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Categorizing digital data collection and intervention tools in health and wellbeing living lab settings: A modified Delphi study

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ABSTRACT

Background: Health and Wellbeing Living Labs are a valuable research infrastructure for exploring innovative solutions to tackle complex healthcare challenges and promote overall wellbeing. A knowledge gap exists in categorizing and understanding the types of ICT tools and technical devices employed by Living Labs.
Aim: Define a comprehensive taxonomy that effectively categorizes and organizes the digital data collection and intervention tools employed in Health and Wellbeing Living Lab research studies.
Methods: A modified consensus-seeking Delphi study was conducted, starting with a pre-study involving a survey and semistructured interviews (N=30) to gather information on existing equipment. The follow-up three Delphi rounds with a panel of living lab experts (R1 N=18, R2 - 3 N=15) from 10 different countries focused on achieving consensus on the category definitions, ease of reading, and included subitems for each category. Due to the controversial results in the 2nd round of qualitative feedback, an online workshop was organized to clarify the contradictory issues.
Results: The resulting taxonomy included 52 subitems, which were divided into three levels as follows: The first level consists of 'devices for data monitoring and collection' and 'technologies for intervention.' At the second level, the 'data monitoring and collection' category is further divided into 'environmental' and 'human' monitoring. The latter includes the following third-level categories: 'biometrics,' 'activity and behavioral monitoring,' 'cognitive ability and mental processes,' 'electrical biosignals and physiological monitoring measures,' '(primary) vital signs,' and 'body size and composition.' At the second level, 'technologies for intervention' consists of 'assistive technology,' 'extended reality – XR (VR & AR),' and 'serious games' categories.
Conclusion: A common language and standardized terminology are established to enable effective communication with living labs and their customers. The taxonomy opens a roadmap for further studies to map related devices based on their functionality, features, target populations, and intended outcomes, fostering collaboration and enhancing data capture and exploitation.

1. Introduction

According to the European Network of Living Labs (ENoLL) "Living Labs (LLs) are open innovation ecosystems in real-life environments using iterative feedback processes [...]. They focus on co-creation, rapid prototyping, and testing and scaling up innovations & businesses, [...]." In the Health and Wellbeing domain, Living Labs have emerged as valuable infrastructures that enable research studies to occur in real-life environments with the involvement of multiple stakeholders, ensuring a strong focus on end-users and co-creation approach. Living Labs are effective in promoting collaboration and participation, leading to successful implementation outcomes, particularly in developing and

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implementing new healthcare innovations [1]. With the increasing prevalence of digital technologies, more and more studies are integrating digital data collection and intervention tools to enhance their effectiveness and expand their scope [2]. However, the proliferation and diversity of these tools present significant challenges in comprehending, comparing, and harnessing their full potential across different infrastructures. The lack of a unified framework to navigate this complexity leads to inefficiencies and missed opportunities in leveraging technology for health improvement [3].

Integrating new information and communication technology (ICT) concepts and solutions into Living Labs is crucial for aligning them with the unique requirements, aspirations, and creative potentials of local contexts and cultures [4]. Despite the widespread use of ICT tools for data collection and digital health interventions in Health and Wellbeing Living Labs, there is a noticeable lack of research on the specific methods and tools systematically employed for data collection purposes [3]. Additionally, information is scarce regarding the classification of ICT and other technical devices (including mobile applications, wearable devices, remote sensing systems, and virtual reality platforms) within the Living Labs in the Health and Wellbeing domain, despite their frequent applications.

