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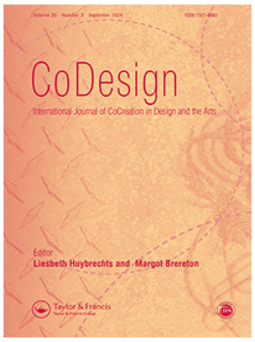
DOI
10.1080/15710882.2024.2435606

Publication date
2024

Document Version
Final published version

Published in
CoDesign



CoDesign
International Journal of CoCreation in Design and the Arts

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ncdn20

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To cite this article: Ela Liberman Pincu, Elmer D. van Grondelle & Tal Oron-Gilad (03 Dec 2024): A Context-based Design Toolkit (CoDeT) for Socially Assistive Robots (SARs): a methodological approach, CoDesign, DOI: 10.1080/15710882.2024.2435606

To link to this article: https://doi.org/10.1080/15710882.2024.2435606

CODESIGN
https://doi.org/10.1080/15710882.2024.2435606

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A Context-based Design Toolkit (CoDeT) for Socially Assistive Robots (SARs): a methodological approach

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ABSTRACT
This paper presents the Context-based Design Toolkit (CoDeT) methodology – a practical toolkit designed to facilitate collaborative design and evaluation of Socially Assistive Robots (SARs). CoDeT elicits user and other stakeholder needs, perceptions, and preferences. The methodology for creating a CoDeT is three-phased. The first phase is the Contextual space in which the designer generates a use-case-specific toolkit. The second phase is the Investigation space, which refers to utilising the toolkit among different users and stakeholders. The third phase is the Design Space, which returns to the design team to analyse the outcomes and define design guidelines. Rather than an exhaustive research investigation, our work provides guidelines and illustrative examples for using CoDeT effectively. Following the CoDeT methodology enables designers to gain insights regarding stakeholders' and users' perceptions and expectations of robotic roles and their most suitable appearances.

ARTICLE HISTORY
Received 29 July 2024
Accepted 22 November 2024

KEYWORDS
Participatory design; visual qualities; design space; robot appearance; robot role

1. Introduction

1.1. Design toolkits

Design toolkits are collections of tools and resources that help designers apply design thinking to their work and create products and services. Design toolkits provide guidelines, templates, and best practices to create effective designs, including user research, ideation, prototyping, testing, and collecting feedback from potential users (Benedek and Miner 2002; Kwok, Harrison, and Malizia 2017; Tim and Jocelyn 2010; Viera et al. 2020). Many examples of design toolkits are available to improve designers' work. However, most cannot be easily adapted to the unique requirements of Socially Assistive Robots (SARs).

Feil-Seifer and Mataric (2005) define SARs as an intersection of assistive robots and socially interactive robots. Like assistive robots, SARs aim to provide assistance to human users, and this assistance is carried out through social interaction. This requires developing effective interactions to create close and effective relationships with a human user to assist and achieve measurable progress. The robot's embodiment is one of the key

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properties for developing the interaction component between humans and SARs (Fong, Nourbakhsh, and Dautenhahn 2003). The robot's appearance and interaction modalities must be linked to its role and give the correct impression regarding its task and intended users (Feil-Seifer and Matarić 2005).

To achieve this, we developed a methodology for creating a use-case-specific, human-robot relationship-driven, Context-based Design Toolkit (CoDeT) for SAR designers. To apply this methodology, the designer creates a particular CoDeT for user research of new SAR designs. This toolkit is then facilitated to investigate users' and stakeholders' perceptions and preferences regarding the SAR's roles and matching Visual Qualities (VQs). VQs in product design refer to the aesthetic elements that contribute to the overall look and feel of a product. These include aspects such as colour, shape, texture, form, and composition. By carefully considering these visual elements, designers can create products that are not only functional but also visually appealing and engaging to users (Liberman-Pincu, Parmet, and Oron-Gilad 2023). Our previous work link appearance with users' perceptions of a SAR's characteristics; VQs such as colour, figure, and abstraction level emerged as significant factors affecting both children's and adults' perceptions (Liberman-Pincu and Oron-Gilad 2021; Liberman-Pincu, Van Grondelle, and Oron-Gilad 2021). For example, to achieve the perception of a friendly SAR, a designer should consider using an A-shape or hourglass structure and avoid a V-shape, choose light colours (from a set of choices we found that a combination of white and blue was preferred), and avoid dark colours (Liberman-Pincu, Parmet, and Oron-Gilad 2023). In addition, children perceived chamfered-edged robots as more mature and intriguing than rounded-edged ones (Liberman-Pincu and Oron-Gilad 2021).

When designing SARs, it is important to consider the ideal appearance of the robot to facilitate effective interaction with users. In other words, what characters should the embodiment convey to establish a desired relationship? For instance, should the robot express professionalism or compassion when designing a robot for hospital environments? What are the users' needs, perceptions, and preferences regarding a medical robot? What are the requirements of other relevant stakeholders? The CoDeT was developed to provide a methodology that supports design teams in synthesising outcomes derived from the elicitation of users and stakeholders.

1.2. Contextual layers of Socially Assistive Robots (SARs)

Studies show that users' preferences and expectations regarding the robot's characteristics and appearance differ by use context (Korn and Korn 2019; Roesler et al. 2022; Złotowski, Khalil, and Abdallah 2020). For an effective human-robot interaction, it is crucial to identify and formulate the needs and expectations of the users, as this affects both the embodiment and interaction components (Rosén 2021). The physical form of the SAR affects users' perceptions of the robot's personality and can help understand its nature and capabilities (Beer et al. 2011; Broadbent et al. 2013; Liberman-Pincu, Parmet, and Oron-Gilad 2023; Oh et al. 2019; Pinney, Carroll, and Newbury 2022; Roesler, Heuring, and Onnasch 2023; Złotowski et al. 2016). However, most studies focus on robots' anthropomorphism (human-, animal-, or machine-likeness) rather than their visual qualities by using degrees of anthropomorphism to fit different domains. Furthermore, matching a robot's appearance and tasks can improve users' acceptance

(Goetz, Kiesler, and Powers 2003; Złotowski et al. 2016). Minor design manipulations such as add-ons, clothes, and head-light colours can affect users' perceptions, attitudes, and behaviours (Dou et al. 2022; Ela Liberman-Pincu et al. 2021; Liberman-Pincu and Oron-Gilad 2023; Trovato et al. 2016).

Still, SAR manufacturers tend to design and deploy the same robotic embodiment for diverse contexts (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022). We argue that since users' experience differs with the context of use, applying the same robotic embodiment for diverse contexts is suboptimal as it neglects to address the contextual layers in the visual design in a similar way to how SARs' social interaction abilities are crucial for fulfilling their roles in different application areas.

