



**HAL**  
open science

## Breaking social isolation for older people living alone with technology

Jérôme Dinet, Yann Morère, Rui Nouchi, Kohei Sakaki, Fabien Clanché,  
Matthieu Casteran

► **To cite this version:**

Jérôme Dinet, Yann Morère, Rui Nouchi, Kohei Sakaki, Fabien Clanché, et al.. Breaking social isolation for older people living alone with technology. Behaviour and Information Technology, 2024, 43 (9), pp.1740-1751. 10.1080/0144929X.2023.2298706 . hal-04493690

**HAL Id: hal-04493690**

**<https://hal.univ-lorraine.fr/hal-04493690v1>**

Submitted on 4 Feb 2025

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Breaking Social Isolation for Older People Living Alone with Technology

Jérôme DINET

*University of Lorraine*

2LPN, UR 7489

Nancy, France

jerome.dinet@univ-lorraine.fr

Yann MORÈRE

*University of Lorraine*

LCOMS, EA 7306

Metz, France

yann.morere@univ-lorraine.fr

Rui NOUCHI

*Tohoku University*

IDAC

Sendai, Japan

rui.nouchi.a4@tohoku.ac.jp

Kohei SAKAKI

*Tohoku University*

IDAC

Sendai, Japan

kohei.sakaki.b4@tohoku.ac.jp

Fabien CLANCHE

*University of Lorraine*

Staps-DEVAH, UR3450

Nancy, France

fabien.clanche@univ-lorraine.fr

Matthieu CASTERAN

*University of Lorraine*

2LPN, UR 7489

Metz, France

matthieu.casteran@univ-lorraine.fr

**Abstract**—This paper is aiming to present two studies investigating attitudes of older people towards different technologies to break their social isolation and investigating the impacts of Immersive Virtual Reality (IVR) on physical and mental dimensions. The first study, based on focus groups conducted with 23 older people (aged from 65 to 93 years-old) allowed to collect attitudes and opinions of older people about different technologies to help them to break social isolation. The second study, based on an experiment conducted with 42 older people (aged from 63 to 85 years-old) allowed to investigate the impact of a specific Immersive Virtual Reality (IVR) on physical and mental dimensions. The first study confirm that Immersive Virtual Reality (IVR) can be a relevant digital tool for elderly people according to them, *i.e.*, a digital tool perceived as useful, usable and acceptable. The second study demonstrates that use of a specific Immersive Virtual Reality (IVR) system can reduce the perception of social isolation and can have positive impacts on physical dimensions such as the weight and the waist circumference. Theoretical and applied implications are discussed.

**Index Terms**—technology, acceptability, older people, social isolation, loneliness

## I. INTRODUCTION

As people generally live longer, maintaining physical autonomy of older adults, and thus their independence, is a key challenge that all modern societies must face and succeed to ensure the economic and social well-being of the entire population. Moreover, loneliness is also a key challenge in the social domain related to aging. So, the ability to stay connected to community services and to maintain social interactions is considered today to be crucial to well-being and successful aging [18] [56] [94] (for a synthesis, see [83]). To stay connected with other, to maintain social interactions and to preserve physical activity, walking is one the best activities for older adults because it has positive effects on physical and

mental health for older adults [50]. But, in our large and modern cities, three activities related to walking are particularly complex for older adults [83] because there are many sensory, motor and cognitive changes with age: walking and obstacle negotiation, navigation, and street crossing. Finally, because older adults are often aware of their limitations and because our towns are more and more complex for pedestrians (*e.g.*, crossing a street), more and more older adults are anxious with outdoor activities [9], and several studies revealed a significant relationship between anxiety and fear of falling in different countries [3], [9], [12], [45], [60], [69]. Moreover, social isolation is also related to mental representation about neighborhood and social factors (*e.g.*, population density, crime rate, ethnic) that influence people’s use and perception of their space and their activities performed outdoor [33], [70], [75]. Fear of falling is the most common public health problem, which can lead to loss of confidence, reducing physical and social activities, depression, loss of mobility, increased risk of falls, physical weakness, and strong negative impact on an older people’s quality of life. There is increasing evidence that fear of falling is a major barrier to walking and other outdoor activities which in turn lead to increased fall risks [27], [42]. This relationship between fear of falling and restricted physical activity holds important implications among older and middle-aged adults, and the fear of outdoor falling is one of the major barriers preventing people from meeting the recommended levels of social and physical activity [39], [54], [65].

In parallel, even if data about social isolation of older adults varies by country (percentages from 25 in Denmark to 60 in Greece; [80], loneliness is a serious problem among older persons, loneliness has been consistently identified as one of the specific “social problems” which accompanies old age and growing older in all the countries, in urban areas [37], [43], [46], [62], [85] or in rural areas [88], [90]. While being alone does not directly imply loneliness, actual/perceived isolation and loneliness can negatively affect mental health

The first study was supported by grants issued from Fondation MAIF (<https://www.fondation-maif.fr>) and the second study was funded by the Tohoku University-Université de Lorraine Joint Research Fund 2020.

[40], [66], [68]. Living alone, having few social network ties, and having infrequent social contacts are all markers of social isolation. Loneliness and social isolation have direct influences on physical and mental health [64], [67], [76], [79], [84] and are risk factors for all-cause morbidity and mortality with outcomes comparable to other risk factors such as smoking, lack of exercise, obesity and high blood pressure, and loneliness has been associated with decreased resistance to infection, cognitive decline and mental health conditions such as depression and dementia [31], [41], [53], [57]. Risk factors for loneliness and social isolation among older people include [5]: family dispersal, decreased mobility and income, loss of loved ones, and poor health. It is thought that societal change including reduced inter-generational living, greater geographical mobility and less cohesive communities have also contributed to higher levels of loneliness in the older population. Social isolation of old people living alone is a real problem and is directly related to the quality of life [89]. We can note that, despite some detrimental impact on vulnerable individuals, there was no large increase in loneliness but remarkable resilience in response to COVID-19 [58] even for older adults [85].

