# A Research Agenda for Human-Robot Co-creativity with Older Adults: a Scoping Review

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*Abstract*— **This review is the first study in a long-term research project exploring how social robotics and AI-generated content can contribute to the creative experiences of older adults, with a specific focus on collaborative drawing and painting. We searched and selected literature on human-robot co-creativity according to PRISMA guidelines, and analyzed articles to identify methods and strategies for researching co-creative robotics. We found that none of the studies involved older adults, which shows the gap in the literature for this often involved participant group in robotics research. The analyzed literature provides valuable insights, informing a research agenda to investigate human-robot co-creativity for and with older adults. We argue that future research should focus on ecological and developmental perspectives on creativity, on how behavior can be matched to the values of older adults, and on what type of devices work best.**

## I. INTRODUCTION

The world's population is rapidly aging. According to the United Nations, the number of people aged 60 years or older is expected to more than double by 2050, reaching approximately 2.1 billion [1]. This demographic shift is having significant social, economic, and health implications. In 2019, the World Health Organization published a review of 900 studies, concluding that creative activities can promote health and well-being and help prevent and slow age-related physical and cognitive decline [2]. Here, the term 'creative activities' is referring to forms of personal, everyday creativity, such as making music, drawing, dancing, or crafts. According to Cohen [3], such acts of everyday creativity are fundamental to psychological development and well-being in later life.

Creech et al. [4] present a systematic literature review into creativity and quality of later life, which highlights the benefits of the collaborative and relational nature of creativity. Co-creativity is also linked to well-being; an aging study by Zeilig et al. [5] suggests that sharing agency in co-creative activities can empower people with dementia. These studies share the view that co-creativity can foster social connections and create a safe space that facilitates involvement and sharing.

Social robots are playing a growing role in healthcare and well-being. There are few examples, however, of creative robot applications that are designed involving older adults. Social robots offer unique opportunities to support creativity through assistance and social interaction. In addition, technological advancements in generative AI bring new opportunities to suggest tailored content in creative collaborations. There are unanswered questions, however, on the needs and desires of older adults, and how to design appropriate human-robot co-creative systems.

In the next section, we begin by outlining theories, guidelines, and frameworks relevant to the development of Human-Robot Co-Creativity (HRCC) for older adults. In Section III, we describe the methodology we used for this scoping review. Based on the analysis of selected articles, we document the results in Section IV. In Section V we provide a conclusion and discussion, leading to a research agenda outlined in Section VI.

## II. BACKGROUND

Investigating the prospective role of social robots in co-creative systems bridges several fields. We will focus mainly on the fields of Human-Robot Interaction, Computational Creativity, and Arts & Health in this study. We present guidelines and frameworks from these fields as a background for our scoping review.

### A. Creativity and well-being

Definitions of creativity generally share the common theme that it involves generating something new, valuable, and surprising. There are different approaches, however, to understanding this complex concept. Glăveanu [6] takes an ecological perspective, describing creativity as a phenomenon that emerges through interaction in a social and material environment. Kaufman & Beghetto [7] take a developmental perspective, looking at the individual. Individuals are more likely to be creative when they are given challenging tasks that require new solutions, have a degree of autonomy and control over their work, and can collaborate and communicate effectively with others.

Both ecological and developmental perspectives align with the values that older adults attribute to their creative experiences. In a Dutch study by Groot et al. [8], older participants reported appreciating creative activities for 1) offering an environment where they feel safe, accepted, and free, 2) promoting personal and artistic growth, and 3) enabling meaningful social interactions (Fig. 1). Based on the previous study, Liu et al. [9] investigate the relationship between context, mechanisms, and outcomes, and mention 'a welcoming environment' as a consistent underlying mechanism. Liu et al. [9] recommend deepening our understanding of environments and affective atmospheres in art activities with

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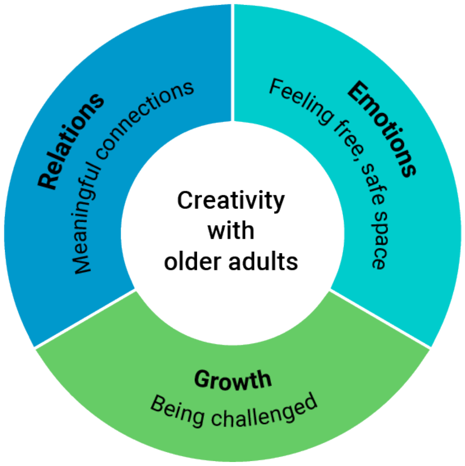


Fig. 1. Values that older adults attribute to their creative activities, based on a Dutch nationwide study by Groot et al. [8]

older adults. Groot et al. [8] recommend Participatory Action Design as a research approach to capture the essence of older participants' creative experiences.