Previous analysis of existing SARs in various use contexts (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022) led to the formation of four contextual layers:

(1) **The domain in which the SAR exists**. Based on a literature survey and market research, seven popular domains for SARs were identified: Healthcare (including Eldercare and Therapy), Educational, Authority (including Security), Companion, Home assistance, Business, and Entertainment.
(2) **The physical environment where it is intended to operate**. SARs operate in diverse environments, which can be classified based on two levels. First, the physical location of SARs can be indoor or outdoor, influencing engineering decisions related to lighting, noise, humidity, dust, and surface conditions. Second, the privacy level determines whether SARs operate in personal (home or private office), semi-public (workplace, assisted living residence), or public settings.
(3) **The intended users**. Users can be categorised based on various factors. These include demographic information (such as gender, age, or culture) and their specific needs, abilities, and disabilities (both cognitive and physical). Additionally, users can fall into different roles, such as professional (trained to work with the robot, like a nurse using a medical robot), non-professional (e.g. a hotel guest interacting with a receptionist robot), or random (occasional passers-by). Some users may also be familiar with the robot due to regular interactions in a workplace or other settings, even if it's not part of their professional duties (e.g. a security robot stationed at a building entrance).
(4) **The role**. The human-robot relationship is tied to the robot's role and tasks, addressing questions like: 'Is this robot here to assist me, and how?' Various theories classify relationships hierarchically, exploring aspects like obedience, supervision, and leadership. Our model adopts eight roles from the literature, including Information exchange, Physical load reduction, Transport, Manipulation, Cognitive stimulation, Emotional stimulation, Physical stimulation, and Regulation. Each role fits into a three-level hierarchy of human-robot interactions: robot-led, equal, or human-led.

Defining the use case for a particular robot in detail is crucial to place it in a specific context and reduce inaccurate assumptions and biases regarding its role, behaviour, and functionality. It guides the designer when creating and defining the main components and is essential when involving users in Participatory Design (PD) processes. Introducing the domain and environment, presenting the users, and explaining the robots' roles and functions helps participants imagine and define the human-robot relationship (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022). The CoDeT methodology is aimed at addressing these four contextual layers by exploring non-designers, stakeholders', and end-users' contextual perceptions and preferences for SARs to fulfil their roles (i.e. perceived characters) and to address their visual qualities (VQs), suitable for the specific contexts of use. We do this in the form of Participatory Design (PD) workshops.

1.3. Participatory design (PD)

PD is a process that involves non-designers, stakeholders, and end-users in different stages of the design (i.e. from user needs in preliminary design research to usability testing in the final stages (Yasuoka-Jensen and Kamihira 2016)). This approach is increasingly important in design culture and can increase user satisfaction and product success (de la Guía, Lucía, and de-Miguel-Molina 2017; Simonsen and Robertson 2012). Using a wide selection of research methods, designers and developers can elicit tacit knowledge regarding users' and stakeholders' expectations, perceptions, needs, and desires to be used later in the design process (de la Guía, Lucía, and de-Miguel-Molina 2017; Spinuzzi 2005) and to support a creative development atmosphere that considers the user experience (Liu, Moultrie, and Ye 2019; Rosenzweig 2015; Sanders, Brandt, and Binder 2010), accounting for different preferences among stakeholders (e.g. gender, age), and domain-specific human-robot interaction qualities, i.e. different human-robot relationships. For example, users and caregivers (Oros et al. 2014; Pino et al. 2015) or users and developers (Lazar et al. 2016). Incorporating diverse perspectives into the design process (e.g. vulnerable groups or sensitive topics (Drain, Shekar, and Grigg 2018; Raman and French 2022); expertise and cultural perceptions (Calvi et al. 2022; Taffe and Kelly 2020)) are essential to gain a broader understanding and aesthetic perceptions influenced by cultural norms and values (Domingues, Zingale, and De Moraes 2017). Yet, it is important to note that in the context of industrial product design, especially complex products in robotics, while we strive to incorporate the principles of PD, the process often requires a balance between collaborative input and the specialised expertise of designers. Hence, the outcome of a PD process is not the final design but rather a design space model that informs the designers. The design space model we refer to is intended to capture and integrate the diverse perspectives of all participants, including non-designers. However, the final design decisions must be informed by the technical and aesthetic expertise of the designers to ensure feasibility, effective and efficient functionality, and market viability.

In Human-Robot Interaction studies, participatory design processes were applied to extract user needs and identify the essential robotic characteristics, e.g. (Gasteiger et al. 2022; Pnevmatikos, Christodoulou, and Fachantidis 2022; Rogers, Kadylak, and Bayles 2022). Different PD frameworks and tools were suggested for the HRI design process, but as far as we know, they are always built upon off-the-shelf robots. For example, The Time, Space, and Structure (TSS) framework (Bertel Lykke, Rasmussen, and Christiansen 2013) can help create real-world learning environments, and Situated Participatory Design (sPD) (Stegner, Senft, and Mutlu 2023) can help design human-robot interactions with older adults through realistic, iterative interactions with the robot. These frameworks are beneficial in eliciting needs and expectations but may be biased due to the use of existing robotic designs. Axelsson et al. (2022) suggested a framework with co-design canvases to be applied in different parts of the design process. Here, the design team draws a picture of the robot based on defined design guidelines. Yet, participants are involved in defining the requirements of the robots but not in preferring the visual aspects of the designs.

Another advantage of CoDeT is that it is built as a **tangible toolkit**. Tangible toolkits are valuable for facilitating participatory design focus groups, as they can help participants feel more engaged in the design process by providing them with a hands-on experience, facilitate communication between participants and designers by providing a common language and visual representation of ideas, encourage participants to think more creatively and generate new ideas by providing a physical medium for brainstorming, make the design process more accessible to participants who may not have experience with design software or other digital tools, and provide a more tangible record of the design process, making it easier to document and share ideas with others (Brandt 2007; Rygh and Clatworthy 2018).

CoDeT focuses on users' perception of the robot's **role** and **appearance**. It contains printed cut-outs of robotic components representing different VQs (e.g. structure, morphology, colour) related to a specific use case, sticky notes to define the robot's desired characteristics, and drawing materials for design adjustments. Participants in the PD workshop are urged to discuss and create new design models for a particular use case. Participants are encouraged to discuss their expectations regarding the robot character and to create design models by selecting and assembling these cut-outs. The CoDeT is use-case-specific; each use case requires a designated set of cut-outs. This paper aims to provide methods and guidelines for developing a CoDeT and presents its application to a use case. CoDeT gathers requirements from users and stakeholders for new SARs and applications. The following sections define the CoDeT methodology, demonstrate its guidelines and principles for creating a specific toolkit (Contextual space), detail the workflow of the PD workshops (Investigation space), and explain how to use the outcomes in the design process (Design space), as shown in Figure 1. Rather than focusing on a specific study, it uses outcomes from various contexts to illustrate the methodology.

