes, to some extent', 'not really' or 'never'); additionally, there were 11 items related to the ethical use of care robots, such as personal information protection, privacy protection, and participation in research and development, wherein risks to the individual are assumed (Table 1). The respondents were asked to rate the 11 questionnaire items on a 4-point Likert scale (e.g. To what extent and from whom do you agree to obtain or use information about home-care robots? Scores ranged from 1 = 'disagree' to 4 = 'agree').

Data from the three countries were obtained between November 2018 and February 2019. In Japan, we systematically sampled the names of home-care offices from the list obtained from the government's Long-Term Care Insurance service information disclosure system. The questionnaires were distributed to older people, family caregivers, and home-care staffs through home-care offices. In Ireland, the respondents to the questionnaire were chosen based on the following criteria: 1) people aged 65 years or older who were using or may use health or social care services, 2) family caregivers of people aged 65 years or older who were using or may use services related to nursing care, and 3) home-care/health and social care professionals including nurses and care providers. In Finland, the respondents were potential users of home-care robots including adults aged 65 years or older, family caregivers of people aged 65 years or older, and home-care professionals. In all three countries, the respondents could send the answers either by postal mail or via the Internet. Details of the survey are provided in another report

Table 1
Factors and items in the ethical perception model regarding the use of care robots in home care.

Questionnaire		Factor	Item
1)	Home-care robots should be allowed to take photos or record videos that can identify the user, with their permission.	Acquisition of personal information	Identifiable photo and video
2)	Home-care robots should be allowed to take photos or record videos as long as the individual cannot be identified (e.g. by blurring images so that only silhouettes are shown or by converting images to text).		Unidentifiable photo and video
3)	Health care professionals should be allowed to use photos and videos recorded by home-care robots for clinical care and monitoring.	Use of personal information for medical and long-term care	Photos and videos for providing care and monitoring
4)	Health care professionals should be allowed to receive information on vital signs obtained by a home-care robot (e.g. blood pressure, body temperature, respiration, and pulse).		Notifying vital signs information
5)	Health care professionals should be allowed to use verbal information obtained by a home-care robot from the user.		Notifying voice information
6)	Health care professionals should be allowed to use information about the user's location obtained by a home-care robot.		Notifying location information
7)	The person whom you can trust (non-family member), if agreed by both parties, should be allowed to use information obtained by a home-care robot.		Use of information by non-family members
8)	Health care professionals should be allowed to use secondary information (e.g., blurred images and analysed data) collected by a home-care robot.	Secondary use of personal information	Secondary use of information by professionals
9)	Researchers should be allowed to use secondary information (e.g., blurred images and analysed data) collected by a home-care robot.		Secondary use of information by researchers
10)	I want to help other people and society by participating in the research and development of home-care robots.	Participation in research and development	Proactive participation in research and development
11)	I am open to using a home-care robot even during the research and development stage if it would benefit me.		Use during research and development

(Suwa et al., 2020b).

The Japanese definition of a robot is 'an intelligent machine that combines sensing, thinking/controlling, and acting technologies' (Robot Policy Study Group, 2006). Home-care robots employ robot technology aimed at helping users remain independent and reduce the burden on caregivers. Japan has been officially promoting the development and implementation of care robots (Ministry of Economy, Trade, and Industry, 2018). We considered potential respondents to not have seen or dealt with home-care robots before, and therefore, provided them with the following definition of home-care robots: 'Home-care robots come in many forms. The term "home-care robot" used in this survey refers to devices and systems that perform functions such as monitoring of older people and their surroundings and provide support for older people and their caregivers (including communication that enables interactive conversation, assistance with activities of daily living, and managing medications)'. Additionally, images and illustrations of home-care robots were included in the questionnaire form (Fig. 1).

A total of 1,004 respondents completed the questionnaire, with 528 from Japan, 296 from Ireland, and 180 from Finland. The respondents comprised not only people with a single attribute but also those with multiple attributes, such as being both an older adult and family caregiver. Data of respondents with multiple attributes were treated separately for each attribute. We excluded 118 answers from Ireland for the analysis because they did not answer the required number of questions. As a result, the total number of respondents whose data were analysed included 664 from Japan, 208 from Ireland, and 260 from Finland, with 1,132 people in total.

2.2. Analysis

We analysed the respondents' characteristics by country. As there were some missing responses, the imputation of missing values was performed based on a linear regression approach (SPSS, Inc., 2021). Descriptive statistics, such as mean values for each item, were confirmed before and after the imputation of missing data, and it was confirmed that imputation did not change the mean value and reduce the standard deviation.