There are different interventions and methods to improve social skills and to enhance social support [59], a series of studies showing that technologies can be relevant and efficient for older adults living at home or in institutional settings [13], [15]–[18], [36], [44], [49], [101], [102] even if these technologies are simple such as telephone [11] or radio and TV [82]. Several studies demonstrated that Immersive Virtual Reality (IVR) can be relevant and acceptable for older people to promote and maintain physical and social activities [4], [6], [7], [21], [30], [48], [81]. Moreover, several recent studies showed that the older adults reported positive experiences and positive attitudes with Immersive Virtual Reality (IVR) [2], [4], [22]. So, if IVR technologies can be used as a tool to reduce social isolation of older adults and to increase engagement in physical activity, we assume that an IVR system is efficient if behavioral changes are transferred from the virtual to the real physical world.

In this vein, we present two complementary studies:

- The first study, based on focus groups conducted with 23 older people (aged from 65 to 93 years-old), is aiming to collect attitudes and opinions about different technologies to help them to break social isolation.
- The second study, based on an experiment conducted with 42 older people (aged from 63 to 85 years-old), is aiming to investigate the impact of Immersive Virtual Reality (IVR) on physical and mental dimensions.

## II. STUDY 1

The first study conducted with older people was to collect opinions and attitudes towards different technologies to help seniors to increase their physical activity outside.

### A. Participants

Twenty-three French seniors participated to focus groups, each focus group having from 3 to 6 participants (aged from 65 to 93 years-old). All participants were French native-speakers, all were women, use some digital technologies (such as smartphones or tablets), and live alone. The duration of these focus groups were from 60 to 75 minutes (Fig.1).



Fig. 1. One of the focus groups conducted with volunteers older people.

### B. Focus group: Design and Procedure

Focus groups are well suited to "give voice" to marginalized groups such as older adults [93] [94] [98]. Focus groups are particularly relevant to collect attitudes and opinions of older adults about specific tools such as digital technologies (e.g., [99] [100]). The quality of discussion is not only determined by the individual characteristics of the participants but the overall composition of the group. One the most common recommendations in the focus group literature is to create groups that are homogeneous with regard to the topic [95] [96] [94]. For example, it is easier for participants with incontinence to discuss this sensitive topic when they know that all the members of the group share the same problem. the questions should be short and simple using language familiar to older adults [97].

All the focus groups were located in the same place, *i.e.*, institution where older people can practice some activities such as cooking, practicing sports, and they were always moderated by the same experimenters.

In our study, each focus group had three steps:

- First, after a brief presentation of the main goals of the study, participants were asked to verbalise freely their opinions and attitudes towards technology. Moreover, they were asked to explain what kind of technology they use in their daily life, for what activities, in what context, etc. (e.g., to search for information about health, to communicate and to share photos with their children, to practice e-banking).

- Second, three digital tools are presented to participants by the experimenter. These digital tools have been presented with three videos displaying seniors using them (Fig.2) (i) a wearable device/sensor used to collect data about gait and balance; (ii) an Immersive Virtual Reality (IVR) system to simulate navigation at home; (iii) a connected watch with its smartphone. Participants were asked to give their opinions about each of these digital tools, their advantages and limits *a priori*.
- Finally, like for the first step, participants were asked to verbalise freely their opinions and attitudes towards technology (utility, usability, acceptability).



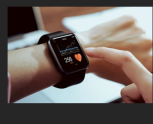
	UTILITY	USABILITY	ACCEPTABILITY
	+/- e.g., "Useful for physicians", "Very small", "Not really useful for seniors"	++ e.g., "Easy to use", "No action is required", "Not in my leg"	++ e.g., "If invisible, I am OK to use it", "Only for a short period", "Not during the night"
	+++ e.g., "Innovative", "Useful for physicians and for seniors", "Complementary"	++ e.g., "With some help, easy to use", "I have just to walk"	+++ e.g., "Really funny", "I would like to test that", "Very cool, like in movies"
	+/- e.g., "Funny", "Easy to wear", "Too much information"	+/- e.g., "Too complex to use", "Too more actions and buttons"	++ e.g., "Useful for physicians", "I do not want to be constantly followed"

Fig. 2. Utility perceived, usability and acceptability for each of the three digital devices displayed to elderly people during the focus groups: a wearable device/sensor (at the top); Immersive Virtual Reality (or IVR, at the middle); a connected watch (at the bottom line).

### C. Results and discussion

Contents of verbalisation of participants produced during all the focus groups have been analysed by using an inductive content analysis, *i.e.*, where coding categories are derived directly and inductively from the raw data. In inductive content analysis, researchers avoid using preconceived categories, allowing the categories and names for categories to 'flow from the data' instead. They immerse themselves in the data to allow new insights to emerge. Similar to a grounded theory approach, the main purpose is to develop theories. The advantage of the conventional approach of content analysis is that direct information is gained from the study participants without preconceived theoretical perspectives having been imposed.

For each technology displayed during the focus group, a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) has been conducted to interpret verbalisation produced by the participants. For instance, for the wearable device/sensor, several participants express that "it is small", "easy to wear" (Strengths), but "I do not want to use it during the night", "I am OK to wear it only for a very short period" (Weaknesses), and "I regret that no information is provided for

the user" (Opportunities). In the same way, for the connected watch, some participants express that "it is easy to wear it" (Strength) but "it is too complex to use" and "I do not want to be constantly followed" (Weaknesses). Several examples of verbalisation produced by the older people during these focus groups are provided in Fig.2.

Based on this SWOT analysis, utility, usability and acceptability have been estimated. As Fig.2 summarizes, our results obtained in the first study tend to demonstrate that an Immersive Virtual Reality (IVR) system could be a relevant digital tool for elderly people, *i.e.*, a digital tool perceived as useful, usable and acceptable.

It is the reason why we investigate more precisely, in an experiment presented below (study II), the impacts of an IVR on physical and mental dimensions for older people. In particular, we hypothesize that an IVR can have positive impacts of physical data and social isolation for elderly people.