Consequently, a knowledge gap exists in categorizing and understanding the types of ICT tools and technical devices employed by Living Labs [5]. Given the heterogeneity of research design, target populations, and health outcomes, having a taxonomy [6] would enable researchers to identify commonalities and differences in the tools employed. Thus, the absence of a specific taxonomy in this field creates substantial barriers, not only for researchers but also for policymakers, healthcare providers, and technology developers [7]. Without a clear categorization and understanding of available tools, stakeholders face challenges in selecting appropriate technologies, leading to suboptimal health interventions and potential misuse of resources. In addition, this gap makes it difficult to track progress, compare results, and build on previous research, which ultimately slows down the advancement of effective innovative solutions [5]. This issue extends to data collection and exploitation practices, as there is currently no standardized representation of collected datasets, hindering cross-organizational collaboration and impeding the accessibility of Living Lab's captured data to external stakeholders. Therefore, there is a need for a comprehensive taxonomy that categorizes and organizes the digital data collection and intervention tools utilized in Health and Wellbeing Living Lab research studies, as remarked by Maga et. al. in their Health and Wellness Living Lab data model proposal [8]. Such a taxonomy potentially provides a structured framework to systematically classify these tools based on their functionality, features, target populations, and intended outcomes. By establishing a common language and standardized terminology, this taxonomy would facilitate knowledge exchange, collaboration, and benchmarking among researchers, practitioners, and stakeholders involved.

The primary objective of this research article is to address the identified gaps by introducing a comprehensive taxonomy that effectively categorizes and organizes the digital data collection and intervention tools employed in Health and Wellbeing Living Lab research studies. The taxonomy will establish a standardized language and terminology, thereby fostering knowledge exchange, collaboration, and benchmarking among researchers, practitioners, and stakeholders engaged in Health and Wellbeing Living Lab initiatives.

1. Methods

1.1. Study design

In health and wellbeing settings, consensus-seeking Delphi studies are extensively used methods to create taxonomies [9,10]. The definition of what constitutes consensus is blurry since prior studies have reported a range between 50-97 % with 75% being the median threshold to define consensus [11]. For this study, a 70 % or higher agreement level was considered a supermajority agreement, and an 80 % or higher strong supermajority agreement. Taxonomy development principles as suggested by Nickerson et al. (2013) [12] were adopted and the 5-step Delphi process described in Figure 1 was executed.

1.2. Pre-study survey and interviews

The pre-study questionnaire collected information about 1) the data collection technology name, and short description, 2) the object of data collection (keyword), 3) the equipment models used by LL, 4) the link to detailed specifications of the equipment, 5) output data format and 6) availability of open data sets. The questionnaire was filled out by 10 Health and Wellbeing Living Labs who were partners of the VITALISE European Commission H2020 project focusing on harmonizing living labs, operational procedures and opening Living Lab Infrastructure to researchers to facilitate and promote research activities in the Health and Wellbeing domain in Europe and beyond. The survey was complemented by semistructured interviews with each Living Lab's core members responsible for data collection and management (N=30, duration per interview ca. 2 hours). Two independent researchers worked on identifying the common characteristics of the collected technologies to define a preliminary taxonomy. After reaching a consensus among researchers, the first set of categories, subcategories, and their definitions were prepared for the first Delphi round [3].

1.3. Recruitment of expert panelists

The expert panel was defined based on two main criteria:

- Professionals that have at least 3 years of experience working in health and wellbeing Living Labs and participating in data collection with technical devices OR
- Professionals having experience with ICT tools and data collection in real-life environments.

Purposive and snowball sampling was utilized to populate the expert panel according to a rigorous selection process [13]. We contacted 32 experts who also demonstrated heterogeneity in background knowledge and experience as we wanted a diverse sample that would enhance credibility. Their expertise ranged from computer, electronic, and technology engineers, medical informatics, psychologists, occupational therapists, organizational and living lab management, clinical and medical expertise, and were all esteemed members of the Living Lab community. The panelists were English speakers but came from 10 different countries (Greece, Canada, Australia, Finland, Spain, Belgium, Hungary, Austria, Turkey, Netherlands) as we wanted to avoid possible language biases and misinterpretations. The number of panel members in each round was as follows: 1st Delphi round (N=18), 2nd Delphi (N=15), online workshop (N=14) and 3rd Delphi round (N=15). The panel size is acceptable and common for consensus-seeking studies [11].