Thereafter, a confirmatory factor analysis was performed. The responses to the 11 items were divided into four factors based on the following constructs: 'acquisition of personal information' (Items 1 and 2), 'use of personal information for medical and long-term care' (Items 3 to 7), 'secondary use of personal information' (Items 8 and 9), and 'participation in research and development' (Items 10 and 11). Model evaluation was based on the chi-square to degrees of freedom ratio (χ^2/df) ratio, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). Comparison between the models was performed using the Akaike's information criterion (AIC) (Burnham & Anderson, 2004; Finch, 2020). As a rule, around 2–5 is considered a reasonable value for the χ^2/df ratio. A CFI of 0.95 or higher is preferred, and a CFI of 0.9 or higher is acceptable. An RMSEA of less than 0.05 is good and less than 0.08 is acceptable. When we improved the model, we decided to focus on the χ^2/df ratio, the CFI, and the RMSEA criteria and chose a model with a smaller AIC. First, using data from all three countries, the basic model was evaluated according to the criteria, and then iteratively improved. For the final model, Pearson's correlation coefficient was calculated for the correlation between the factors. Additionally, Cronbach's alpha reliability coefficient was calculated to ascertain internal consistency between the items within the factors. We have confirmed that the χ^2/df ratio, CFI, and RMSEA of the final model meet the standards of Japan, Ireland, and Finland. Finally, we summed the scores of the sub-items for each factor obtained by confirmatory factor analysis and compared the descriptive statistics of the three countries using analysis of variance and multiple comparisons by Tukey method. SPSS version 28 and AMOS version 28 were used for the analyses. The statistical significance was set at 5%.

This study underwent an ethical review by the Chiba University Graduate School of Nursing Ethics Review Committee (No. 30-19) in Japan and the University College Dublin's Human Research Ethics Committee – Humanities (HS-18-81-KODATE) in Ireland, and was approved by both bodies. For Finland, two separate ethical approvals were obtained for this study. Specifically, we obtained the ethical approval necessary to conduct the study from the city of Seinäjoki, to which the participants belonged, and the Joint Municipal Authority of Ilmajoki and Kurikka (JIK), which provides social and medical services to both municipalities.

3. Results

3.1. Characteristics of the respondents by country

The descriptive statistics of the survey by country are included in the Appendix. Although we conducted the survey with potential users of home-care robots in each country, the proportions of the answers to each

Fig. 1. Illustrations of home-care robots provided in the questionnaire form.

question varied widely. Japanese (77.1%) and Irish (70.3%) respondents were more open to using home-care robots than their Finnish (52.8%) counterparts. The proportions of answers that indicated respondents' positive willingness to use home-care robots was the highest in Japan, followed by Finland and Ireland.

3.2. Data preparation

The number of participants for whom missing values were assigned ranged from 7 to 13 in Japan, 15 to 26 in Ireland, and 13 to 20 in Finland. The number of respondents whose data were used in the analysis was 664 in Japan, 208 in Ireland, and 260 in Finland; therefore, the ratios of the number of people were 1.1–2% in Japan, 7.2–12.5% in Ireland, and 5–7.7% in Finland. Even after imputing the missing values, the average score of each item remained almost unchanged. Ireland and Finland demonstrated smaller standard deviations (Table 2).

3.3. Model verification

A confirmatory factor analysis resulted in a χ^2/df ratio of 8.629, a CFI of 0.954, an RMSEA of 0.082 (90% confidence interval [90% CI]: 0.074, 0.090; $p < 0.05$), and an AIC of 383.911, indicating room for improvement in the RMSEA. Thus, Item 3 (Health care professionals should be allowed to use photos and videos recorded by home-care robots for clinical care and monitoring) was moved from the factor 'use of personal information for medical and long-term care' to the factor 'aquisition of personal information'. As a result, a χ^2/df ratio of 6.032, a CFI of 0.97, an RMSEA of 0.067 (90% CI: 0.059, 0.075; $p < 0.05$), and an AIC of 285.219 were obtained. The χ^2/df ratio, the RMSEA and the AIC were smaller than those of the original model. However, the RMSEA value still exceeded the goodness threshold of 0.05. Therefore, we created a model in which Item 7 (The person whom you can trust [non-family member], if agreed by both parties, should be allowed to use information obtained by a home-care robot) was deleted from the factor 'use of personal information for medical and long-term care'. This yielded a model with a χ^2/df ratio of 5.158, a CFI of 0.98, an RMSEA of 0.061 (90% CI: 0.051, 0.070; $p < 0.05$), and an AIC of 201.595, all of which demonstrated an improvement from the second model. Although the RMSEA values remained slightly above the good standard, they were within an acceptable range. Ultimately, 10 items were adopted in the final model: Items 1 to 3 for 'acquisition of personal information', Items 4 to 6 for 'use of personal information for medical and long-term care', Items 8 and 9 for 'secondary use of personal information', and Items 10 and 11 for 'participation in research and development'.