In "A Roadmap for Therapeutic Computational Creativity", Pease et al. [10] delve into the connection between Computational Creativity and mental health and well-being. The authors discuss the benefits and risks associated with this connection. They also highlight potential opportunities, such as the genre of autotelic creativity known as *casual creators* [11]. Casual creators prioritize the pleasure of the creative process over the end product and offer enjoyable and easily accessible creative experiences that may be particularly valuable for older adults. Although this contrasts with the self-reported values of 'being challenged' and 'personal and artistic growth' in [8], autotelic experiences may contribute to an atmosphere in which people feel safe, accepted, and free. The roadmap also discusses the concept of the 'third hand', a metaphor for the therapist's role in supporting and encouraging patients' creative processes, without imposing their own ideas or disrupting the patient's autonomy [12]. The researchers recommend collaboration with mental health professionals, to determine the limitations and possibilities of therapeutic computational creativity [10].

### B. Interaction design for computational creativity

Kaufman & Beghetto [7] mention two main requirements for people to be creative 1) a degree of autonomy and control, and 2) effective communication with others. Autonomy and control present challenges for the design of co-creative systems. While traditional creativity support tools focus on human control, Gemeinboeck & Saunders [13] suggest embodied creative agents that share the world with humans, and act autonomously, beyond their creator's intent. Mixed-Initiative Creative Interfaces [14] are in between, a form of AI-enabled creativity support tools, where both humans and the system can take the initiative during creative collaboration. This raises questions, e.g., on how agency can be shared and how initiative can be negotiated to support both well-being and mutual creativity.

The requirement of effective communication also poses interaction design challenges. Bray & Bown [15] argue that computational creativity systems are often complex and opaque, limiting visibility and clarity of their conceptual models. Understanding may be improved when users can clearly perceive the system's structure, and develop a mental model of how this structure leads to behavior. This is crucial to facilitate a suitable level of autonomy and control. Dialogues can be expected to contribute to understanding and common ground, either language-based or through creative artifacts. A dialogic approach, as suggested by Bown et al. [16], can enable both human and artificial agents (e.g. social robots) to actively influence the creative process and products, and adapt to the other's behavior.

Social robots offer unique opportunities for embodied interaction, sharing agency, and (non-)verbal communication. They can suggest tailored AI-generated content and support creative exploration. The articles reviewed below shed some light on how interaction design challenges may be faced and how guidelines may be applied.

### C. Analysis of design research

Studies in HRCC are a form of design research, focused on understanding specific interaction design problems. We propose using the Function-Behavior-Structure (FBS) ontology, as described by Gero & Kannengiesser [17], for analyzing and comparing this kind of study. The ontology is based on the notion that all designs can be represented in a uniform way, and that design systems can be conceptualized in three ontological categories. Function (F) is about 'what the system is for', Behavior (B) covers 'what it does', and Structure (S) describes the components and their relationships, or 'what it consists of'. In addition, we apply a layered framework for interactions between creative collaborators, proposed by Kantosalo et al. [18], to the 'Behavior' of co-creative systems into interaction layers of modalities, styles, and strategies to provide a finer-grained view of 'what a co-creative system does'. We use the FBS ontology together with Kantosalo's framework for the analysis of reviewed articles on HRCC below.