1.4. Utilization of Delphi consensus process and Online workshop

An online eDelphi tool specially designed for Delphi studies was used as a systematic data collection method (eDelphi.org). Both quantitative statements and qualitative questions were utilized. There is an ongoing debate about reading the optimal type of Likert scales in Delphi studies [14,15]. In this study, quantitative statements were assessed using a 4-point agreement scale, supplemented by a fifth option ('no answer') for instances where respondents felt uncomfortable making a judgment on a particular item. The scale comprised the following options: 1) strongly disagree, 2) disagree, 3) agree, 4) strongly agree, and 5) no answer. Excluding the neutral option compelled respondents to take a stance if they did not choose the "no answer" option, thereby reducing the potential for neutral bias [16]. Combining scales for reporting

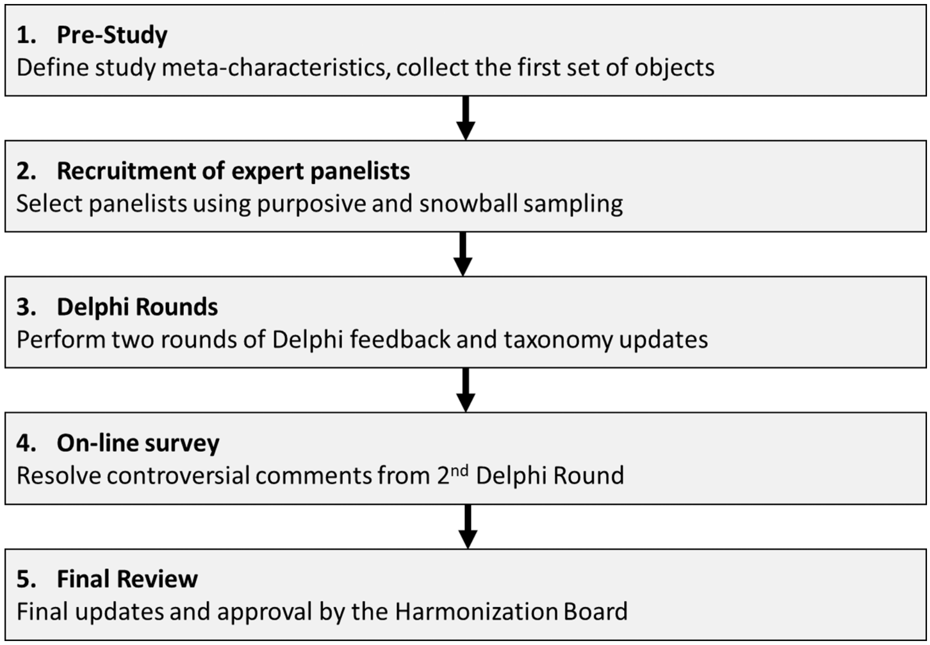

Figure 1. Phases in the development of the taxonomy

purposes is a common practice in Delphi studies [17]. This approach allowed us to collect more reliable and nuanced responses during the data collection phase, revealing the depth of opinion held by the respondents [18]. Consequently, this provides valuable insight for adjusting definitions and categorization as necessary. Supermajority agreements (at least 70 % agreement) and strong supermajority agreements (at least 80 % agreement) were defined as thresholds for ending conditions. Judgment questions for qualitative statements were formulated as follows in all rounds:

1. Do you disagree or agree with the definition?
2. The definition is easy to understand?
3. Item belong to this main or subcategory?

In the comment section, the panelist could provide additional qualitative information regarding their judgments and suggest new items, which in their opinion should be included in a specific category. Based on Round 1 feedback, the need for adding multiple category levels was verified in Round 2 by asking the panelist if the addition is a) useful, b) necessary, and c) easy to understand.