### III. STUDY 2

Results issued from the first study show that an Immersive Virtual Reality (IVR) system can be useful, easy to use, and acceptable by older people to help them to break social isolation. This second study will investigate if an IVR can have positive effects on physical and mental dimensions. To assess the impact on loneliness and perception of social isolation, the University of California Los Angeles (Revised UCLA) loneliness scale can be used [49], [72]–[74]. Revised UCLA is a 20-item scale (e.g., "How often do you feel that you lack companionship?", "How often do you feel you can find companionship when you want it") designed to measure one's subjective feelings of loneliness as well as feelings of social isolation. Participants is asked to rate each item on a scale from 1 (Never) to 4 (Often). This scale has good concurrent and discriminant validity, internal consistency and stability [73] and has been validated for different cultures: Spain [87]; Canada [23]; Korea [46]; Portugal [63]; Turkey [28]; Taiwan [93]; Italy [10]; Ireland [78]; Belgium [34]; United Arab Emirates [25]; and France [23]. To assess the impact on physical dimension, weight and waist circumferences are relevant because they are very good predictors of disability among older adults (e.g., [35], [38], [55], and have similar predictive accuracy compared with body mass index [92]. Moreover, studies confirmed that weight and waist circumference are associated with functional and physical decline, and reduced quality of life for older adults [8], [16]: Elevated weight and waist circumference are associated with lower quality of life, a decline in physical function, and a slightly higher risk of disability over time.

We hypothesized that the use and navigation in an Immersive Virtual Reality (IVR) system can have positive impacts on real behaviors (walking) in the real world and on perception of social isolation. Forty-two older adults participated to our experiment (63-85 years-old), half of whom interacted with a specific Immersive Virtual Reality (IVR) daily for 4 months in their homes and half of whom served as a standard-of-care control.

	IVR group (n = 21)	Control group (n = 21)	Total (N = 42)
<b>SEX(n, %)</b>			
Male	8 (38%)	7 (33.3%)	15 (35.7%)
Female	13 (61%)	14 (66.6%)	27 (64.21%)
<b>AGE</b>			
Mean (SD)	78.4 (6.7)	77.8 (6.9)	78.1 (6.8)
Min.-Max.	64-85	63-84	63-85
<b>REASONS FOR LIVING ALONE (n, %)</b>			
Never having married	2 (9.5%)	2 (9.5%)	4 (9.5%)
Divorced	3 (14.2%)	4 (19%)	7 (16.6%)
Separated	1 (4.7%)	0	1 (2.3%)
Widowed	14 (66.6%)	15 (71.4%)	29 (69%)
<b>SCORE MMSE</b>			
Normal (> 24)	17 (80.9%)	16 (76.1%)	33 (78.5%)
Mild (21-24)	4 (19%)	5 (23.8%)	9 (21.4%)
Moderate (10-20)	0	0	0
Severe (<10)	0	0	0
<b>AIDS(n, %)</b>			
Using glasses	19 (90%)	20 (95.2%)	39 (92.8%)
Hearing Diff.	5 (23.8%)	6 (28.5%)	11 (26.1%)
Limited mobility	2 (9.5%)	2 (9.5%)	4 (9.5%)

TABLE I  
DISTRIBUTION AND CHARACTERISTICS OF STUDY PARTICIPANTS.

#### A. Participants

Forty-two French older adults aged 65 to 85 years participated to our experiment (percentage of female= 64.2; mean age = 78.1, SD = 7.1 years). Distribution of participants is presented in Table I. All participants have lived alone for different reasons (separated, widowed, divorced, never having married). Participants are distributed in two separate groups: 21 participants in the experimental group and 21 participants in a control group. Participants in the experimental group were asked to interact with a specific Immersive Virtual Reality (IVR) daily for 4 months in their homes, at least 15 minutes per day. No specific information has been provided for participants who served as a standard-of-care control.

#### B. Eligibility criteria and distribution of participants

Participants were included in our study if they (1) were adults over 65 years old; (2) could communicate in French fluently; (3) were able to consent to participate in the study; (4) have lived in cities located in the East of France; (5) had normal or mild levels of cognition (scored >21 on Mini-Mental State Examination or MMSE); and (6) live alone at least from 3 years. Individuals were excluded if they met any of the following criteria: (1) vision impairment at a level that would make it impossible for them to use the Immersive Virtual Reality (IVR) system; (2) open wounds or skin conditions on the face, or chronic neck pain/injury that might make it unsafe to wear the IVR headset; (3) inability to provide consent; (4) have lived alone since one, two or three years.

#### C. The Immersive Virtual Reality (IVR) Used

The IVR used in our study was specifically created for a series of experiments investigating the behaviors of pedestrians with specific needs (e.g., older adults, adults with motor impairment) in urban areas. This IVR has been developed by Human Games© company and requires the use of an HTC Vive headset (Fig.3) Participants in the experimental group were asked to spend at least 15 minutes per day, in their home, within this specific IVR while they were seated. They were asked to “simply explore the virtual town and to navigate in this town to become familiar with it”. Several training sessions were organized to familiarize participants with the IVR system.

In this IVR system, pedestrian/user can freely navigate in a city, i.e., s/he can cross streets, s/he can move where s/he wants, s/he can stop to move where s/he wants. Other pedestrians and vehicles are also present. On the one hand, IVR headset provides an immersion that focuses the user’s attention on her/his actions in the virtual environment. On the other hand, the controllers/joysticks allow natural gestures to be reproduced to catch, use or throw objects.

#### D. Dependent Variables

Whatever the group (experimental vs. control), each participant was asked to come in the laboratory to collect several objective and subjective data related to his/her daily life activity and his/her affect:

- Weight (in kg.);
- Waist circumference (in cm.);



Fig. 3. Two screenshots of urban scenes extracted from the IVR created by Human Game© used in our experiment.