In our paper, we use the terms 'toolkits', 'methodology', and 'guidelines' to refer to distinct but interconnected components of the CoDeT:

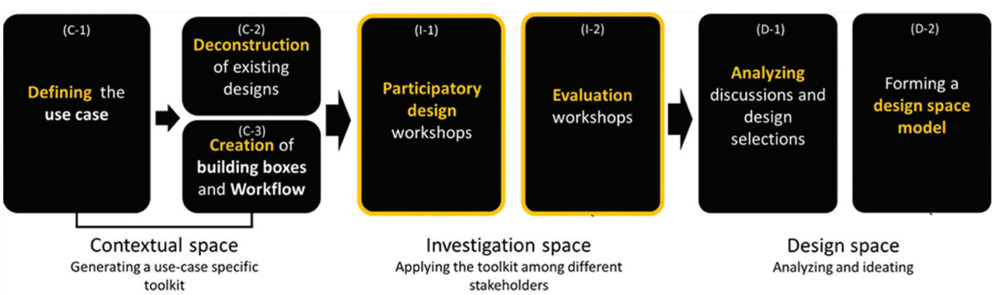

Figure 1. The CoDeT methodology consists of three phases (contextual-preparatory, investigation in which users are involved, and design) parsed into steps.

Toolkits: These are the tangible tools used during PD workshops, including printed cut-outs of visual qualities, sticky notes, and drawing materials. They facilitate the participants' hands-on creation and evaluation of design models.

Methodology: This refers to the structured process of CoDeT, which includes the Contextual, Investigation, and Design phases. The methodology outlines how the toolkits are made and used.

Guidelines: The term 'guidelines' in our paper is used in two contexts. First, it refers to the principles and recommendations derived from the analysis of workshop outcomes, which inform the design of SARs by providing insights into user preferences and contextual requirements. Second, it refers to the practical instructions for effectively using CoDeT, as demonstrated in the methodology section. These guidelines include steps for conducting PD workshops, utilising the toolkit, and analysing the results.

While these terms are related, they are not used interchangeably. Each term represents a specific aspect of the CoDeT framework, contributing to a comprehensive approach to context-based design.

2. The CoDeT methodology: contextual, investigation, and design spaces

The methodology for creating and applying a CoDeT consists of three phases (contextual-preparatory, investigation, and design) parsed into seven steps. Figure 1 charts the methodology, and we now define each one of the phases.

In the ***Contextual space,*** the designer generates a use-case-specific toolkit by (C-1) mapping the use case by the four context layers (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022) and (C-2) deconstructing the visual qualities of existing robots and related products before (C-3) creating the relevant building boxes of the toolkit and determining the workflow for the investigation phase. For example- for a security robot, we will search for existing security robots and other security products to explore their design language.

The following phase, the ***Investigation space***, refers to utilising the toolkit among different stakeholders. We use the toolkit in two ways: (I-1) reconstruction, where participants of the PD workshops are asked to create design models using the printed cut-outs of the toolkit, and (I-2) evaluation, where new participants are invited to evaluate these design model outcomes to confirm or reiterate designs and expectations.

In the final phase, the ***Design space*** returns to the design team. The designer (D-1) analyzes the participants' selections and discussion by two main themes: role and appearance. Then, this analysis process is used to understand users' needs, perceptions, and preferences to (D-2) form a design space model and generate guidelines for the process of the robot's appearance design.

The following sections detail each phase of the CoDeT methodology and illustrate them through examples obtained from case studies conducted with three different focus groups: Engineering Students, Older Adults Residents of an Assisted Living Facility, and Robotic Conference Participants. This work provides practical guidelines using examples for effectively utilising CoDeT; therefore, it does not aim to contain an exhaustive research investigation of any particular context.

2.1. Phase I: the contextual space

This phase is preparatory and dedicated to generating the use-case-specific CoDeT.

2.1.1. C-1: defining the use case for the toolkit

The first step is defining the use case by the domain, environment, users, and robots' roles and functions (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022). Precise definitions guide the designer when creating the building boxes and the workflow for the toolkit. For example, does the robot need arms for its intended role? Should it have wheels?

For demonstration, we chose to exemplify how we built the CoDeT for three SAR use cases that differ by their contextual layers (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022): MAR: a Medical Assistant Robot MAR for a hospital environment, COR: a COVID-19 Officer Robot, and PAR: a Personal Assistant Robot for home/domestic use, all share similar requirements (e.g. must be mobile and have a screen to perform their roles) and are indoor scenarios to simplify the demonstration, as detailed in Table 1.

2.1.2. C-2: deconstruction of visual qualities

This step aims to understand what is already out there in the market. We start by collecting images of existing commercial robots and products related to the intended use case. Then, using a deconstruction process, we isolate recurring visual qualities and create a preliminary taxonomy. The deconstruction process encompasses the following two steps: Market Survey and VQ Identification, and Group and Inner Classifications, as we demonstrate in (Liberman-Pincu, Parmet, and Oron-Gilad 2023).

Table 1. Defining the use case – An example of three SARs' use cases defined by four layers of context.

		Domain	Environment	Users	Role	Requirements
MAR	This robot will serve as an assistant for the medical staff. Through it, the medical team will be able to communicate in video calls with isolated patients and bring equipment, food, and medicine into patients' rooms.	Healthcare	Public Indoor	Medical crews Professional Hospitalized and caregivers. Non-professional	Information exchange/ Transport Human-led interaction/ equal	(1) must be mobile. (2) must have a screen.
COR	This robot will ensure passersby compliance with COVID-19 restrictions—Social distancing and wearing a face mask.	Authority	Public Indoor	Passersby Non-professional	Regulation Robot-led interaction	
PAR	This robot will assist users with daily tasks, recommend activities at home and outside, and remind them of their tasks and appointments. The robot allows users to watch videos, listen to music, play, and have video chats with family and friends.	Home assistance	Personal Indoor	Diverse Non-professional	Physical load reduction/ Cognitive stimulation/ Emotional stimulation Human-led interaction/ equal	

For the *Market Survey and VQ Identification*, we curated a dataset of 90 commercial SAR images to identify prevalent VQs. These VQs encompass various factors, including colour, morphology, and dimensions. By methodically grouping designs based on these attributes, we gain valuable insights into the visual appearances of SARs.

Then, for the *Grouping and Inner Classifications*, we categorised SARs into distinct groups, such as human-like, pet-like, and machine-like. Within each group, we delved deeper into the inner classifications. For instance, under the category of robot morphology, we explore the contrast between realistic dog-like robots and abstract representations of humanoid robots.