TABLE I
KEYWORDS SEARCHED IN DATABASES

| Actors | Activities | Applications |
|---|---|---|
| Human-machine | Co-creativ* | Creativ* support |
| Human-computer | Creative collaboration | Support* creativity |
| Human-robot | Art* collaboration | Stimulat* creativity |
| Human-AI | Collaborative creativity | Art therapy |
| Robot* | Collaborative art | Creativ* Robot* |
| Artificial Intelligence | Collaborative drawing | |
| AI | Collaborative painting | |
| Machine Learning | Collaborative sketching | |

## III. Method

Six databases were used to conduct the scoping review: ACM, IEEE, Google Scholar, PsycINFO, Pubmed, and

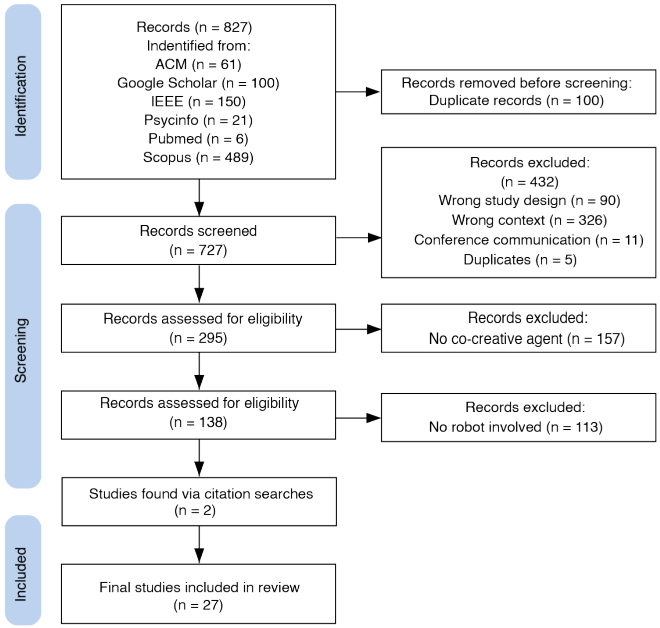


Fig. 2. PRISMA flow diagram for the scoping review.

Scopus. Keywords were chosen for *'Actors'* (e.g. human-robot), *'Activities'* (e.g. co-creativity), and *'Application'* (e.g. creativity support), see Table I. Only conference and journal articles, published in English from 2012 were included. A preliminary search revealed that before 2012, no articles on human-robot co-creativity were found. The search results (n=827) were imported in Rayyan [19], where duplicates (n=100) were removed, and labels were assigned. We followed the PRISMA guidelines [20] during the process of searching and selecting articles (Fig. 2). Based on a first screening of titles and abstracts, articles (n=432) were excluded when they a) did not involve human subjects in evaluating a robotic system, b) described a distinctive context (e.g., business, innovation, teaching, or product development) when they were conference workshop proposition papers, or c) were found to be duplicates. In a second screening, papers (n=157) were removed that did not show evidence of a 'co-creative agent', here defined as a computational actor involved in building shared creative artifacts, in co-presence with one or more human collaborators [21]. In the last step of the screening, studies that did not involve a robot were removed (n=113). Doing the exclusion selection in separate steps allowed for acquiring a broader view, and offered the opportunity to also keep studies with non-robotic agents in mind. After adding 2 papers found through forward and backward citation searches, a final set of 27 articles was used for analysis.

## IV. Results

The FBS ontology [17] and Kantosalo's Interaction Framework for Human-Computer Co-Creativity [18] were used for the analysis of reviewed articles. An overview is presented in Table II.

### *A. Function*

When looking at the reviewed articles presented in Table II, we can distinguish four categories based on their research focus: 1) Creativity support 2) Creative collaboration 3) Art therapy, and 4) Artistic work. 'Creativity support' forms the largest group, with studies investigating factors of social robot behavior that affect human creativity. Studies of 'Creative collaboration' explored the interaction dynamics, and how the process of collaboration can be facilitated. In the category of 'Art therapy', the focus was on specific requirements for art therapy robots and how to design responsive systems for affective and assistive collaborative painting and drawing. In the category of 'Artistic work', the focus is on the relationship between humans and machines in creative encounters, and studies are carried out in the context of the researchers' own artistic practice, mostly in performances involving the audience. Regarding participants and target groups, we found that studies on 'Creativity support' involved mostly children, while adults and professional artists and designers participated in the 'Creative collaboration' studies. In the category of 'Artistic work', the artists themselves also played an important role, as well as the audience.