The factor loadings of the final model ranged between 0.63 and 0.92, and all factor loadings were greater than 0.6, showing a high influence of the factors upon the model (Fig. 2). Inter-factor correlations ranged from 0.46 to 0.79. The correlation between the factors 'use of personal information for medical and long-term care' and 'secondary use of personal information' was the highest, and the correlations between the factors 'participation in research and development' and the other factors were generally low (Table 3). The internal consistency among the items ranked below each factor was high, ranging from 0.755 to 0.887 for each factor, and 0.886 overall (Table 4).

When the final model was fitted to the Japanese data, a χ^2/df ratio was 4.892, a CFI was 0.966, and an RMSEA was 0.077 (90% CI: 0.064, 0.089; $p < 0.05$), and all factor loadings were greater than 0.6. For Ireland, a χ^2/df ratio was 2.630, a CFI was 0.963, and an RMSEA was 0.089 (90% CI: 0.065, 0.113; $p < 0.05$), and all factor loadings were greater than or equal to 0.6. For Finland, a χ^2/df ratio was 1.795, a CFI was 0.985, and an RMSEA was 0.055 (90% CI: 0.030, 0.079; $p = 0.332$), and all factor loadings were greater than 0.6, excluding the item 'Home-care robots should be allowed to take photos or record videos as long as the individual cannot be identified'. Among the three countries, the fit was relatively good in Finland and poor in Ireland (Fig. 3).

Additionally, we checked the final model fit for all respondents without considering multiple attributes. For Japan (n=528), a χ2/df ratio was 3.613, a CFI was 0.970, and an RMSEA was 0.070 (90% CI: 0.056, 0.085; $p < 0.05$). For Ireland (n=178), a χ2/df ratio was 2.020, a CFI was 0.973, and an RMSEA was 0.076 (90% CI: 0.047, 0.104; $p = 0.065$). For Finland (n=180), a χ2/df ratio was 1.656, a CFI was 0.981, and an RMSEA was 0.061 (90% CI: 0.027, 0.090; $p = 0.264$).

We further tested our final model by respondents' attributes—older adults, family caregivers and care workers. For older adults (n=396), a χ2/df ratio was 2.401, a CFI was 0.984, and an RMSEA was 0.060 (90% CI: 0.042, 0.078; $p < 0.177$). For family caregivers (n=292), a χ2/df ratio was 2.075, a CFI was 0.981, and an RMSEA was 0.061 (90% CI: 0.039, 0.082; $p = 0.192$). For care worker (n=442), a χ2/df ratio was

Table 2
Descriptive statistics before and after imputation of missing values.

		Before imputation			After imputation		
		n	mean	SD	n	mean	SD
Identifiable photo and video	Japan	654	2.67	1.02	664	2.67	1.02
	Ireland	189	2.32	1.08	208	2.34	1.03
	Finland	247	2.36	1.05	260	2.37	1.03
	Total	1090	2.54	1.05	1132	2.54	1.03
Unidentifiable photo and video	Japan	654	2.66	0.96	664	2.66	0.96
	Ireland	190	2.43	1.02	208	2.44	0.98
	Finland	245	2.54	0.99	260	2.54	0.96
	Total	1089	2.59	0.98	1132	2.59	0.96
Photos and videos for providing care and monitoring	Japan	656	2.78	0.93	664	2.78	0.93
	Ireland	192	2.56	1.02	208	2.57	0.98
	Finland	244	2.78	1.01	260	2.78	0.98
	Total	1092	2.74	0.97	1132	2.74	0.95
Notifying vital signs information	Japan	657	3.45	0.74	664	3.45	0.73
	Ireland	193	3.25	0.87	208	3.26	0.84
	Finland	243	3.45	0.88	260	3.45	0.85
	Total	1093	3.41	0.8	1132	3.41	0.78
Notifying voice information	Japan	657	3.04	0.91	664	3.04	0.91
	Ireland	188	2.96	0.9	208	2.96	0.85
	Finland	245	2.85	1.02	260	2.86	0.99
	Total	1090	2.98	0.94	1132	2.98	0.92
Notifying location information	Japan	651	3.08	0.89	664	3.08	0.88
	Ireland	188	3.03	0.95	208	3.03	0.9
	Finland	240	3.14	0.99	260	3.14	0.95
	Total	1079	3.08	0.92	1132	3.08	0.9
Use of information by non-family members	Japan	657	2.81	0.95	664	2.81	0.94
	Ireland	188	2.94	0.95	208	2.93	0.91
	Finland	245	2.81	1.01	260	2.81	0.98
	Total	1090	2.83	0.96	1132	2.83	0.94
Secondary use of information by professionals	Japan	657	2.79	0.94	664	2.79	0.93
	Ireland	185	2.62	1.02	208	2.64	0.96
	Finland	243	2.97	1.02	260	2.96	0.98
	Total	1085	2.80	0.97	1132	2.80	0.95
Secondary use of information by researchers	Japan	656	2.80	0.93	664	2.80	0.92
	Ireland	182	2.52	1.05	208	2.55	0.99
	Finland	243	2.81	1.04	260	2.81	1.01
	Total	1081	2.76	0.98	1132	2.76	0.96
Proactive participation in research and development	Japan	655	2.92	0.95	664	2.92	0.94
	Ireland	186	3.13	0.97	208	3.12	0.92
	Finland	246	2.95	1.02	260	2.95	0.99
	Total	1087	2.96	0.97	1132	2.96	0.95
Use during research and development	Japan	656	2.84	0.98	664	2.84	0.98
	Ireland	187	3.04	1.05	208	3.02	1.00
	Finland	246	2.72	1.11	260	2.72	1.08
	Total	1089	2.84	1.03	1132	2.84	1.01