To demonstrate this methodology, we showcase a taxonomy created for SARs' visual qualities related to the robot's body (structure, outline, and colour) and screen design (morphology, dimensions, and graphics (GUI)), as shown in Figure 2. Other components that can be included in the CoDeT are robotic arms, wheels, accessories, or textures related to the context of the investigation. Since the general approach is to keep the CoDeT simple and succinct, we included morphology only in the shape of the screen, maintaining a relatively small set of cut-outs yet still gaining an understanding of the users' expectations and perceptions.

2.1.3. C-3: creation of the CoDeT building boxes and workflow

Using the taxonomy, we create the building boxes and decide on the workflow for administering the toolkit for a use case. The building boxes are physically printed cut-outs presenting possible visual qualities that participants can use to build their robot models. The workflow means that participants assemble a robotic design by selecting one visual quality at a time; this way, they can discuss its meaning and relevance without being biased by other visual qualities.

The parts were designed using CAD software as 3D models. Then, the building boxes were printed as 2D drawings, cut to the shape, and laminated so participants could

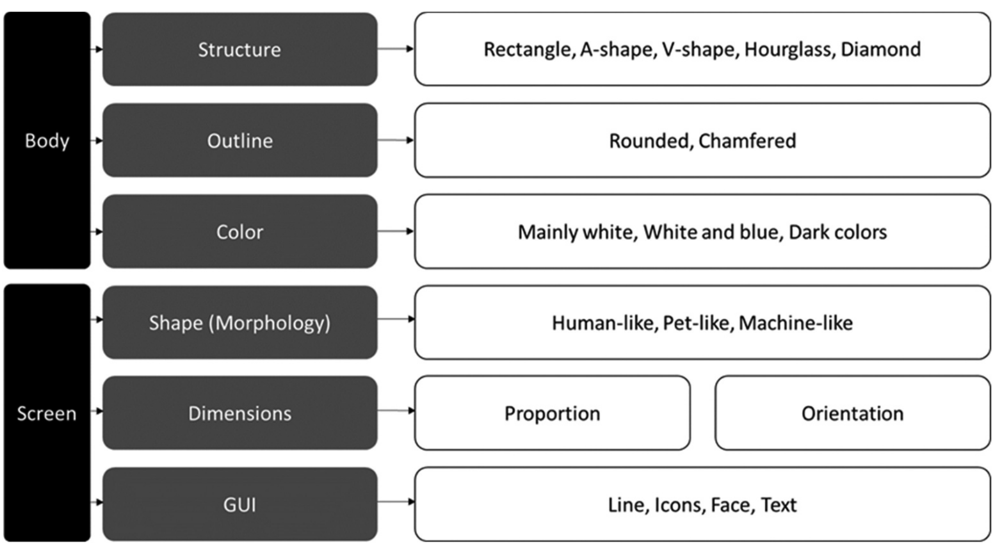

Figure 2. A taxonomy of SAR visual qualities used in our studies.

physically hold and move them around. Participants were asked to build the robot's body in three steps (e.g. body first, then outline, then colour). Each selection affected the suggested options for the next step (e.g. if the choice was to use an hourglass structure, only hourglass structures were presented in the cut-outs of the following steps). This way, one can maintain a small number of possibilities for participants to discuss and agree upon and avoid confusion with decisions already made. The following step was the screen design, starting with the screen's shape (human head, dog head, rectangle, or rounded), then its orientation and proportion (compared to the body), and finally, the GUI. Figure 3 presents the building boxes and the participatory design workflow for our workshops. We chose this order because the structure is the most prominent visual quality of the robot's body. Notably, the workflow can be reversed or altered to emphasise the screen or other visual qualities more.

2.2. Phase II: the investigation space

The second phase of the methodology refers to applying the CoDeT among non-designer stakeholders. Stakeholders of socially assistive robots differ depending on the context of use. For example, users, patients, caregivers, healthcare providers, developers, and policymakers (Koh et al. 2021; Oruma et al. 2022; Papadopoulos et al. 2020). Previous studies suggested that the same context can be perceived differently due to cultural background (Korn, Akalin, and Gouveia 2021b; Lim, Rooksby, and Cross 2021), age, or gender (Chien et al. 2019; Kuo

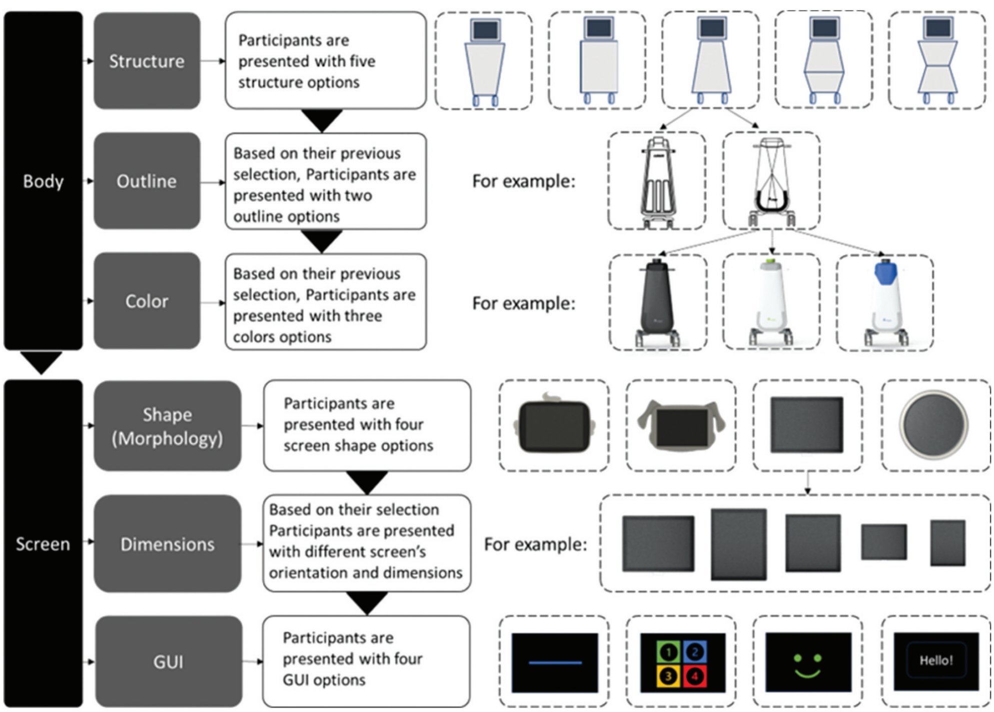

Figure 3. An example of the building boxes based on the taxonomy of SAR visual qualities and the participatory design workflow. Each selection affected the suggested options for the next step.

et al. 2009; Shen and Koyama 2022); therefore, when applying the CoDeT, the designer must use participants with similar demographic characteristics in each workshop session.