### *B. Behavior: Strategies, styles, modalities*

All studies in the category of **Creativity support** propose the strategy of stimulating human creativity, through various social behaviors of a robot. Creativity demonstration was used to stimulate creativity with children (n=4) and with adults (n=1). The robot demonstrated verbal creativity in storytelling applications and figural creativity in a drawing game. It was found that creativity demonstrations and scaffolding (e.g. asking questions, prompting, and suggestions), as well as the promotion behavior of the robot can contribute to higher levels of human creativity. When mirroring or contrasting robot movements were congruent with user input, this positively affected creativity [24][33]. The studies applied mostly factorial designs, using pre-defined, validated content. For example, in multiple studies the robot demonstrated creativity by selecting pre-defined suggestions with a validated creativity score, dependent on the condition [22][23][31].

In the category of **Creative collaboration**, two studies explored expressive robot movements to improve non-verbal communication [34][36]. In the context of collaborative drawing, the effects of direct versus indirect motion paths on collaborative interaction were compared, but the results were inconclusive. The researchers recommend further in-the-field experiments, combining qualitative and quantitative methodologies. An arts-led, process-led approach is proposed by Gomez Cubero et al. [37], to explore how co-creativity emerges through human-robot dialogue and improvisation. The researchers developed custom tools to support collaborative drawing with an industrial robot and put these into practice. In a study involving designers, a mobile robot was introduced for collaborative sketching and generating ideas through 'conceptual shifts' [35]. Using the

TABLE II
REVIEWED PAPERS, STRUCTURED USING THE FBS ONTOLOGY [17] AND THE
INTERACTION FRAMEWORK FOR HUMAN-COMPUTER CO-CREATIVITY [18].

| Function | | | Behavior | | | | Structure | |
|---|---|---|---|---|---|---|---|---|
| | | | Interaction layers | | | | | |
| Focus | Participants | Domain | Strategies | Styles | | Modalities | Robots, devices | Refs |
| Creativity support | Children | Storytelling | Stimulate human creativity | Demonstrate verbal creativity | Game-based | Speech, GUI | Jibo, tablet | [22][23] |
| | Children | Storytelling | Stimulate human creativity | Mirror/contrast user input | Open-ended | TUI | Robotic object (YOLO) | [24][25][26] |
| | Children | Storytelling | Stimulate human creativity | Promotional behavior | Open-ended | Speech, GUI | EMYS, tablet | [27] |
| | Children | Storytelling | Stimulate human creativity | Demonstrate verbal creativity | Open-ended | Speech, GUI | Furhat, tablet | [28][29] |
| | Children | Storytelling | Stimulate human creativity | Scaffold creativity/reflection | Open-ended | TUI | Stuffed animal, physical tools | [30] |
| | Children | Drawing | Stimulate human creativity | Embodied presence | Game-based | Speech, GUI | Jibo, tablet | [22] |
| | Children | Drawing | Stimulate human creativity | Demonstrate figural creativity | Game-based | Speech, GUI | Jibo, tablet | [23] |
| | Children | Construction | Stimulate human creativity | Scaffold creativity/reflection | Game-based | Speech, GUI | Jibo, tablet | [23] |
| | Adults | Storytelling | Stimulate human creativity | Demonstrate verbal creativity | Game-based | Speech, GUI | Robovie, display | [31] |
| | Adults | Drawing | Stimulate human creativity | Embodied presence | Game-based | Speech, GUI | Nao, tablet | [32] |
| | Adults | Performance | Stimulate human creativity | Mirror/contrast user input | Open-ended | TUI | Robotic object, tablet | [33] |
| Creative collaboration | Adults | Drawing | Non-verbal communication | Expressive robot movement | Open-ended | TUI, GUI | Cobot, physical tools | [34] |
| | Designers | Drawing | Conceptual sketching | Suggesting conceptual shifts | Open-ended | TUI | Drawbot, physical tools | [35] |
| | Adults | Drawing | Non-verbal communication | Expressive robot movement | Open-ended | TUI | Cobot, physical tools | [36] |
| | Artists | Performance | Arts-led, process-led | Dialogue through improvisation | Open-ended | TUI, GUI | Cobot, tablet, dance floor | [37] |
| | Children | Drawing | Human/machine learning | User-specific training data | Open-ended | TUI | Cobot, physical tools | [38] |
| Art therapy | Adults | Painting | Responsive art approach | Express matching emotions | Open-ended | Speech, TUI | Baxter, BMI, physical tools | [39] |
| | Adults | Painting | Balance contingency/artistry | Suggesting visual metaphors | Open-ended | Speech, TUI | Baxter, physical tools | [40] |
| | Adults | Painting | Connect to personal art | Personalized visual metaphors | Open-ended | Speech, TUI | Baxter, physical tools | [41] |
| | Children | Drawing | Personalization | Speech-assisted co-drawing | Open-ended | Speech, GUI | Cobot, tablet | [42] |
| Artistic work | Artist | Paint/perform | Human-machine symbiosis | Mimicry, memory a.o. | Open-ended | TUI, ambient | Cobots a.o., art installation | [43] |
| | Audience | Performance | Embodied Creative AI | Shared creative spaces | Open-ended | Ambient | Robotic objects, art installation | [44] |
| | Audience | Performance | Embodied Creative AI | Performance Body Mapping | Open-ended | Ambient | Robotic objects, art installation | [45] |
| | Audience | Paint/perform | Robotic art of audience input | Speech-to-AI-art | Open-ended | Speech, ambient | Kuka robot, art installation | [46] |