Notes: SD = standard deviation

2.539, a CFI was 0.975, and an RMSEA was 0.059 (90% CI: 0.042, 0.076; p = 0.174).

3.4. Comparison of the total score between the three countries

When the total scores for each factor among the three countries were compared, significant differences were found among the three factors other than the factor 'use of personal information for medical and long-term care'. In Japan, the score for the factor 'acquisition of personal information' was higher than in the other two countries. In Ireland, compared to the scores of the other two countries, the score for the factor 'secondary use of personal information' was lower and the score for the factor 'participation in research and development' was higher ($p < 0.05$) (Fig. 4).

4. Discussion

This study, which was conducted in Ireland, Finland, and Japan, found that the impact of ethical issues regarding the use of care robots in home care can be explained by the same model. Two of the four factors included in the confirmatory factor analysis were related to personal information, and the other two were related to research and development; namely, the secondary use of personal information and participation in development research. As the country model demonstrated the characteristics of each country, it is worth discussing the data from the three countries in turn.

4.1. Finland

The data from Finland stand out in that the item 'identifiable photo and video' in the factor 'acquisition of personal information' was rated higher at 0.74 than in the other two countries. Additionally, the item 'notifing vital signs information' in the factor loadings for 'use of personal information for medical and long-term care' was high at 0.81. These results reflect the current situation of Finland. The use of home care is already common, and trusted medical and nursing staff use data of older adults through ICT (i.e. Kanta). Therefore, it is possible that Finns are less concerned about sharing their personal information with care robots so that older adults can receive better care (Haverinen et al., 2022; Kujala et al., 2022). Since 2013, when Kanta was introduced, digital health strategies have been implemented by leveraging the foundations of public medical and nursing care provided in local communities. Therefore, it is possible that the well-developed infrastructure and trust in the system design are positively promoting the use of medical information (e.g. 'eHealth strategy: the Finnish Nurses Association 2015–2020', etc.) (Finnish Nurses Association's digital social and