- The number of steps per day, outside, assessed with a pedometer (Fitbit©) provided for each participant;
- The time of use per day of the IVR (in min.), only for the experimental group;
- Perception of intensity of activity, assessed by a Likert-scale: “According to you, over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example, for fun or exercise, walking, walking the dog, etc. (from 0 “Never” to 7 “Often”);
- Assessment of loneliness, by using the French version of the Revised UCLA Loneliness Scale (R-UCLA; [74]; French version: [19]. This scale is a 20-item scale designed to measure one’s subjective feelings of loneliness as well as feelings of social isolation where respondents were asked to rate each item from one of four choices: “Never”, “Rarely”, “Sometimes” or “Often”. The average loneliness score on the measure is 20. A score of 25 or higher reflects a high level of loneliness. A score of 30 or higher reflects a very high level of loneliness. In this study, each participant was asked to complete the scale twice (at the beginning and at the end of the experiment).

#### E. Results and discussion

For the assessment of loneliness by using the French version of the Revised UCLA Loneliness Scale, results indicate that the measure are highly reliable, both in terms of internal consistency (coefficient  $\alpha = .92$ ) and test-retest reliability over a 4-month period ( $r = .73$ ).

As Table II shows, four main interesting results have been obtained:

- The mean weight and the mean waist circumference of participants using the specific IVR system decrease significantly ( $p. = .002$ ) while these data remain stable for the control group;
- The number of steps outside and the perception of intensity of activity increase significantly for participants using the specific IVR system ( $p. < .001$ ), while these data remain stable for the control group;
- the loneliness score (*i.e.*, perception of social isolation) decreases significantly for participants using the IVR

system ( $p. < .001$ ), while this score remains stable for the control group;

- The positive impacts related to the use of the IVR exist even if the time spent to use this IVR system decreases.

In other words, the use of IVR has positive impacts on physical dimensions (weight, waist circumference) and on mental dimensions (loneliness score) because it has a positive influence on the number of steps performed outside. This result is really interesting because positive impacts exist even if the time spent to use the IVR decreased ( $p. = .02$ ).

#### IV. GENERAL DISCUSSION

Results obtained in the first study, based on focus groups conducted with 23 seniors, confirmed that an Immersive Virtual Reality (IVR) system can be a relevant digital tool for elderly people according to them, *i.e.*, a digital tool perceived as useful, usable and acceptable.

Results obtained in the second study, based on an experiment conducted with 42 seniors, have mainly shown that use of a specific Immersive Virtual Reality (IVR) system can reduce the perception of social isolation and can have positive impacts of physical data (weight and waist circumference) for older adults because activity performed with the IVR stimulates activity performed outdoor (*i.e.*, walking as pedestrian). In other words, walking in the virtual world has a direct and positive impact on walking activity performed outdoor, in the real world.

Even if walking comes an increased risk of injury as a pedestrian, walking has plenty of health benefits for older adults [32], [52], [83], [91], [101], including more positive feeling, better social life, inexpensive, may reduce social isolation and anxiety, help to reduce chronic pain, controls blood sugar more effectively, helps joint flexibility, improves coordination and balance, helps bone and muscle health, maintains weight and waist circumference, and increases confidence. There is currently a growing interest in social issues globally, such as the isolation—as well as physical or mental health decline—of older people, social participation lowers the risk of future isolation [29].

	Fist session (Week 1)	Last session (Week 10)	<i>p.</i>
<b>WEIGHT (in kg.; Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	66.8 (7.9)	63.7 (8.7)	.002
Control group ( <i>n</i> = 21)	67.1 (9.1)	67 (8.8)	<i>ns</i>
<b>WAIST CIRCUMFERENCE (in cm.; Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	102 (12.3)	97.5 (14.2)	.003
Control group ( <i>n</i> = 21)	101 (13.9)	100.5 (11.2)	<i>ns</i>
<b>NUMBER OF STEPS OUTSIDE (Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	3890 (878)	7604 (754)	<.001
Control group ( <i>n</i> = 21)	4002 (652)	3791 (448)	<i>ns</i>
<b>TIME OF USE OF IVR (in min. per day; Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	15 (3.8)	12 (4.7)	.02
Control group ( <i>n</i> = 21)	-	-	-
<b>PERCEPTION OF INTENSITY OF ACTIVITY (from 0 to 7; Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	1 (0.1)	5.5 (0.3)	<.001
Control group ( <i>n</i> = 21)	0.8 (0.2)	1.3 (0.3)	<i>ns</i>
<b>LONELINESS SCORE (Mean and SD)</b>			
IVR group ( <i>n</i> = 21)	37.06 (4.2)	21.43 (6.1)	<.001
Control group ( <i>n</i> = 21)	37.02 (5.7)	36.71 (6.6)	<i>ns</i>

TABLE II

MEAN (AND SD) OBTAINED IN THE EXPERIMENT CONDUCTED IN THE STUDY 2, FOR THE TWO GROUPS (IVR GROUP AND CONTROL GROUP), AT THE BEGINNING AND THE END OF THE EXPERIMENT.

Even if future studies are needed to control the possible impact of some individual factors (e.g., gender, status, hobbies), our experiment confirms that as Immersive Virtual Reality (IVR) has become more accessible, affordable, and comfortable, it provides a unique opportunity to use these technologies to enable older adults to escape from their often confined area [4], [6], [7], [102]. More precisely, the use of a specific IVR can modify positively human behaviors of older adults from the virtual to the real and physical world. In other words, impacts of an Immersive Virtual Reality can be positive because its use can help individuals (here, older adults) to adopt new intentions and new positive behaviors in real and physical world.

#### ACKNOWLEDGMENT

We are grateful to the participants, all volunteers in the two studies presented in this paper. And we are grateful to the "Office Nancéien des Personnes Agées" (ONPA) for supporting the first study and assisting the recruitment.