We use the toolkit in two ways: to create design models with participants in the **PD workshops** and then to evaluate these models by participants in the **evaluation workshops**. We recommend conducting multiple focus groups to ensure robustness and capture variations in the design models and feedback. Each focus group lasts around 90 minutes, with group sizes varying but optimally consisting of 5–10 participants. The participants' characteristics are diverse from one group to another, but we strive to keep the groups homogeneous. Using the provided building boxes, sticky notes, and drawing materials, participants in the PD workshop are urged to discuss and create new design models for a particular use case. To assess these outcomes, in the evaluation workshops, new focus groups are exposed to the robotic models, and their perceptions of the designs are discussed to see if they match the intentions of the PD groups. This two-directional assessment informs the design space model of the third phase. Figure 4 illustrates the workflow of the two types of workshops. The following sections show examples of this process through a case study.

The following sections will elaborate and exemplify the Investigation space and the Design space (Figure 1) of the CoDeT methodology. For this, as shown in Figure 4, we use eight focus groups' outcomes. Three PD workshops were conducted among end users (older adult residents of an assisted living facility) and three among developers (two among robotic conference participants and one among engineering students). Following that, two additional evaluation workshops were conducted among older adult end users. We present the outcomes of the investigation space and how they led to the design space.

2.2.1. *Participatory design workshops*

To initiate the session, we introduce the relevant contexts (e.g. as outlined in Table 1). By discussing the domain, environment, potential users, and stakeholders, as well as

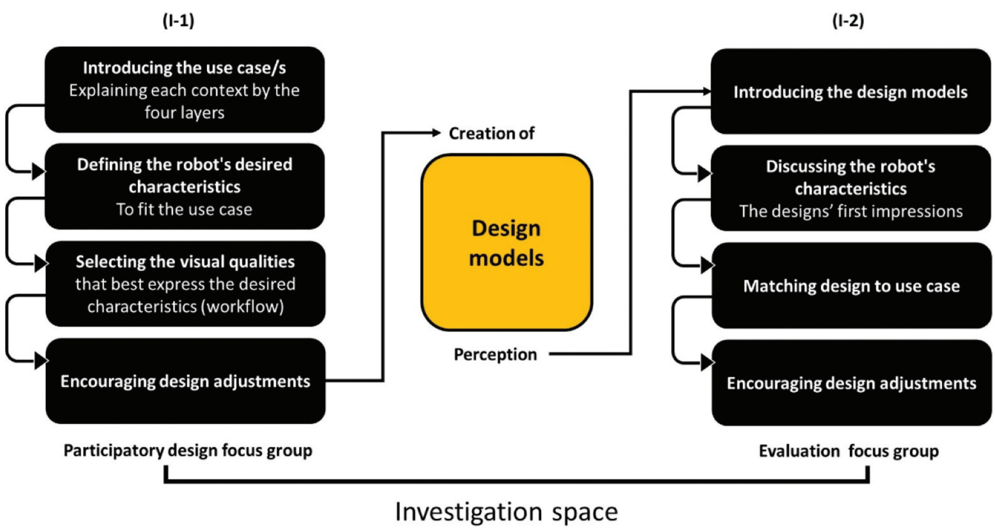

Figure 4. The workflow of the investigation space workshops, where two kinds of workshops are defined. The participatory focus groups create robotic design models with the CoDeT. Then, those designs are presented to an evaluation focus group for agreement, confirmation, or necessary modifications.

explaining the robot's roles and functions, workshop participants can envision and define the human-robot relationship. It is crucial to explore each layer thoroughly to ensure a holistic approach that aligns with stakeholder perspectives and contextual needs. Next, participants suggest suitable characteristics for the robot that resonate within this multi-faceted context. Suggestions are written on the board or attached using sticky notes for the group discussion. Then, the participants and the moderator discuss and agree on the most prominent characters for the presented use case. Next, using the printed cut-outs of the robotics parts, participants create design models following the structured workflow (illustrated in Figure 3) to express their perceptions and expectations. Lastly, following a collective decision on the robot's design model, participants are encouraged to add and draw features not included in the CoDeT building boxes.

Figure 5 summarises the exploratory PD process and presents exemplars of participants' suggested characters for a medical assistant robot and a COVID-19 officer robot (top), an example of robotic conference participants discussing body structures and debating over the morphology and size of the robot's screen (centre) and adjustments participants made to their final robotic designs (bottom).