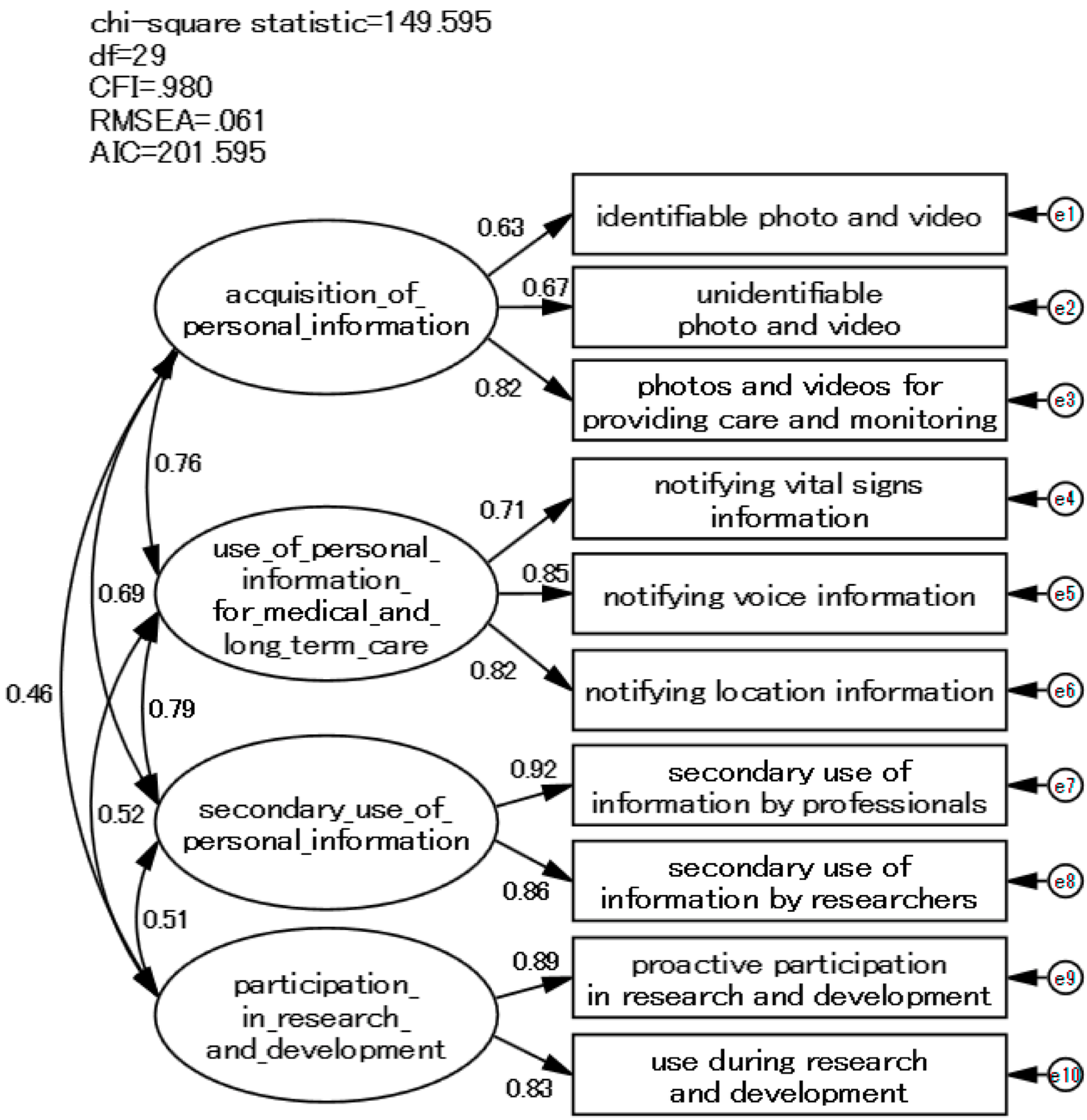

Fig. 2. The ethical perception model regarding the use of care robots in home care (Final model).
Notes: df, degrees of freedom; CFI, comparative fit index; RMSEA, root mean square error of approximation; AIC, Akaike's information criterion

Table 3
Inter-factor correlations among the factors in the final model.

	Factor 1	Factor 2	Factor 3
Factor 1: acquisition of personal information			
Factor 2: use of personal information for medical and long-term care	0.76		
Factor 3: secondary use of personal information	0.69	0.79	
Factor 4: participation in research and development	0.46	0.52	0.51

Table 4
Internal consistency within the factors and the final model.

	Cronbach α
Overall	0.886
acquisition of personal information	0.755
use of personal information for medical and long-term care	0.832
secondary use of personal information	0.887
participation in research and development	0.844

health services strategy, 2021; Finnish Nurses Association ehealth expert working group, 2015).

4.2. Japan

The average scores for the three items related to 'acquisition of personal information' were 8.1 in Japan, 7.7 in Finland, and 7.4 in Ireland. The score in Japan was significantly higher than that in the other two countries. In the Japanese model, the factor loading of the item 'photos and videos for providing care and monitoring' related to the factor 'acquisition of personal information' was 0.74, which was lower than that for Ireland (0.90) and Finland (0.91). Based on these findings, we concluded that although the Japanese are tolerant of the acquisition of personal information, it is difficult for them to imagine specific applications for such data collection, such as in providing care and watching over people in a super-aged society. A data collection system called the Long-term care Information system For Evidence (LIFE) was introduced within the long-term care insurance system in 2021, followed by a movement to build evidence for care (Ministry of Health, Labour and Welfare, 2021). Considering this point, the government should address the fact that secondary use of personal