#### REFERENCES

- [1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955.
- [2] V.V. Abeele, B. Schraepen, H. Huygelier, C. Gillebert, K. Gerling, and R. Van Ee, "Immersive Virtual Reality for Older Adults: Empirically Grounded Design Guidelines", *ACM Transactions on Accessible Computing (TACCESS)*, vol. 14(3), 2021, pp.1-30.
- [3] A. Abyad, and S.O. Hammami, "Fear of falling in the elderly-an emerging syndrome", *Middle East Journal of Age and Ageing*, vol. 14(3), 2017, pp.16-25.
- [4] L. Appel, E. Appel, O. Bogler, M. Wiseman, L. Cohen, N. Ein, and J.L. Campos, "Older adults with cognitive and/or physical impairments can benefit from immersive virtual reality experiences: a feasibility study", *Frontiers in medicine*, vol. 6, 2020, 329.
- [5] S.M. Bernard, "Loneliness and social isolation among older people in North Yorkshire: Stage 1 report, 2013.
- [6] S. Baker, J. Warburton, J., Waycott, F. Batchelor, T. Hoang, B. Dow, and F. Vetere, "Combating social isolation and increasing social participation of older adults through the use of technology: A systematic review of existing evidence", *Australasian Journal on Ageing*, vol. 37(3), 2018, pp.184-193.
- [7] S. Baker, J. Waycott, J., E. Robertson, R. Carrasco, B.B. Neves, R. Hampson, and F. Vetere, "Evaluating the use of interactive virtual reality technology with older adults living in residential aged care", *Information Processing and Management*, vol. 57(3), 2019, 102105. <https://doi.org/10.1016/j.ipm.2019.102105>
- [8] Batsis, J. A., Zbehlik, A. J., Barre, L. K., Mackenzie, T. A., and Bartels, S. J. (2014). The impact of waist circumference on function and physical activity in older adults: longitudinal observational data from the osteoarthritis initiative. *Nutrition Journal*, 13(1), 1-13.
- [9] Birhanie, G., Melese, H., Solomon, G., Fissaha, B., and Teferi, M. (2021). Fear of falling and associated factors among older people living in Bahir Dar City, Amhara, Ethiopia-a cross-sectional study. *BMC geriatrics*, 21(1), 1-11.
- [10] Boffo, M., Mannarini, S., and Munari, C. (2012). Exploratory structure equation modeling of the UCLA Loneliness scale: A contribution to the Italian adaptation. *Testing, Psychometrics, and Methodology in Applied Psychology*, 19(4), 345–363. doi:10.4473/TPM19.4.7
- [11] Cattani, M., Kime, N., and Bagnall, A. M. (2011). The use of telephone befriending in low level support for socially isolated older people—an evaluation. *Health and Social Care in the Community*, 19(2), 198-206.
- [12] Chang, H. T., Chen, H. C., and Chou, P. (2016). Factors associated with fear of falling among community-dwelling older adults in the Shih-Pai study in Taiwan. *PLoS one*, 11(3), e0150612.
- [13] Charness, N. (2019). Promising Technology to Promote Healthy Aging. *The Gerontologist*, 59(1), 190–191, <https://doi.org/10.1093/geront/gny133>.
- [14] Chen, Y. R. R., and Schulz, P. J. (2016). The effect of information communication technology interventions on reducing social isolation in