An online workshop was carried out between rounds 2 and 3 to clarify contradictory comments regarding definitions. The Mentimeter tool and the same 5-point Likert scale were used, collecting real-time feedback for specific categories that had not yet reached a supermajority consensus. Mentimeter is an interactive presentation and polling tool commonly used for engaging audiences during workshops. The live polling tool of Mentimeter was used to facilitate real-time audience interaction and feedback collection. Furthermore, the participants were asked to decide on controversial suggestions made in the previous Delphi round. Workshop outcomes were verified in the final 3rd Round.

2. Results

2.1. Delphi Round 1

Table 1 presents the evolution and consensus level for definition and easy-to-understand agreement for the main categories in Rounds 1 and 2. Round 1 categories were defined based on the pre-study results. Only 3 out 8 of the categories achieved a supermajority consensus on both agreement and clear description of the category in the 1st Delphi Round. As there was a major misunderstanding between biosignals and physiological monitoring and the differences among them were not clearly defined, a new category replaced the initial ones called “Biosignals and Physiological monitoring”. Furthermore, based on the suggestion by two panel members and with the support of the literature, a new category was included, the “vital signs” based on the HL7 framework classification (global standards for the transfer of clinical and administrative health data between applications). The category of “Mobile and Computer games” was added as well.

Moreover, the qualitative comments indicated a lack of clarity regarding whether the categories were intended for classifying data collection devices or technologies for intervention. Therefore, a higher

Table 1
Taxonomy main categories evolution and consensus level, round 1 and round 2.

Round 1	Agree%	Easy%	ROUND 2	Agree%	Easy%
Environment/ context monitoring	71*	71*	Environmental monitoring	87**	87**
Biometrics	94**	88**	Biometrics	100**	100**
Activity tracking/ monitoring	78*	83**	Activity and behavioral monitoring	85**	79*
Cognitive function	71*	56	Cognitive ability and mental processes	79*	79*
Biosignals	75*	67	Biosignals and physiological monitoring	67	67
Physiological monitoring	78*	89**	Vital signs	80**	93**
Assistive technology	88**	100**	Assistive technology	92**	86**
Virtual reality/ interactive technology	94**	94**	Extended reality	92**	79*
			Mobile and Computer Games	79**	87**

* Supermajority (=>70%, but < 80%), ** Strong supermajority (=>80%).

distinction level was created dividing the categories into "Categories of devices for data monitoring and collection" and "Categories of technologies for interventions". The "Categories of devices for data monitoring and collection" were also divided into Environmental and Human monitoring.

2.2. Delphi Round 2

Table 2 presents the validation for added classification levels. Both 1) "data monitoring and collection devices" and "intervention technologies as well as 2) "environmental monitoring" and "human monitoring" division achieved a 100 percent consensus level for usefulness and necessity. The classification was also considered easy to understand since it ranged between 87 to 93 percent.

As there were controversial comments and results in the 2nd Round of feedback, it was decided to insert a different method in the activity to achieve a more effective conflict resolution. For that purpose, an online workshop was organized using the Mentimeter tool to gather the participants' feedback and enable open discussion. The session's goal was to start from a general overview that serves the study's primary goal –*to support researchers to search and discover the data and devices that Living Labs can offer*. This resulted in the taxonomy which is shown in Table 3.

2.3. Delphi Round 3

Table 3 presents the consensus levels for definition and easy-to-understand agreement in Round 3.

After the 3rd Round, all but one of the categories achieved a strong supermajority consensus (i.e., 80% or more agree) on agreement of the category definition. The remaining body composition category reached the supermajority consensus level (71 %). In the case of body composition, it was suggested that adding illustrative examples to the definition would make it more understandable (reach 60 % consensus). Furthermore, the definition of electrical biosignals (60 % consensus) was claimed to be too theoretical, thus making it more difficult to understand. The final taxonomy categories, their definitions, and abbreviations are presented in Table 4.