Sketch-RNN model and the Google Quick, Draw! API, input sketches were mapped to suggestions with visual and semantic similarity. Results showed that the mobile, embodied agent performed better in provoking exploratory thinking and collaborative ideation, compared to a web-based agent. The alignment of human, robot, and machine learning is suggested by Twomey [38] in a study where the robotic system is trained on audience-specific content in the form of children's drawings.

With **Art therapy**, the focus is on investigating how a robot can learn to understand and adapt to the creative and emotional expressions of a human interaction partner. Cooney & Menezes [39] propose to generate responsive art for emotion regulation, through robot expressions of either matching or positive emotions. Using wireless electroencephalography (EEG), brain signals were captured and classified based on Russell's valence/arousal model, and then translated into visual features for paintings. Affective image databases were used to train the system and Deep Convolutional Generative Adversarial Networks (DC-GANs) for synthesizing compositions. To balance contingency and artistry, Cooney & Berck [40] made use of visual metaphors that are responsive to perceived emotions. In a follow-up study, Cooney [41] proposes metaphors that connect more to emotional artistic expressions. Personalization was also facilitated, through the robot's open questions, letting users add their own tags to describe the content. Another implementation of personalization is suggested by Shaik et al. [42], by letting the system adapt sketches based on verbal feedback and explicit directions from users, which were disabled children.

In the category of **Artistic work**, Sougwen Chung [43] explores human-machine symbiosis, studying concepts of mimicry, memory, collectivity, and spectrality. For example, mimicry is explored with the robot mimicking the artists drawing gestures and for memory, the machine learns the artist's drawing style, with neural nets trained on the artists drawing collection. Saunders & Gemeinboeck [44] investigate how embodied, creative AI can act as a performer by embedding a group of autonomous robots into the walls of a gallery. The robots are programmed as curious agents, driven to explore their world. By punching on the walls and making holes, they make changes to the environment, communicate their presence, and involve the audience. In another study by Saunders & Gemeinboeck [45], professional dancers and non-humanlike robots were brought together in co-embodied explorations of forms and movements. Sola et al. [46] suggest speech-to-AI-art transformations and created an interface that allowed the audience to tell a co-creative system about their dreams. Based on prompts from the input text, the AI-system generated a drawing through latent space navigation using the CLIP model. The industrial robot arm captured the audience's stories in a collective painting that hang down into the atrium of a museum as a cascade of dreams.