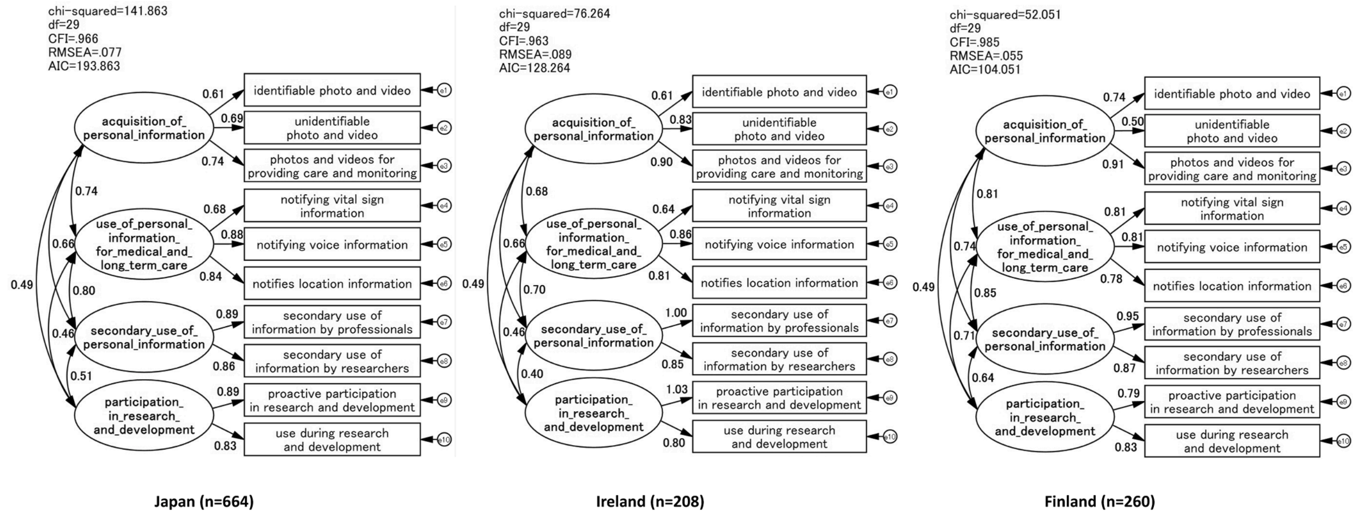

Fig. 3. Application of the final model for each country.
Notes: df, degrees of freedom; CFI, comparative fit index; RMSEA, root mean square error of approximation; AIC, Akaike's information criterion

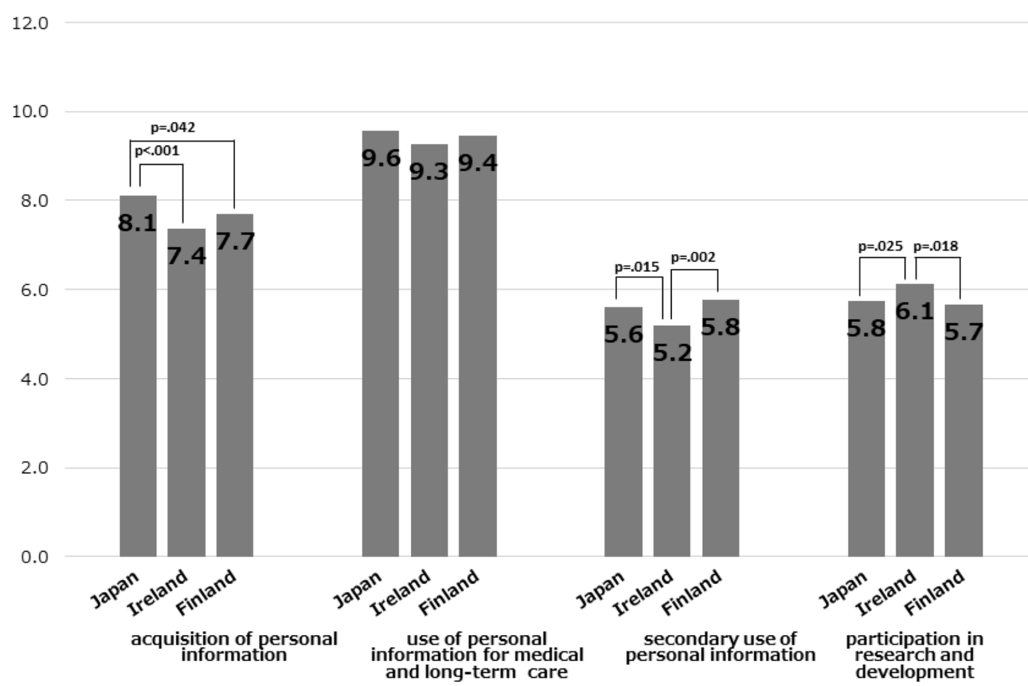

Fig. 4. Results of multiple comparisons of total scores of each factor among Japan, Ireland, and Finland.

information will contribute to improving care quality. To this end, it is also necessary to develop technologies that protect personal information and privacy and to provide users with peace of mind and ease of use. If this progress makes such technology more familiar to people, it is possible that social implementation of home-care robots will become more prevalent.

4.3. Ireland

On items related to the factor 'participation in research and development', the average scores of Irish respondents were significantly higher than those of the other two countries. A positive attitude was shown towards the development of care robots that contribute to public welfare. In contrast, the average score of 'secondary use of personal information' was significantly lower in Ireland than those of the other two countries. Thus, a cautious attitude towards secondary use of personal information is evident. This is supported by the fact that the inter-factor correlation between the factors 'secondary use of personal information' and 'participation in research and development' is low. Although secondary use of personal information is necessary to develop care robots, there is an apparent reluctance among the Irish respondents. This can be attributed to the fact that the readiness for digitalisation and ICT infrastructure is lacking in Ireland, compared to the other two countries (Lolich et al., 2022). To address this issue, one positive measure may be to explain the significance of secondary use of information as a response to the Irish people's willingness to contribute to research and development.