2.4. Sub-item level results

Appendix A presents the final 52 subitems and their evolution according to the above taxonomy. Regarding belongingness, 44 out of 52 items (84,6 %) achieved a strong supermajority level (80% or over agreement) and 47 items (90,4 %) received a supermajority consensus level (i.e., 70% but less than 80% agreed) in the final 3rd Round. Results for easy to understand were somewhat similar, 43 items (82,7 %) gained strong supermajority and 49 items (94,2 %) ended up in supermajority level.

The following main categories achieved strong supermajority agreement for all included items regarding belongingness and easy-to-understand statements: "Environmental monitoring (3 items)", "Biometrics (2)", "Electrical biosignals (4)", "Vital signs (6)", "Extended reality – XR, VR & AR (2)" and "Serious games (3)".

In the case of the "Body composition" category, 3 out of 4 items gained strong supermajority agreement. However, the item concerning body length received only 46% agreement regarding its inclusion. According to open comments, there was confusion regarding the distinction between body height and length. Therefore, it is recommended to remove the "length" item from the category and include "height – lying" (measured on a horizontal surface) instead. This measure is commonly utilized for small children who may have difficulty standing still. Furthermore, it was suggested that circumference measurements should be added to the body composition category since they indicate where the weight is located, which is one of the indicators of health. Based on comments and literature review, core circumference measures include head, neck, biceps, waist, hip, chest, forearm, thigh, and calf. It was also highlighted that body measures relating to fat, mass, muscle, water, and bone should be included. Due to these modification requests, it is suggested that the category would be renamed as "Body size and composition".

Table 3
Taxonomy main categories consensus levels in Round 3

Round 3	Agree%	Easy%
Environmental monitoring	100**	100**
Biometrics	93**	80**
Activity and behavioral monitoring	93**	100**
Cognitive ability and mental processes	93**	87**
Electrical biosignals	86**	60
Vital signs	86**	79*
Body composition	71*	60
Assistive technology	100**	100**
Extended reality – XR (VR & AR)	93**	93**
Serious games	93**	93**

* Supermajority (=>70%, but < 80%), ** Strong supermajority (=>80%)

3. Discussion

In this section, we elucidate the rationale for the relevance of the identified categories to health and well-being, drawing on precedent findings and examples from the literature on digital data collection and intervention tools in living labs.

Emphasizing the goals of human and environmental monitoring, our exploration revealed that while human monitoring focuses on measuring individual health, environmental monitoring delves deeper into including external factors with potential impacts on human health. A robust body of empirical evidence underscores the influence of concentration levels, temperature, and light on health [19,20]. The multifaceted role of living labs, not only as data collection centres but also as active contributors to the development of environmental monitoring systems, is noteworthy [21].

To further broaden the spectrum of data collection tools, wearable technologies have introduced new possibilities and cost reductions in biosignal acquisition in a variety of settings, including living labs [22–24]. Moreover, Virtual reality (VR) tools have been used for studying both the user interaction with devices before their physical prototyping and for training in their use as well as contributing to designing XR/ VR interventions [25]. Assistive technologies have been widely used in Health & Wellbeing living lab environments, mainly aiming to support older adults [26,27]. Serious Games have also been identified as an interventional tool mainly used in Living Labs, to assess usability, usefulness, and effectiveness [28,29]. The use of generative AI is poised to play a pivotal role in these categories and will be considered in future versions of the taxonomy.

Table 2
Additional classification level validation.

Classification by	is useful%	is easy to understand %	is necessary%
" Data monitoring and collection devices" and "Intervention technologies	100**	93**	100**
"Environmental monitoring" and "Human monitoring"	100**	87**	100**

* Supermajority (=>70%, but < 80%), ** Strong supermajority (=>80%)

Table 4
Final taxonomy categories and definitions.