When looking at game-based versus open-ended interac-

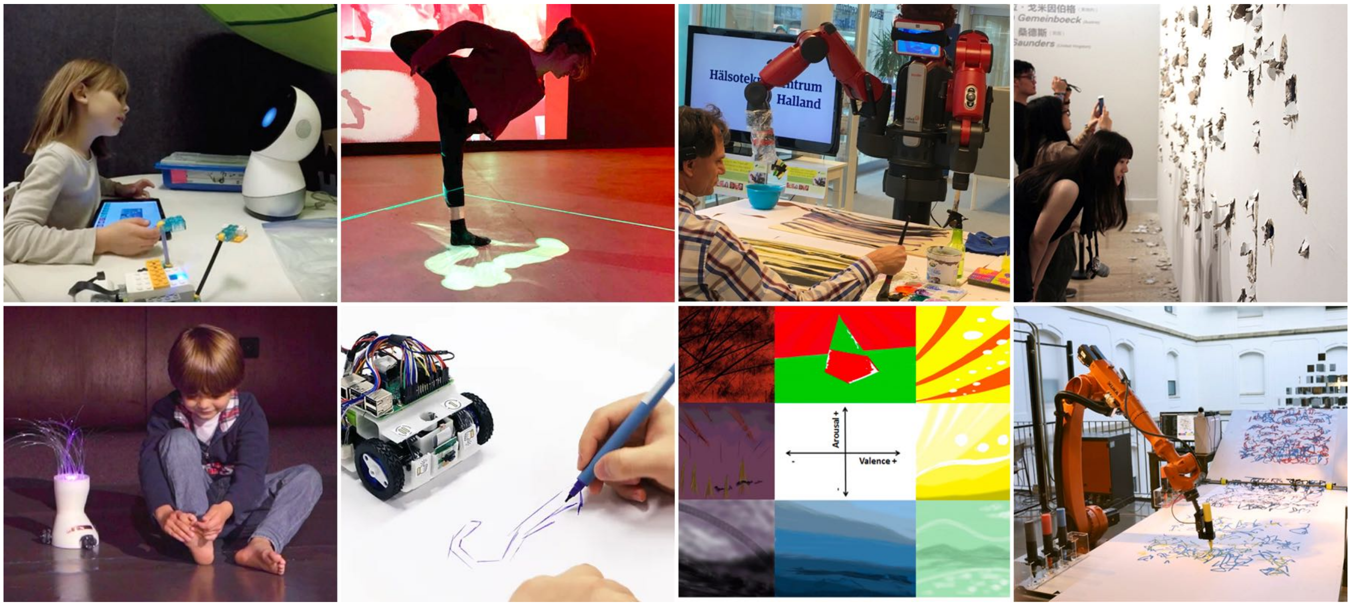


Fig. 3. Per column: 1) Jibo, scaffolding creativity in a construction task [23]; YOLO, a robot toy for storytelling [24]; 2) The robot is present, an arts-led, process-led approach for investigating human-robot dialogues in improvisation [37]; Cobbie, a drawbot for conceptual sketching with designers [35]; 3) Baxter robot used in art therapy; The valence/arousal model for expressing matching emotions; 4) Accomplice - Creative robotics and embodied computational creativity [44]; Dream Painter - Bridging Audience Interaction, Robotics, and Creative AI [46]

tion styles, factorial design studies generally used game-based interaction, e.g., in drawing and storytelling games. This facilitated experimental control when comparing and measuring the effects of social robot behavior. In other studies, open-ended forms of interaction were used, which allows for investigating processes and changes over time, and contributes to ecological validity when researching creative collaboration.

What stands out when looking at the interaction modalities used in the four categories, is that speech is mostly used in the categories **Creativity support** and **Art therapy**. Robot speech is used for demonstrating verbal creativity, and for scaffolding creativity, and prompting creative reflection [23][30]. For art therapy robots, speech is found to be useful as well; verbal and vocal channels allow complex information to be conveyed, in a highly salient fashion, without requiring a person to look away from art-making and possibly lose concentration [39]. Speech also enables users to give explicit feedback or directions or ask for assistance, as suggested by Shaik et al. [42]. In the categories **Creative collaboration** and **Artistic work**, human-machine dialogues are more often based on non-verbal communication such as expressive movement, or through the artistic work itself. With artistic work, we see most examples of ambient interfaces, when exploring new types of human-machine encounters in a spatial setting (Fig. 3).