4.4. Model improvement

In this study, we improved the model based on the χ^2/df ratio, the CFI, and the RMSEA and selected a model with a smaller AIC. Although we assumed the four factor model, we improved the model incrementally by balancing these indices. As a result, Item 3 (Health care professionals should be allowed to use photos and videos recorded by home-care robots for clinical care and monitoring) was moved from the factor 'use of personal information for medical and long-term care' to 'acquisition of personal information'. Because the other items under 'acquisition of personal information' were related to photo and video evidence, even though the users were professional, it was more appropriate to group them as a type of information. Moreover, image information may be uniquely important to people these days. Finally, Item 7 (The person whom you can trust [non-family member], if agreed by both parties, should be allowed to use information obtained by a home-care robot) was omitted from the final model. We were aware that the absolute covariate value of this item was smaller than those of other items in the previous step; therefore, we considered it appropriate to remove the unnecessary items from the improvement process.

4.5. Why a universal model works

Although the extent of the impact on the ethical issues related to the use of care robots is greatly influenced by each country's culture, rate of ageing, health care policies, and status of technology development and level of social implementation, this study showed that a universal model can explain this impact. The model can be explained due to three possible reasons. First, unlike previous surveys of care robots and nursing care, this survey focused on people who are familiar with care, such as older adults receiving care, family caregivers, and care workers. It is possible that more specific intentions towards care were expressed because the participants had shared their experience of care. Second, these three countries have implemented national measures against dementia (Department of Health, 2014; Ministry of Health, Labour and Welfare, 2019; Ministry of Social Affairs and Health, 2013). Therefore, the participants may have been able to answer the survey by specifically envisioning the time when care robots are implemented. Third, technologies such as smartphones and smart speakers are commonly used in daily life, and large amounts of personal information are collected today in countries worldwide (Insider Intelligence, 2022). It is possible that such changes in the social environment are reducing the differences between countries regarding the ethical issues related to the use of care robots.

At the same time, it must be noted that satisfactory values for fit indices were not obtained in some cases. The reason for this is not only due to an insufficient number of respondents but also because of an imbalance between the numbers of respondents from the three countries, which may have caused statistical variance, thereby leading to a relatively low CFI, and a relatively high and statistically non-significant RMSEA. Although potential users of care robots were analysed by country, it is possible that the differences in their attributes may have influenced the model's fit. Therefore, it is necessary to collect a more balanced and larger sample for validation in each country.

4.6. Users' participation in research and development

Ethically Aligned Design, formulated by the IEEE, demands ethical behaviour based on principles derived by researchers and developers of autonomous and intelligent systems. In this study, we included 'participation in research and development' by older adult users, family caregivers, and care workers as one of the factors. The inter-factor correlation between this factor and others was lower than that between the remaining factors. Therefore, 'participation in research and development' can be considered a relatively independent factor. Thus, apart from the appropriate collection and utilisation of personal information by care robots, providing opportunities for users to participate in the development stage of care robots and to make decisions about their use and social implementation can be considered important. The results of this study empirically support the concept of Ethically Aligned Design advocated by the IEEE.

Suggestions can be drawn from this study regarding the relationship between developers and users for future development in other fields. A technique called agile development is generally used for software development. Based on the Agile Software Development Declaration (Manifesto for Agile Software Development, 2001), this technique involves developers and users co-creating and repeating the development process. Unlike traditional waterfall development, which is a one-way development based on specifications, agile development involves users using the technology and providing feedback. Until now, the mainstream method for the development of devices such as care robots has been based on waterfall development. However, it is possible to introduce agile development from an early stage of the development of care robots and focus on planning, improvement, and evaluation while receiving feedback from potential users. Involving users in the development process is also significant from an efficient development perspective.

It is worth noting that developers of care robots should not interpret the models developed in this research to their own advantage. For example, regarding privacy-protected images, it is extremely simplistic to interpret that social implementation of home-care robots will be realised if everyone agrees to the collection of personal data or if users are convinced to be enthusiastic about research and development. Statistical analysis to develop the universal model shows the average of people's tendency of the use of care robots; additionally, we also recognise that how decisions concerning the use of care robots are made varies from person to person in practice, depending on their circumstances and family situation, and that nursing care should prioritise the relational aspects and interactions between caregivers and care recipients (Lolich et al., 2022). Accordingly, we must prioritise the development and social implementation of care robots (Pleschberger, 2007; ROSE Consortium, 2017). Sharkey and Sharkey (2012) raised ethical concerns about the use of care robots for older adults, such as the potential reduction in the amount of human contact and loss of privacy. Hence, they argued for the need for guidelines regarding care robot use. Therefore, to identify the differences in attitudes between users and developers is necessary, and researchers and developers of care robots should determine how to realise or implement the RRI while considering the users' intention and willingness. In this study, our purpose was limited to elucidating the ethical issues related to users' willingness to use home-care robots. In future studies, the broader elements related to the intention to use home-care robots should be surveyed. Additionally, continuity across surveys should be considered to ascertain any possible changes to the results.

4.7. Limitations

Data collected from three countries between November 2018 and February 2019 were analysed, and it was determined that the use of care robots was not common in the surveyed countries. Therefore, it is predicted that the willingness to use care robots may change due to the influence of social conditions. For example, Turja et al. (2022) conducted a longitudinal survey of Finnish care workers and demonstrated that their expectations from care robots changed positively in 2020 compared to 2016. They attributed these changes to social norms towards care robots, the threat of technological unemployment, and stress caused by COVID-19.