Level 1	Level 2	Level 3	Definition
Categories of devices for data monitoring and collection	Environment monitoring (ENVM)		Characterize and monitor the environment, and establish environmental parameters and conditions. As the environment, we refer to the person's surroundings either indoors or outdoors
	Human monitoring (HUMM)	Biometrics (BIOM)	Biological measurements — or physical characteristics — that can be used to identify individuals and their unique characteristics such as fingerprint scanning or voice recognition
		Electrical Biosignals and physiological monitoring measures (EBSIG)	Electrical biosignals, or bioelectrical time signals, usually refer to the change in electric current produced by the sum of an electrical potential difference across a specialized tissue, organ, or cell system like the nervous system
		(Primary) Vital signs(VITAL) (VISI)	A group of the six most important medical signs that indicate the status of the body's vital function according to HL7 standard
		Body size and composition (BODYC)	Measurement of a person's body, used as qualifying elements for vital signs
		Cognitive ability and mental processes(CMPROC)	Measuring the processes involved in the acquisition of knowledge, reasoning, and management of information and the brain-based skills, we need to carry out any task
		Activity and behavioural monitoring (ABM)	Monitoring the individuals' physical activities and tracking their performance. Monitoring behaviour and activities of daily living (ADLs)
Categories of technologies for interventions	Assistive Technology (AT)		Technologies are used to increase, maintain, or improve the functional capabilities of individuals, the feeling of autonomy, safety, and general wellbeing, or also support participation.
	Extended reality – XR, VR & AR (XR)		Allows for a two-way flow of information through an interface between the user and the technology through a simulated experience that can be similar to or completely different from the real world
	Serious games (SGAMES)		All digital games that are used as interventions for health and wellbeing are not including XR

Expanding our discussion to the broader landscape of digital health interventions, we draw attention to the World Health Organization's (WHO) Classification of Digital Health Interventions, Services and Applications for Digital Health (CDISAH) [30]. Although closely related to the work presented in this study, the WHO classification framework targets primarily public health audiences and aims to categorize the device functionality from the end-user perspective.

Having a different scope, our taxonomy proposes a categorization for data and devices that are used in Living Lab studies. This framework not only enhances the rigor of research studies but also drives the field forward, ensuring that Health and Wellbeing Living Lab initiatives can realize their full potential in advancing our common understanding of health and wellbeing in the digital age.

4. Conclusion

A modified Delphi method was employed to develop a comprehensive taxonomy aimed at categorizing and organizing the digital data collection and intervention tools utilized in Health and Wellbeing Living Lab research studies. The resulting three-level taxonomy includes a total of 52 subitems across 10 categories. A high consensus level was achieved on the clarity of category definitions, comprehensibility, and item inclusion. While the consensus level indicates agreement among experts, it's important to note that the validation process primarily relies on validation from experts in the field. Nevertheless, this taxonomy holds the potential to promote standardized terminology, enhancing communication within Living Labs and with their stakeholders. Researchers exploring Living Lab infrastructures for their studies can benefit from readily identifying relevant tools for data collection and interventions in Health and Wellbeing. Moreover, the resulting taxonomy has been adopted as the VITALISE Schema[2] providing a hierarchical structure to refine the proposed data model [8].

Authors' contributions

DP, together with TS, EK, and PB conceptualized the study. BMB administrated the literature review and DP together with TS designed and guided the panels and proceeded with the data curation and formal analysis of the information. EK and PB collaborated in the coordination of the study. DP and TS prepared the first draft and BMB, and EK improved the draft while PB and GE were reviewed. GE enriched data collection harmonization taxonomy needs and benefits. DP edited and made it submission-ready. All authors read and approved the final manuscript.

Summary table

What was known:

- Living Labs are valuable for exploring innovative solutions to tackle complex healthcare challenges and promote overall well-being.
- There is a lack of understanding regarding the types of data collection devices used by Health and Wellbeing Living Labs.