### C. *Structure*

Different types of robots and embodiments were used in the reviewed studies (Fig. 3). Human-like robots were used in almost all studies in using a *Stimulating creativity* strategy, combined with a tablet or a computer screen. With drawing activities in this category, the robot (Jibo, Nao) was not drawing physically, but virtually on the tablet, with separate canvases on the same tablet [22][47][32]. In studies employing *game-based* interaction styles, screens were used to present the game world. Alves-Oliveira et al. [24][25][26] used a non-anthropomorphic robot object to stimulate creativity in children; YOLO serves as a toy character in a storytelling game. The robot interacts through lights, colors, and movements, while the shape of the robot set realistic expectations for the robot's capabilities. In the category of **Creative collaboration**, collaborative robot (cobot) arms were mostly used, together with physical drawing tools. Physical drawing tools were also used with art therapy robots. The Baxter robot used for art therapy [39] can be considered a human-like cobot, with two arms and a screen that can display a face and facial expressions, facilitating non-verbal social communication. With Artistic work, robot arms were used next to custom-made robotic objects, mostly in multi-agent settings. The stage is shared between humans and robots, mostly in performances. In an art installation by Sola et al. [46], the industrial robot arm is behind glass, while the audience can communicate with the robot through a speech interface. In Accomplice, Saunders & Gemeinboeck [44] install robots in their own space behind a wall in a gallery, which they breaking through as they use the wall as their canvas. Saunders & Gemeinboeck [45] used robotic cubes to explore how human and non-human forms of embodiment can be mapped through movement, and how non-humanlike robotic objects can be perceived as affective agents.

## V. Conclusion and Discussion

Selected articles were structured using the FBS ontology [17] and the Interaction Framework for Human-Computer

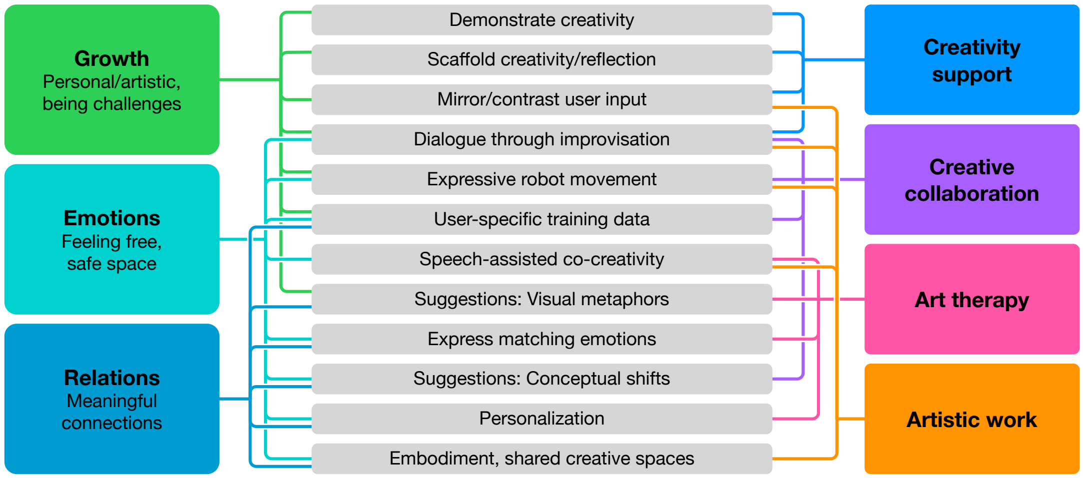


Fig. 4. Values that older adults attributed to their creative activities in a nationwide Dutch study [8], connected to robot behaviors suggested in the reviewed studies, with the corresponding categories (Table II). These values (e.g. meaningful connections) were attributed in the context of human-human interactions. We suggest to investigate if and how human-robot co-creative interactions can be valuable to older adults as well. We propose this mapping of values and behaviors as part of our research agenda (Section VI).

Co-creativity [18]. The search and selection process (see Section III) resulted in a heterogeneous set of studies, describing robotic systems with various functions, behaviors, and structures.

### *A. Function*

Studies in the categories **Creativity support** and **Art therapy** take a developmental perspective, a) aiming to stimulate human creativity and b) aiming to support art therapy through responsiveness and personalization. Studies in the categories **Creative collaboration** and **Artistic work** take an ecological perspective, investigating how creativity emerges through interaction. This is a more process-led approach, involving end users and taking into account the social and material environment. As set out in Section II, both ecological and developmental perspectives align with values that older adults attribute to their creative experience, and must be taken into account when defining the functions of HRCC for older adults.