- the elderly: a systematic review. *Journal of medical Internet research*, 18(1), e4596.
- [15] Chen, H., Bermúdez, O. I., and Tucker, K. L. (2002). Waist circumference and weight change are associated with disability among elderly Hispanics. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 57(1), M19-M25.
- [16] Chipps, J., Jarvis, M. A., and Ramlall, S. (2017). The effectiveness of e-Interventions on reducing social isolation in older persons: A systematic review of systematic reviews. *Journal of Telemedicine and Telecare*, 23(10), 817-827.
- [17] Christman, Z. J., Wilson-Genderson, M., Heid, A., and Pruchno, R. (2020). The effects of neighborhood built environment on walking for leisure and for purpose among older people. *The Gerontologist*, 60(4), 651-660.
- [18] de Grâce, G.-R., Joshi, P., and Pelletier, R. (1993). L'Échelle de solitude de l'Université Laval (ÉSUL): validation canadienne-française du UCLA Loneliness Scale [The Laval University loneliness scale: A Canadian-French validation of the University of California at Los Angeles (UCLA) Loneliness Scale]. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement*, 25(1), 12-27. <https://doi.org/10.1037/h0078812>
- [19] de Jong Gierveld, J., and Havens, B. (2004). Cross-national comparisons of social isolation and loneliness: Introduction and overview. *Canadian Journal on Aging*, 23(2), 109-113.
- [20] Dilanchian, A. T., Andringa, R., and Boot, W. R. (2021). A Pilot Study Exploring Age Differences in Presence, Workload, and Cybersickness in the Experience of Immersive Virtual Reality Environments. *Frontiers in Virtual Reality*, 129.
- [21] Dinet, J., Nouchi, R., Sakaki, K., Dupont, L., Coudrat, L., and Charpillet, F. (2021, October). Promoting Physical Activity for Elderly People: Towards a Hybrid Coaching?. In *ERGO'IA 2021*, October 6-8 2021, Bidart, France.
- [22] DiTommaso, E., and Spinner, B. (1993). The development and initial validation of the Social and Emotional Loneliness Scale for Adults (SELSA). *Personality and Individual Differences*, 14(1), 127-134. [doi:10.1016/0191-8869\(93\)90182-3](https://doi.org/10.1016/0191-8869(93)90182-3)
- [23] DiTommaso, E., Turbide, J., Poulin, C., and Robinson, B. (2007). L'Échelle de Solitude Sociale et Emotionnelle (ESSE): A French-Canadian adaptation of the social and emotional loneliness scale for adults. *Social Behavior and Personality: an international journal*, 35(3), 339-350.
- [24] Dodeen, H. (2014). The effects of positively and negatively worded items on the factor structure of the UCLA Loneliness Scale. *Journal of Psychoeducational Assessment*, 33, 259-267. [doi:10.1177/0734282914548325](https://doi.org/10.1177/0734282914548325)
- [25] Dommès, A. (2019). Street-crossing workload in young and older pedestrians. *Accident Analysis and Prevention*, 128, 175-184.
- [26] Donoghue, O. A., Cronin, H., Savva, G. M., O'Regan, C., and Kenny, R. A. (2013). Effects of fear of falling and activity restriction on normal and dual task walking in community dwelling older adults. *Gait and posture*, 38(1), 120-124.
- [27] Durak, M., and Senol-Durak, E. (2010). Psychometric qualities of the UCLA Loneliness Scale-version 3 as applied in a Turkish culture. *Educational Gerontology*, 36(10-11), 988-1007. [doi:10.1080/03601271003756628](https://doi.org/10.1080/03601271003756628).
- [28] Ejiri, M., Kawai, H., Fujiwara, Y., Ihara, K., Watanabe, Y., Hirano, H., ... and Obuchi, S. (2019). Social participation reduces isolation among Japanese older people in urban area: A 3-year longitudinal study. *PLoS one*, 14(9), e0222887.
- [29] El Kamali, M., Angelini, L., Caon, M., Carrino, F., Röcke, C., Guye, S., ... and Mugellini, E. (2020). Virtual coaches for older adults' wellbeing: A systematic review. *IEEE Access*, 8, 101884-101902.
- [30] Fakoya, O.A., McCorry, N.K. and Donnelly, M. (2020). Loneliness and social isolation interventions for older adults: a scoping review of reviews. *BMC Public Health* 20, 129. <https://doi.org/10.1186/s12889-020-8251-6>
- [31] Franks, M. M., Richards, E. A., McDonough, M. H., Christ, S. L., and Marshall, M. E. (2018). Walking for our health: couple-focused interventions to promote physical activity in older adults. *International Journal of Health Promotion and Education*, 56(6), 280-288.
- [32] Gan, D. R. Y., Fung, J. C., and Cho, I. S. (2020). Neighborhood experiences of people over age 50: Factor structure and validity of a scale. *The Gerontologist*, 60(8), e559-e571.
- [33] Goossens, L., Klimstra, T., Luyckx, K., Vanhalst, J., and Teppers, E. (2014). Reliability and validity of the Roberts UCLA Loneliness Scale (RULS-8) with Dutch-Speaking adolescents in Belgium. *Psychologica Belgica*, 54(1), 5-18. [doi:10.5334/pb.ae](https://doi.org/10.5334/pb.ae)
- [34] Guallar-Castillón, P., Sagardui-Villamor, J., Banegas, J. R., Graciani, A., Fornés, N. S., García, E. L., and Rodríguez-Artalejo, F. (2007). Waist circumference as a predictor of disability among older adults. *Obesity*, 15(1), 233-233.
- [35] Hagan, R., Manktelow, R., Taylor, B. J., and Mallett, J. (2014). Reducing loneliness amongst older people: a systematic search and narrative review. *Aging and Mental Health*, 18(6), 683-693.
- [36] Havens, B., Hall, M., Sylvestre, G., and Jivan, T. (2004). Social isolation and loneliness: Differences between older rural and urban Manitobans. *Canadian Journal on Aging/la revue canadienne du vieillissement*, 23(2), 129-140.
- [37] Heim, N., Snijder, M. B., Heymans, M. W., Deeg, D. J., Seidell, J. C., and Visser, M. (2011). Optimal cutoff values for high-risk waist circumference in older adults based on related health outcomes. *American journal of epidemiology*, 174(4), 479-489.
- [38] Hoang, O. T. T., Jullamate, P., Piphatvanitcha, N., and Rosenberg, E. (2017). Factors related to fear of falling among community-dwelling older adults. *Journal of clinical nursing*, 26(1-2), 68-76.
- [39] Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., and Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: A meta-analytic review. *Perspectives on Psychological Science*, 10, 227-237.
- [40] Holt-Lunstad, J., Smith, T. B., and Layton, J. B. (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS medicine*, 7(7), e1000316.
- [41] Jefferis, B. J., Iliffe, S., Kendrick, D., Kerse, N., Trost, S., Lennon, L. T., ... and Whincup, P. H. (2014). How are falls and fear of falling associated with objectively measured physical activity in a cohort of community-dwelling older men?. *BMC geriatrics*, 14(1), 1-9.
- [42] Jylhä, M. (2004). Old age and loneliness: cross-sectional and longitudinal analyses in the Tampere Longitudinal Study on Aging. *Canadian Journal on Aging/La revue canadienne du vieillissement*, 23(2), 157-168.
- [43] Kahlbaugh, P. E., Sperandio, A. J., Carlson, A. L., and Hauselt, J. (2011). Effects of playing Wii on well-being in the elderly: Physical activity, loneliness, and mood. *Activities, Adaptation and Aging*, 35(4), 331-344.
- [44] Kempen, G. I., van Haastregt, J., McKee, K. J., Delbaere, K., and Zijlstra, G. A. (2009). Socio-demographic, health-related and psychosocial correlates of fear of falling and avoidance of activity in community-living older persons who avoid activity due to fear of falling. *BMC Public Health*, 9(1), 1-7.
- [45] Kim, A. (2020). The impact of social isolation on health-related quality of life of older adults living alone. *Journal of Digital Convergence*, 18(8), 343-351.
- [46] Kim, O. S. (1997). Korean version of the revised UCLA loneliness scale: Reliability and validity test. *The Journal of Nurses Academic Society*, 27(4), 871-879.
- [47] Kim, A., Darakjian, N., and Finley, J. M. (2017). Walking in fully Immersive Virtual Reality: an evaluation of potential adverse effects in older adults and individuals with Parkinson's disease. *Journal of neuroengineering and rehabilitation*, 14(1), 1-12.
- [48] Khosravi, P., and Ghapanchi, A. H. (2016). Investigating the effectiveness of technologies applied to assist seniors: A systematic literature review. *International journal of medical informatics*, 85(1), 17-26.
- [49] Khosravi, P., Rezvani, A., and Wiewiora, A. (2016). The impact of technology on older adults' social isolation. *Computers in Human Behavior*, 63, 594-603.
- [50] Kramer, A. F., and Erickson, K. I. (2007). Effects of physical activity on cognition, well-being, and brain: Human interventions. *Alzheimer's and Dementia*, 3(2), S45-S51.
- [51] Krogstad, J. R., Hjorthol, R., and Tennøy, A. (2015). Improving walking conditions for older adults. A three-step method investigation. *European journal of ageing*, 12(3), 249-260.
- [52] Landeiro, F., Barrows, P., Musson, E. N., Gray, A. M., and Leal, J. (2017). Reducing social isolation and loneliness in older people: a systematic review protocol. *BMJ open*, 7(5), e013778.
- [53] Lee, S., Lee, C., Ory, M. G., Won, J., Towne Jr, S. D., Wang, S., and Forjuoh, S. N. (2018). Fear of outdoor falling among community-dwelling middle-aged and older adults: the role of neighborhood environments. *The Gerontologist*, 58(6), 1065-1074.