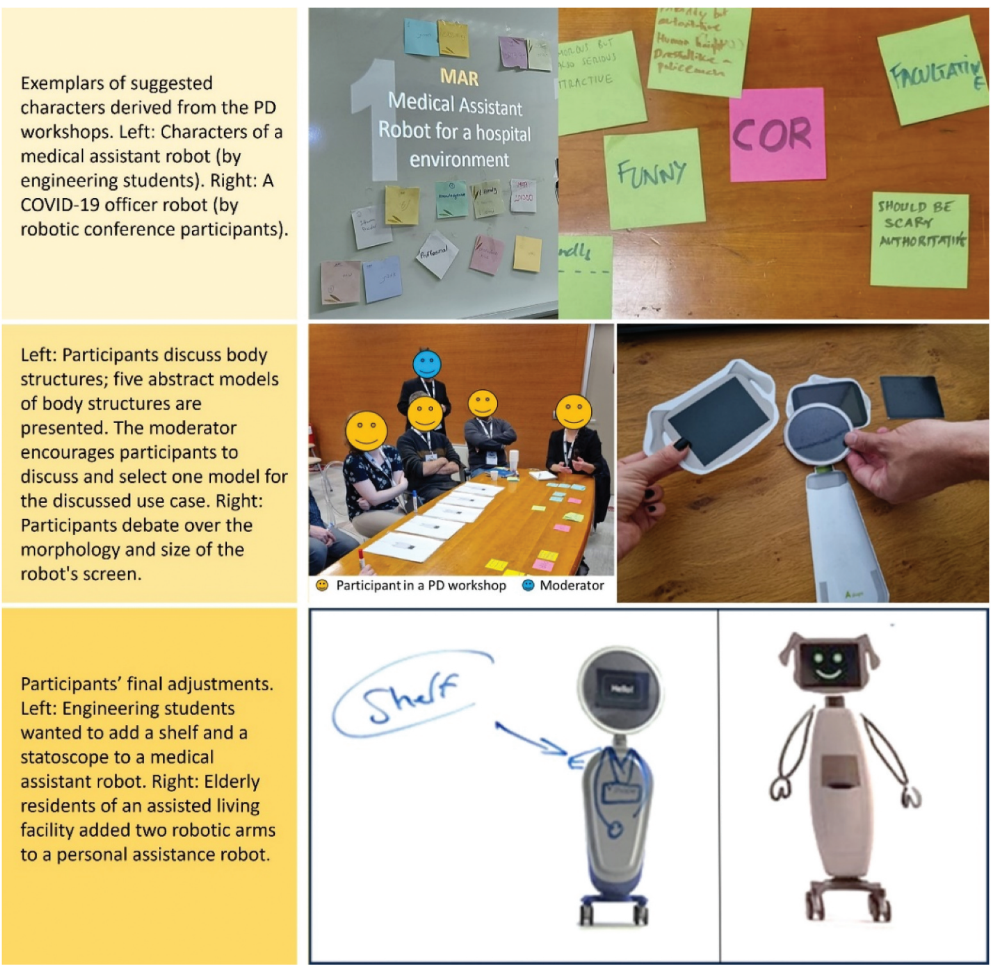

Figure 5. A summary of an exploratory PD process with examples.

2.2.2. Evaluation workshops

The evaluation workshops assess the design models assembled by the PD workshops participants among new participants. These workshops contain three parts: evaluating the robotic model's design perception, evaluating the robots' role perception, and following a PD process for design adjustments, as detailed below.

2.2.2.1. Evaluating design perception. The robotic design models assembled by the PD groups are presented on the board to the new participants. We ask participants to discuss each robot model separately and attribute characteristics and gender, emphasising that there are no wrong answers. Those characteristics are then written on the board and discussed by the group and the moderator.

2.2.2.2. Evaluating robots' role perception. Different contexts of use are written on the board. Participants are asked to discuss and match a robotic model from the robots displayed on the board for each use case.

2.2.2.3. Design adjustments by a PD process. After choosing the suitable robot model for each use case, participants are asked to suggest design adjustments to improve the existing design to fit the use cases better by drawing their ideas on the boards.

Figure 6 summarises the Evaluation workshops process and presents exemplars of older adult residents attributing characteristics to the design models (top) and matching the design model to use cases and adjusting the design (bottom).

Figure 6. A summary of an evaluation workshop process with examples.

2.3. Phase III: the design space

In this phase, the outcomes of all workshops are collected, and the verbal discussions are transcribed. A thematic analysis (Braun and Clarke 2012) is then conducted following two main themes: *Role* and *Appearance*. For each theme, we elicit participants' needs, perceptions, and preferences that arose in the workshops. These are translated into design guidelines to be used by the design team towards the final design. Figure 7 illustrates this analysis process.

To demonstrate how to leverage the results to formulate design guidelines, we used the outcomes of all eight workshops for the PAR (personal assistant robot) as an illustration. Figure 8 presents the workshop participants' design models for PARs by group members (developers/end users) and group type (PD/evaluation).

We analysed the participants' selections and discussions throughout the process. The end users' groups expressed their need for a personal robot with skills like accounting, cleaning, cooking, and more. Indeed, in four out of five workshops, participants added arms to the robot. They also mentioned entertaining skills and a welcoming personality. The thematic analysis revealed that developers and users wanted the design of a personal robot to be adaptable, mainly regarding the colour and morphology of the robot. One participant suggested modifying the robot's gender according to user preference. The need for customisation was evident in participants' selections of VQs; each group selected different body structures, colours, and outlines. Developers selected mostly machine-like morphology, while the end users selected

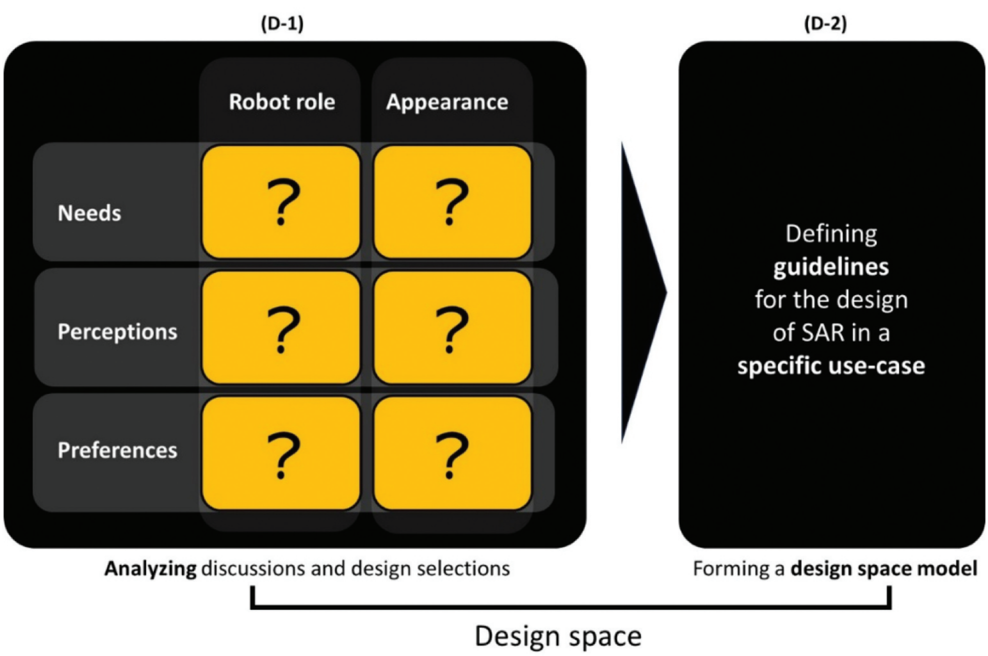

Figure 7. The thematic analysis of participants' verbal discussions follows two themes: role and appearance. Eliciting users' needs, perceptions, and preferences leads the design team to formulate design guidelines for SARs in a specific use case.