What this study added to our knowledge:

- Easy to understand and comprehensive taxonomy (3-level categorization including 10 different categories and 52 subitems) to classify Health and Wellbeing Living Lab data collection and intervention devices.
- Established a common language and standardized terminology to communicate with Living Labs and their customers, as well as enhance captured data exchange and exploitation.
- Enables mapping of related devices based on their functionality, features, and intended outcomes to foster collaboration.

CRediT authorship contribution statement

Despoina Petsani: Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Teemu Santonen:** Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Beatriz Merino-Barbancho:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Gorka Epelde:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Panagiotis Bamidis:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Evdokimos Konstantinidis:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

[2] https://gitlab.com/vitalise-project-group/vitalise-data-model/-/tree/Vitalise_Data_Model_v2_DELPHI

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.

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Appendix A

PRE-TAXONOMY Category	subcategory	after 1st Round Category	subcategory	after 2nd Round category	subcategory	after 3rd Round - Final category	subcategory
Environment/ context monitoring	Concentration levels	Environmental monitoring	*Concentration levels (air pollution levels, humidity, atmospheric pressure, air quality)*	Environmental monitoring	Concentration levels (air pollution levels, humidity, atmospheric pressure, air quality)	Environmental monitoring	Concentration levels (air pollution level, humidity, atmospheric pressure, air quality)
	Blind operation		removed				
	Door operation		removed				
	Technical alerts (Flood)		Technical alerts (Flood)		*Technical alerts (e.g., flood, smoke)*		Technical alerts (e.g., flood, smoke)
	Technical alerts (Smoke)		Technical alerts (Smoke)				
	Technical alerts (Temperature)		*Environmental Temperature (air or water temperature)*		Environmental Temperature (air or water temperature)		Environmental Temperature (air or water temperature)
	Alarm system		moved to assistive technologies				
	Luminosity		Luminosity		Luminosity		Luminosity
	Indoor movements		Indoor movements		moved to activity and behavioral monitoring		
							Audiovisual devices
Biometrics	Basic biometrics	Biometrics	*Face recognition*	Biometrics	Face recognition	Biometrics	Face recognition
			Voice recognition		Voice recognition		Voice recognition
Biosignals	Electrophysiological time-series	Biosignals and physiological monitoring	Electrophysiological time-series	Electrical biosignals	split to specific measures	Electrical Biosignals and physiological monitoring measures	
	Heart rate		moved to vital signs				
			Blood oxygen		Blood oxygen		Blood oxygen
			Blood sugar level		Blood sugar level		Blood sugar level
	EEG		EEG		EEG (electroencephalography)		EEG (electroencephalography)
	ECG		ECG		ECG (electrocardiography)		ECG (electrocardiography)
			EMG (electromyography)		EMG (electromyography)		EMG (electromyography)
			GSR (galvanic skin response)		GSR (galvanic skin response)		GSR (galvanic skin response)
					Vo2 (maximal oxygen consumption)		Vo2 (maximal oxygen consumption)
		vital signs	*diastolic blood pressure*	vital signs	diastolic blood pressure	(Primary) Vital signs	diastolic blood pressure
			systolic blood pressure		systolic blood pressure		Systolic blood pressure
			heart rate		heart rate		heart rate
			body temperature		body temperature		body temperature
			respiratory rate		respiratory rate		respiratory rate
			oxygen saturation		oxygen saturation		oxygen saturation
			body height		moved to body composition		
			body length		moved to body composition		
			body weight		moved to body composition		
			Body Mass Index		Moved to body composition		
				body composition	*body height*	Body size and composition	*body height - lying (measured on a horizontal surface)*
					body length		*Body measures (fat, mass, muscle, water, and bone)*
					body weight		body weight
					Body Mass Index		Body Mass Index
							Circumference measures (head, neck, biceps, waist, hip, chest, forearm, thigh and calf)
physiological monitoring	Patient history & demographics	merged with other categories	changed to questionnaires and surveys				
	Weight BMI		moved to vital signs				
	Virtual reality		Changed to category				
cognitive function	Cognitive training	Cognitive ability and mental processes	moved to assistive technologies	Cognitive ability and mental processes		Cognitive ability and mental processes	
			questionnaires of cognitive function		removed		