- [54] Li, F., Harmer, P., Cardinal, B. J., Bosworth, M., Johnson-Shelton, D., Moore, J. M., ... and Vongjaturapat, N. (2009). Built environment and 1-year change in weight and waist circumference in middle-aged and older adults: Portland Neighborhood Environment and Health Study. *American journal of epidemiology*, 169(4), 401-408.
- [55] Lord, S., and Luxembourg, N. (2007). The mobility of elderly residents living in suburban territories: Mobility experiences in Canada and France. *Journal of Housing for the Elderly*, 20(4), 103-121.
- [56] Luanaiha, C.Ó., and Lawlor, B.A. (2008). Loneliness and the health of older people. *International Journal of Geriatric Psychiatry: A journal of the psychiatry of late life and allied sciences*, 23(12), 1213-1221.
- [57] Luchetti, M., Lee, J. H., Aschwanden, D., Sesker, A., Strickhouser, J. E., Terracciano, A., and Sutin, A. R. (2020). The trajectory of loneliness in response to COVID-19. *The American psychologist*, 75(7), 897-908. <https://doi.org/10.1037/amp0000690>.
- [58] Masi, C. M., Chen, H. Y., Hawkey, L. C., and Cacioppo, J. T. (2011). A meta-analysis of interventions to reduce loneliness. *Personality and Social Psychology Review*, 15(3), 219-266.
- [59] Matsuura, T. (2020). Effects of elderly people's walking difficulty on concerns and anxiety while walking on roads. In *Pedestrians, Urban Spaces and Health* (pp. 214-218). CRC Press.
- [60] Munro, S., Lewin, S., Swart, T., and Volmink, J. (2007). A review of health behaviour theories: how useful are these for developing interventions to promote long-term medication adherence for TB and HIV/AIDS?. *BMC public health*, 7(1), 1-16.
- [61] National Academies of Sciences, Engineering, and Medicine. (2020). *Social isolation and loneliness in older adults: Opportunities for the health care system*. National Academies Press.
- [62] Neto F. (2014). Psychometric analysis of the short-form UCLA Loneliness Scale (ULS-6) in older adults. *European Journal of Ageing*, 11(4), 313-319. <https://doi.org/10.1007/s10433-014-0312-1>.
- [63] Newall, N. E., and Menec, V. H. (2019). Loneliness and social isolation of older adults: Why it is important to examine these social aspects together. *Journal of Social and Personal Relationships*, 36(3), 925-939.
- [64] Ory, M. G., Towne, S. D., Won, J., Forjuoh, S. N., and Lee, C. (2016). Social and environmental predictors of walking among older adults. *BMC geriatrics*, 16(1), 1-13.
- [65] Peplau, L. A., and Perlman, D. (Eds.). (1982). *Loneliness: A sourcebook of current theory, research, and therapy*. New York: Wiley.
- [66] Perlman, D. (2004). European and Canadian studies of loneliness among seniors. *Canadian Journal on Aging/La Revue canadienne du vieillissement*, 23(2), 181-188.
- [67] Petersen, N., König, H. H., and Hajek, A. (2020). The link between falls, social isolation and loneliness: A systematic review. *Archives of gerontology and geriatrics*, 88, 104020.
- [68] Phillips, J., Walford, N., Hockey, A., Foreman, N., and Lewis, M. (2013). Older people and outdoor environments: Pedestrian anxieties and barriers in the use of familiar and unfamiliar spaces. *Geoforum*, 47, 113-124.
- [69] Phillipson, C., Bernard, M., Phillips, J., and Ogg, J. (2001). The family and community life of older people: social networks and social support in three urban communities. *Social Policy Journal of New Zealand*, 19, 1-3.
- [70] Rantakokko, M., Mänty, M., Iwarsson, S., Törmäkangas, T., Leinonen, R., Heikkinen, E., and Rantanen, T. (2009). Fear of moving outdoors and development of outdoor walking difficulty in older people. *Journal of the American Geriatrics Society*, 57(4), 634-640.
- [71] Russell, D., Peplau, L.A., and Ferguson, M.L. (1978). Developing a measure of loneliness. *Journal of Personality Assessment*, 42(3), 290-294.
- [72] Russell, D. (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment*, 66, 20-40.
- [73] Russell, D., Peplau, L. A., and Cutrona, C. E. (1980). The revised UCLA Loneliness Scale: concurrent and discriminant validity evidence. *Journal of personality and social psychology*, 39(3), 472.
- [74] Scharf, T., Phillipson, C., and Smith, A. (2003). Older people's perceptions of the neighbourhood: Evidence from socially deprived urban areas. *Sociological Research Online*, 8(4), 153-164.
- [75] I. Sénécal, "Personnes âgées. Un isolement qui se conjugue surtout au féminin" *Pour*, vol. 242(1), 2022, pp.195-198.
- [76] Shevlin, M., Murphy, S., and Murphy, J. (2014). The latent structure of loneliness testing competing factor models of the UCLA Loneliness Scale in a large adolescent sample. *Assessment*, 22(2), 208-215. [doi:10.1177/1073191114542596](https://doi.org/10.1177/1073191114542596).
- [77] Smith, K. J., and Victor, C. (2019). Typologies of loneliness, living alone and social isolation, and their associations with physical and mental health. *Ageing and Society*, 39(8), 1709-1730.
- [78] Sundström G, Fransson E, Malmberg B, Davey A. (2009). Loneliness among older Europeans. *European Journal of Ageing*, 6, 267-275. [doi:10.1007/s10433-009-0134-8](https://doi.org/10.1007/s10433-009-0134-8).