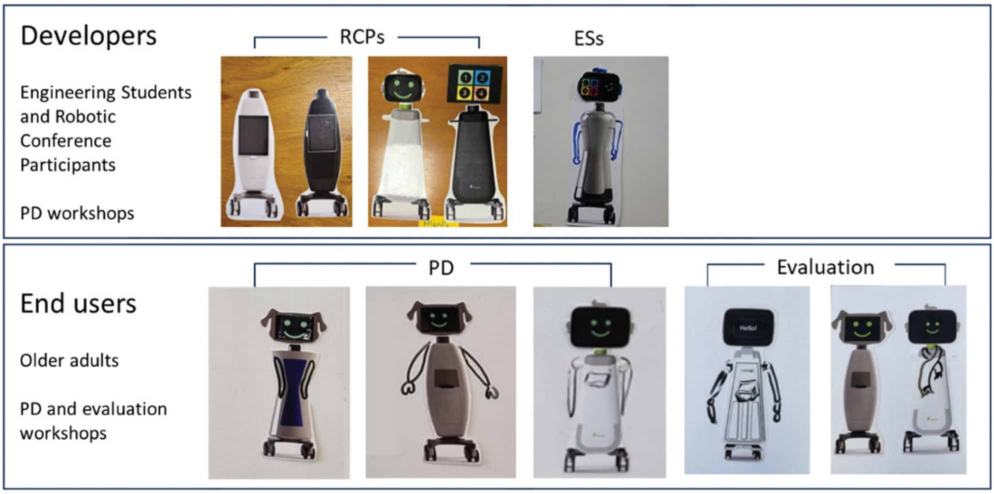

Figure 8. Workshop participants' design models for PARs by group members and type.

either pet-like or human-like. In three out of the eight groups, participants could not agree on the most suitable VQs and assembled or selected two different design models.

Out of the six participatory design (PD) groups, five chose to position the robot's screen on top of its body, creating a head-like appearance. This design choice was likely influenced by the intuitive association of a screen with a 'face', facilitating a more natural interaction for users. However, one group, consisting of participants from a robotics conference, opted to place a large screen on the front of the robot. This alternative placement was driven by the idea of enhancing accessibility and visibility, allowing the screen to be easily viewed by both standing and seated individuals. This aligns with the study's findings that different user groups may have varying preferences for robot design, as seen in the evaluation of the CLARA and GoBe robots, where screen height and placement affected user interaction and satisfaction (Jerez et al. 2024).

We used this analysis to define the design guidelines regarding the robot's appearance, physical features, and behaviour. The appearance of a personal robot should convey a sense of friendliness along with professionalism; based on (Liberman-Pincu, Parmet, and Oron-Gilad 2023), the A-shape structure strikes a balance between friendliness and professionalism. It conveys openness and trust, while its clean lines and stability lend a professional aesthetic. Rounded edges soften its appearance, making it more inviting. Using smiling faces or other expressive features can further enhance the robot's friendliness. To enhance the overall user experience and foster a stronger emotional connection, the design should incorporate customisation options. These could include different colour schemes or the ability to modify the robot's morphology using add-ons. Such flexibility allows users to tailor the robot's appearance to their preferences and context, ultimately creating a more personalised and engaging interaction. The design must include robotic arms to enhance the robot's functionality, allowing it to perform physical tasks as highlighted explicitly by the participants, and a relatively big screen to provide ample display space for information, communication, and user interaction. Figure 9

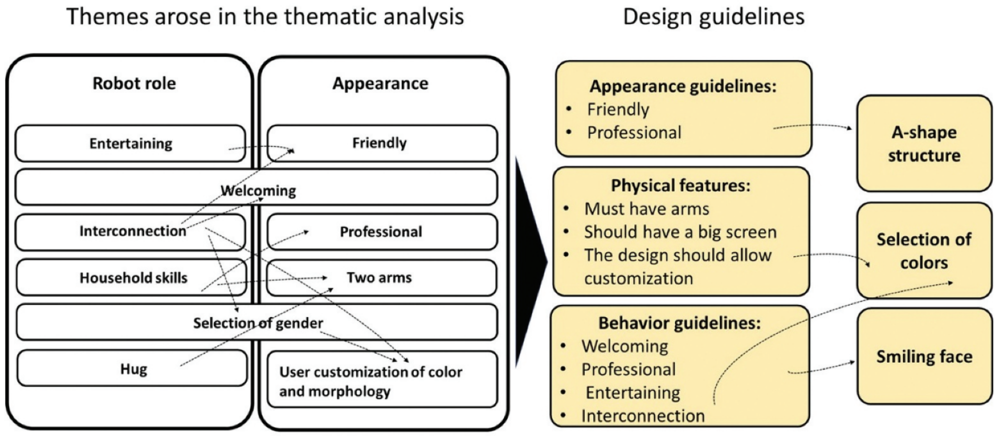

Figure 9. Notable themes derived from the thematic analysis of all focus groups (PD and Evaluation groups), the interconnections of appearance and role, and the design guidelines generated by the design team following the CoDeT methodology.

summarises some of the notable themes that arose in the thematic analysis, the connection between them, and design recommendations.

3. Discussion

SAR manufacturers often use a 'one design fits all' approach, deploying the same robotic embodiment for diverse contexts. However, previous studies highlight the impact of the SAR's robotic embodiment on users' perceptions, attitudes, and behaviours (Broadbent et al. 2013; Roesler, Heuring, and Onnasch 2023; Ela Liberman-Pincu et al. 2021). By selecting different VQs, product designers can lead users to form varied human-robot relationships (Liberman-Pincu, Parmet, and Oron-Gilad 2023). Designers often start from scratch when designing new robots due to the lack of standards in this field. As a result, their personal taste, norms, and aesthetic perceptions can significantly influence the design process. The end users' perceptions and norms do not always align with these design choices. Therefore, a user-centred approach using PD processes is essential for achieving the SARs' goals according to the use context, such as compliance in the case of an officer robot or trust in the case of a medical robot.

The CoDeT methodology is dedicated to designing toolkits for human-robot interaction research. It is based on the idea that the design of SARs should be context-based, considering the specific needs and expectations of stakeholders and users. The methodology involves a series of steps, including identifying the key stakeholders and users, defining the design goals and requirements, and generating a set of design elements that can be used to create a tangible toolkit. The toolkit can then be used to create SARs that are tailored to the specific needs of the stakeholders and users.

In this paper, we provide practical guidelines for creating and utilising CoDeT. We then demonstrate the CoDeT methodology through examples from three SAR use cases that differ by their contextual layers: MAR: a Medical Assistant Robot for a hospital environment, COR: a COVID-19 Officer Robot, and PAR:

a Personal Assistant Robot for domestic use, all three share common features (e.g. mobility and screen) to simplify the demonstration. The classification of SAR visual qualities into screen and body was based on the needs of our selected use cases, focusing on screens for interaction and bodies for mobility. This, however, may not cover all SARs' possible embodiments. Future research should include a wider range of SAR features, such as those without screens and with arms for support, to better understand their impact on interaction and functionality.

We used examples from PD workshops conducted among three focus groups: Engineering Students, older adult residents of an Assisted Living Facility, and Robotic Conference Participants. These workshops provided insights regarding stakeholders' and users' perceptions and expectations of robotic roles and their most suitable appearances. It is important to note that these were all convenient samples, chosen for practical reasons such as accessibility and feasibility. The main objective of this paper is to outline means and guidelines for developing a context-based design toolkit. The CoDeT aims to elicit requirements from potential users or other stakeholders towards the development of new SARs, SAR applications, or SAR implementations. This work does not discuss the outcomes of a specific study aimed at developing a particular SAR or use context. Instead, outcomes from various contexts are used to demonstrate the methodology steps and components. Following this methodology allows researchers to identify the key factors that influence the design of SARs, such as the specific tasks that the robot will perform, the environment in which it will operate, and the expectations of the stakeholders and users. By taking these factors into account, researchers can create SARs that are more effective and better suited to the needs of the stakeholders and users.