Furthermore, the number of responses received from each country was small and may not be sufficiently representative of each country's population. We could not check our final model for responses to each attribute in all countries. Additionally, as discussed previously, the fit indices used in this study have not always demonstrated reasonable results. A possible reason is the insufficient number of respondents. Although we were able to build a unified model for the three countries targeted in this study, whether this model can be applied to other countries, such as developing countries in which the burden of nursing care will increase in the future, remains unknown.

Appendix Table
Descriptive statistics of the responses by country.

		Japan n=528		Ireland n=296		Finland n=180		Total n=1,004	
		n	%	n	%	n	%	n	%
Sex	Female	405	76.7	122	41.2	121	67.2	648	64.5
	Male	122	23.1	38	12.8	54	30.0	214	21.3
	Not specified	0	0.0	7	2.4	1	0.6	8	0.8
	No answer	1	0.2	129	43.6	4	2.2	134	13.3
Age group	39 or younger	57	10.8	16	5.4	26	14.4	99	9.9
	40s	103	19.5	21	7.1	19	10.6	143	14.2
	50s	133	25.2	15	5.1	16	8.9	164	16.3
	60s	102	19.3	24	8.1	34	18.9	160	15.9
	70s	78	14.8	49	16.6	42	23.3	169	16.8
	80 or older	55	10.4	41	13.9	37	20.6	133	13.2
	No answer	0	0.0	130	43.9	6	3.3	136	13.5
Attribute (Multiple answers)	Older adults	176	33.3	128	43.2	107	59.4	411	40.9
	Family caregivers	169	32.0	90	30.4	85	47.2	344	34.3
	Care workers	319	60.4	136	45.9	67	37.2	522	52.0
	No answer	0	0.0	0	0.0	1	0.6	1	0.1
I am open to using home-care robots	Yes	407	77.1	208	70.3	95	52.8	710	70.7
	No	117	22.2	70	23.6	60	33.3	247	24.6
	No answer	4	0.8	18	6.1	25	13.9	47	4.7
Would you like to use a home-care robot at home when providing care to your family?	Yes	170	32.2	42	14.2	22	12.2	234	23.3
	Yes, to some extent	196	37.1	59	19.9	67	37.2	322	32.1
	Not really	117	22.2	35	11.8	43	23.9	195	19.4
	Never	39	7.4	15	5.1	37	20.6	91	9.1
	No answer	6	1.1	145	49.0	11	6.1	162	16.1
Would you like to use a home-care robot at home when receiving care yourself?	Yes	208	39.4	52	17.6	23	12.8	283	28.2
	Yes, to some extent	169	32.0	61	20.6	67	37.2	297	29.6
	Not really	107	20.3	36	12.2	41	22.8	184	18.3
	Never	41	7.8	14	4.7	39	21.7	94	9.4
	No answer	3	0.6	133	44.9	10	5.6	146	14.5

5. Conclusions

In this study, we used data obtained from surveys conducted in Japan, Ireland, and Finland—countries with different geographies, cultures, demographics, and systems. The survey respondents comprised those who receive or provide care (i.e. potential users of care robots), namely, older adults, family caregivers, and home-care staff. This study showed that a model developed through a systematic analysis of the data can universally explain the impact of users' ethical perceptions related to their willingness to use care robots. As a policy suggestion, it is first necessary in the future to conduct a longitudinal survey, grasp the changes in ethical awareness, and work on the development and social implementation of care robots that truly contribute to human well-being.

Funding

This work was supported by the Pfizer Health Research Foundation, International Joint Research, and IAAR Next-generation Research of Social Value Creation Research Support Program, Chiba University, Japan. The funding sources did not have any involvement in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

CRediT authorship contribution statement

Hiroo Ide: Data curation, Formal analysis, Writing – original draft. **Sayuri Suwa:** Conceptualization, Methodology, Writing – original draft, Project administration, Funding acquisition. **Yumi Akuta:** Formal analysis, Writing – original draft. **Naonori Kodate:** Conceptualization, Methodology, Investigation, Writing – original draft. **Mayuko Tsujimura:** Methodology, Investigation, Data curation. **Mina Ishimaru:** Methodology, Writing – review & editing. **Atsuko Shimamura:** Methodology, Writing – review & editing. **Helli Kitinoja:** Conceptualization, Methodology. **Sarah Donnelly:** Methodology, Investigation. **Jaakko Hallila:** Methodology, Investigation. **Marika Toivonen:** Methodology, Investigation. **Camilla Bergman-Kärpijoki:** Investigation. **Erika Takahashi:** Investigation. **Wenwei Yu:** Validation, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank all the supporting organisations and respondents of the study.

Appendix

Appendix Table

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