- [79] Tamplin, J., Loveridge, B., Clarke, K., Li, Y., and Berlowitz, D. J. (2020). Development and feasibility testing of an online virtual reality platform for delivering therapeutic group singing interventions for people living with spinal cord injury. *J. Telemed. Telecare* 26 (6), 365-375. [doi:10.1177/1357633X19828463](https://doi.org/10.1177/1357633X19828463)
- [80] Toepoel, V. (2013). Ageing, leisure, and social connectedness: How could leisure help reduce social isolation of older people?. *Social indicators research*, 113(1), 355-372.
- [81] Tournier, I., Dommès, A., and Cavallo, V. (2016). Review of safety and mobility issues among older pedestrians. *Accident Analysis and Prevention*, 91, 24-35.
- [82] Tsuji, T., Saito, M., Ikeda, T., Aida, J., Cable, N., Koyama, S., ... and Kondo, K. (2020). Change in the prevalence of social isolation among the older population from 2010 to 2016: A repeated cross-sectional comparative study of Japan and England. *Archives of Gerontology and Geriatrics*, 91, 104237.
- [83] van Tilburg, T.G., Steinmetz, S., Stolte, E., van der Roest, H., de Vries, D.H. (2021). Loneliness and Mental Health During the COVID-19 Pandemic: A Study Among Dutch Older Adults, *The Journals of Gerontology: Series B*, 76(7), e249-e255. <https://doi.org/10.1093/geronb/gbaa111>.
- [84] Van Tilburg, T., Havens, B., and de Jong Gierveld, J. (2004). Loneliness among older adults in the Netherlands, Italy, and Canada: A multifaceted comparison. *Canadian Journal on Aging/La Revue canadienne du vieillissement*, 23(2), 169-180.
- [85] Velarde-Mayol, C., Fragua-Gil, S., and García-de-Cecilia, J. M. (2015). Validation of the UCLA loneliness scale in an elderly population that live alone. *Semergen*, 42(3), 177-183.
- [86] Victor, C. R., Scambler, S. J., Shah, S., Cook, D. G., Harris, T., Rink, E., and De Wilde, S. (2002). Has loneliness amongst older people increased? An investigation into variations between cohorts. *Ageing and Society*, 22(5), 585-597.
- [87] Victor, C., Scambler, S., Bond, J., and Bowling, A. (2001). Being alone in later life: loneliness, social isolation and living alone. *Reviews in Clinical Gerontology*, 10(4), 407-417.
- [88] Wenger, G. C., and Burholt, V. (2004). Changes in levels of social isolation and loneliness among older people in a rural area: a twenty-year longitudinal study. *Canadian Journal on Aging/La revue canadienne du vieillissement*, 23(2), 115-127.
- [89] Wilmut, K., and Purcell, C. (2021). Why are older adults more at risk as pedestrians? A systematic review. *Human factors*, 0018720821989511.
- [90] J.S.C.H. Woo, S.C. Ho, A.L.M. Yu, and A. Sham. "Is waist circumference a useful measure in predicting health outcomes in the elderly?", *International Journal of Obesity*, vol. 26(10), 2002, pp.1349-1355.
- [91] C. Wu, and G. Yao, "Psychometric analysis of the short-form UCLA Loneliness Scale (ULS-8) in Taiwanese undergraduate students", *Personality and Individual Differences*, vol. 44(8), 2008, pp.1762-1771. [doi:10.1016/j.paid.2008.02.003](https://doi.org/10.1016/j.paid.2008.02.003).
- [92] I.H. Yen, and L.A. Anderson, "Built environment and mobility of older adults: important policy and practice efforts", *Journal of the American Geriatrics Society*, vol. 60(5), 2012, pp.951-956.
- [93] D.L. Morgan, "Focus groups as qualitative research (2nd ed.)", Thousand Oaks, CA: Sage, 1997.
- [94] D.L. Morgan, "Planning for focus groups", Thousand Oaks, CA: Sage, 1998.
- [95] R.A. Krueger, "Moderating focus groups", Thousand Oaks, CA: Sage, 1988.
- [96] R.A. Krueger, and M. Casey, "Focus Groups: A Practical Guide for Applied Research (4th Ed.)", Thousand Oaks, CA: Sage, 2000.
- [97] J. Light, and C. Binger, "Building communicative competence with individuals who use augmentative and alternative communication", Baltimore, MD: Brooks, 1988.
- [98] H. Halaweh, S. Dahlin-Ivanoff, U. Svantesson, and C. Willén, "Perspectives of older adults on aging well: a focus group study" *Journal of aging research*, 2018.

- [99] E. Vaportzis, M. Giatsi Clausen, and A.J. Gow, "Older adults perceptions of technology and barriers to interacting with tablet computers: a focus group study", *Frontiers in psychology*, vol. 8, 2017, 1687.
- [100] M. Heinz, P. Martin, J.A. Margrett, M. Years, W. Franke, H.I. Yang, H. I., and C.K. Chang, "Perceptions of technology among older adults", *Journal of gerontological nursing*, vol. 39(1), 2013, pp.42-51.
- [101] F. Muhla, F. Clanché, K. Duclos, P. Meyer, S. Maïaux, S. Colnat-Coulbois et G. C. Gauchard, "Impact of using immersive virtual reality over time and steps in the Timed Up and Go test in elderly people", *Plos One*, mars 2020, <https://doi.org/10.1371/journal.pone.0229594>.
- [102] G. Personeni, F. Clanché, T. Bastogne, A. Renaux, F. Muhla, G. C. Gauchard, « Assessment of the risk of fall in elderly people by virtual reality », *Hegel Vol. 13(1)*, 2023, DOI : 10.3917/heg.131.0000 .