Returning to the motivation that led us to the development of the CoDeT and its application methodology, we discuss four aspects of applying the CoDeT methodology, integrating our main results and the existing literature.

3.1. Context-based design

The human-robot relationship and the user experience are influenced by four contextual layers that define the context of use: the domain in which the SAR exists, the physical environment where it is intended to operate, its intended users, and its anticipated role. Users' expectations of the robot's character differ by the use context (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022; Korn and Korn 2019; Roesler et al. 2022; Złotowski, Khalil, and Abdallah 2020). In our use case studies, we noted that the context and the robot's intended role had a greater impact on the participants' selections of characters and VQs than their personal preferences, as reflected by higher agreements among participants on the desired characters and VQs.

However, there was a unique use case for the PAR, where personal preferences played a more significant role. Applying the same robotic embodiment for diverse contexts of use is suboptimal and neglects to address the importance of linking role and appearance in SARs. CoDeT is context-focused, leading participants to assemble design models that fit the desired characteristics in a structured workflow.

3.2. Involving different stakeholders

The stakeholders of socially assistive robots vary depending on the context of use, including users, patients, passers-by, caregivers, and developers. Each stakeholder can bring different insights and highlight other aspects. In our example, in the case study of PAR, the older adult residents of an assisted living facility were more focused on interconnection aspects, while developers (robotic conference participants and engineering students) were more concerned with the technical issues of the robot's adaptability. Furthermore, stakeholders may even possess opposing views and requirements (Lazar et al. 2016; Oros et al. 2014; Pino et al. 2015). For instance, in our example, when asked to select VQs to assemble a PAR, older adult users mostly preferred human-like or pet-like morphologies and a smiling face for the GUI, while the developers preferred machine-like robots and avoided using a smiling face GUI in most cases. These findings are consistent with previous research (Bradwell et al. 2019), emphasising the significance of the investigation space and user involvement in the design process.

CoDeT provides an easy way to involve stakeholders in a PD process to gain a wider perspective and highlight these opposing views. This may help the design team overcome conflicting demands. The group outcomes, discussions, and insights provide a solid foundation for design space and guidelines considering different needs.

3.3. Culturally sensitive

The users' cultural background affects their perception of aesthetics (Domingues, Zingale, and De Moraes 2017). Users' cultural values, beliefs, and habits affect their trust, compliance, acceptance, and expectations of robots in addition to robots' role perception (Bartneck et al. 2005; der Pütten, Astrid, and Krämer 2015; Evers et al. 2008; Haring, Silvera-Tawil, et al. 2014; Korn, Akalin, and Gouveia 2021; Lim, Rooksby, and Cross 2021; Rau, Li, and Li 2009, 2010; Syrdal et al. 2011). Previous research on cultural design preference in terms of visual appearance focused mainly on robot morphology (Bartneck 2008; Haring, Mougenot, et al. 2014; Nomura, Sverre Syrdal, and Dautenhahn 2015), although researchers have no clear agreement regarding the appropriate design for each culture. Other studies evaluated the cultural effect on specific visual aspects of robots, such as the choice of materials (Lee and Šabanović 2014) and dimensions (Lee et al. 2012). Although understanding cultural aesthetic preferences is important when designing products for global distribution (Jordan 2000; Razzaghi, Ramirez, and Zehner 2009), we found no studies on robotic aesthetics perception and culture.

We suggest that using CoDeT before implementing a SAR in a new culture can provide an understanding of these differences and help design culturally appropriate embodiments.

3.4. Personal customisation

For the case study of a personal robot, the design was suggested to be adjustable to the user's preferences. These findings correlate with previous findings regarding personal robot design; participants tend to follow their preferences and tastes in this unique context (Ela Liberman-Pincu, van Grondelle, and Oron-Gilad 2022). Their selections are more affected by their demographic data (Liberman-Pincu, Parmet, and Oron-Gilad 2023). Using the CoDeT in the implementation phase of a PAR as a mass-customisation tool may increase user acceptance and trust (Ela Liberman-Pincu and Oron-Gilad 2022; Lacroix, Wullenkord, and Eyssel 2022), contribute to the sense of agency and ownership (Sun and Sundar 2016), help users define and establish the human-robot relationship, and encourages users to be more proactive in human-robot interactions (Ela Liberman-Pincu, Bulgaro, and Oron-Gilad 2023).

4. Conclusions and recommendations

When embarking on the design of new SARs, designers must go beyond mere functionality. Delving into the contextual layers, the *intended domain* (In what specific contexts or fields will the SAR operate? e.g. Healthcare, companionship, education, etc.), The *Environment*, i.e. where will the SAR be deployed? Indoor or outdoor? public or private? *Users* (Who are the primary users? Their abilities and needs) and the *Robot's Role* (What function will the SAR serve? Who is leading the interaction?) becomes paramount during development. Aligning the selected VQs of the robot with a character that resonates within this multifaceted context is a pivotal aspect of the design process.

We advocate for adopting the CoDeT methodology, which involves conducting PD focus groups among diverse stakeholders. This approach should occur during both the development stage for new use cases and the implementation phase when introducing the design to new cultures. Additionally, allowing customisation at the implementation stage provides an avenue to adapt SAR designs to different cultural perceptions of VQs and robotic roles. Future research should aim to apply CoDeT in designing actual SARs and evaluate their performance and user experience in real scenarios to demonstrate its effectiveness fully. Notably, this recommendation holds particular significance for personal SARs, where individual preferences play a dominant role.

We summarise the CoDeT advantages as follows:

- *Participatory Design*: Engage diverse stakeholders (users, caregivers, experts) through focus groups during development.
- *New Use Cases*: Apply CoDeT to explore novel SAR applications, considering cultural nuances.
- *Implementation Phase*: Introduce the design to new cultures, adapting it as needed.
- *Customisation*: Allow users to tailor a SAR's appearance and behaviour based on cultural and personal perceptions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by the Ministry of Innovation, Science and Technology, Israel (grant 3-15625), and by the Ben-Gurion University of the Negev through the Helmsley Charitable Trust, the Agricultural, Biological and Cognitive Robotics Initiative, the W. Gunther Plaut Chair in Manufacturing Engineering and by the George Shrut Chair in Human Performance Management.

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