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(*continued*)

PRE-TAXONOMY		after 1st Round		after 2nd Round		after 3rd Round - Final	
Category	subcategory	Category	subcategory	category	subcategory	category	subcategory
			cognitive tasks and paradigms		cognitive tasks and paradigms		cognitive tasks and paradigms
			memory		memory		memory
			attention		attention		attention
					processing speed		processing speed
Activity monitoring and tracking	Body battery	Activity and behavioral monitoring and tracking	removed	Activity and behavioral monitoring and tracking		Activity and behavioral monitoring and tracking	
	Body position		Body position		*human body location (indoors or outdoors)*		human body location (indoors or outdoors)
	Calories burned		moved to Biosignals and physiological monitoring				
	Gait		Gait		removed		
	Energy expenditure		removed				
	Human balance		Human balance		Human balance		Human balance
	Inverse kinematics data		Inverse kinematics data		*movement monitoring*		movement monitoring
	Movement measurement		Movement measurement		*movement monitoring*		
	Orientation		Orientation		Orientation		Orientation
	Physical activity		Physical activity		*Physical activity level*		Physical activity level
	Physical performance		Physical performance		Physical performance		Physical performance
	Physiological and behavioral biomarkers		moved to Biosignals and physiological monitoring				
	Temperature		Moved to Vital Signs				
	Sleep		Sleep		Sleep		Sleep
	Steps		Steps		Steps		Steps
	Stress level		Stress level		Stress level		Stress level
	Vo2		moved to Biosignals and physiological monitoring				
	Well-being evaluation		removed				
	Blood oxygen		moved to Biosignals and physiological monitoring				
	Blood sugar level		move to Biosignals and physiological monitoring				
			Walking speed		Walking speed		Walking speed
			Technology Usage patterns		*Technology Usage habits and patterns*		Technology Usage habits and patterns
			fall detection		fall detection		fall detection
			Gesture detection		*Gesture recognition and detection*		Gesture recognition and detection
			Digital questionnaires and surveys		removed		
			audio stream		*audiovisual devices*		moved to environmental monitoring
			Video stream		*audiovisual devices*		moved to environmental monitoring
Assistive Technology	Alarm system	Assistive Technology	Alarm system	Assistive Technology	*reminders and alerts*	Assistive Technology	Reminders and alerts
	Engaged users		removed				
	Natural language understanding		Natural language understanding		Natural language understanding		Natural language understanding
	Safe bathroom usage		Supporting bathroom usage		removed		
	Safe walk assistance		walk assistance		walk assistance		walk assistance
	Technology Usage habits		moved to activity and behavioral monitoring and tracking				
	Video stream		moved to activity and behavioral monitoring and tracking				
	Voice commands		changed to natural language processing				
	Walking speed		moved to activity and behavioral monitoring and tracking				
					coaching		coaching
					support activities of daily living (ADLs)		Support activities of daily living (ADLs)
					training		training
Virtual reality/		extended reality		Extended reality – XR (VR & AR)	*Virtual reality (VR)*	Extended reality – XR (VR & AR)	Virtual reality (VR)
					Augmented reality (AR)		Augmented reality (AR)

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PRE-TAXONOMY Category	subcategory	after 1st Round Category	subcategory	after 2nd Round category	subcategory	after 3rd Round - Final category	subcategory
interactive technology	Web Interaction		removed				
	Gesture detection (smile)		moved to activity and behavioral monitoring and tracking				
	Alternative and augmentative Interaction		Alternative and augmentative Interaction		removed		
	Intuitive user interface		Intuitive user interface		removed		
		Mobile and computer games	*Mobile games* *Computer games*	serious games	*cognitive gaming* *physical gaming - exergames*	serious games	cognitive gaming physical gaming - exergames
					educational games		educational games

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