An important finding regarding participants is that older adults did not engage in any of the reviewed studies. While Cooney & Menezes [39] thank older adults in their acknowledgments for providing input, they evaluated their system with younger adults. It is not clear why older adults have not yet been involved in HRCC research. Robots and AI-generated content offer opportunities that can be beneficial for this specific target group, which is growing worldwide, and there are specific needs and wishes to be taken into account. That is why we are making a case for investigating HRCC for, and with, the target group of older adults.

### *B. Behavior*

Evidence shows that robots are capable of demonstrating creativity, and that this social behavior can be designed to stimulate human creativity. Other social behaviors are found to be effective as well, such as mirroring and contrasting user input to promote divergent and convergent thinking. Studies on robots in **Art therapy** provide valuable insights into the importance of recognizing, modeling, and synthesizing emotions in drawings and paintings. Here, the emphasis is on tailoring and balancing content to user needs e.g., using personalized visual metaphors. These ideas on how an art therapy robot could behave as a 'third hand' also inform future research in HRCC for older adults. Studies in the category of **Creativity support** often used games to structure the interaction, which contributes to experimental control when measuring the effects of robot behavior. However, the majority of studies used open-ended forms of interaction, investigating how dialogues and collaborations develop.

The modality of speech is considered an important channel for transparency and effective communication, promoting autonomy and control. This is emphasized in the categories **Creativity support** and **Art therapy**. Robot speech is used, e.g., to demonstrate verbal creativity, scaffold creativity, and promote creative reflection. User speech input is suggested as a means for explicit feedback, requesting assistance, and personalizing suggested content. The research projects in the category of **Artistic work** place creative robots in spatial settings, sometimes with multiple agents, and letting artists and audiences contribute to a physical shared space that fosters creativity. Both speech and embodied, spatial interactions are important for HRCC with older adults, to contribute to an environment where people feel free and safe.

### *C. Structure*

Results show that in the categories **Creativity support** and **Art therapy**, mostly human-like robots were used. The robot YOLO is an exception, an abstract robotic object that serves as a toy, while the shape of the robot sets realistic expectations for the robot's capabilities [25]. A shared stage for humans and robots, as explored in studies on **Artistic work**, could be interesting for older adults as well, when designed as an environment fostering creativity, and where people feel free and safe.

An important limitation of this study is that we analyzed the literature describing HRCC systems, while we didn't have access to these systems themselves. Most articles didn't give a complete description of a system, and sometimes it was designed to study the effects of a single behavior in isolation, rather than HRCC as a complete process. Therefore, we used the FBS ontology [17] and the Interaction Framework for Human-Computer Co-Creativity [48] loosely, for structuring the available information and investigating possible relationships between components. There are opportunities to work this out in more detail, for example, machine learning techniques were also sometimes described. As part of a system's structure, it is interesting to investigate how these techniques align with a system's behavior and function. We will attempt to elaborate on this in an extended version of this literature review. Another limitation is the fact that none of the studies involved older adults. While the reviewed studies offer a lot of valuable insights, we can not build upon findings from previous HRCC research with the elderly target group. To uncover requirements and opportunities we will involve older adults in future research, as well as artists and therapists who are working with the target group.

## VI. Research Agenda

We propose a participatory, mixed-methods approach for investigating HRCC for, and with, older adults. Older adults must be involved throughout the entire process, in identifying opportunities and requirements, developing HRCC activities, and testing hypotheses in both controlled experiments and in-the-field settings. When investigating the design of the system, we will consider the following:

**Function:** Consider both ecological and developmental perspectives on creativity when defining functional requirements for the target group.

**Behavior:** Align values that older adults attribute to creative activities with the opportunities of HRCC (Fig. 4) to investigate how:

1) A robot's social behavior can support and enhance creative experiences for older adults;
2) AI-generated content can be tailored and responsive to specific needs and desires; and,
3) Intuitive dialogues (verbal, non-verbal, through artifacts) can support co-creativity.

**Structure:** Investigate what types of robot and devices fit best and provide opportunities for:

1) Social interaction with older adults;
2) Creative support and exploration; and,
3) Shared creative experiences and spaces where older adults feel free and safe.


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## References


[1] U. N. D. of Economic and P. D. Social Affairs, "World population prospects 2022: Summary of results," 2022.

[2] D. Fancourt and S. Finn, "What is the evidence on the role of the arts in improving health and well-being? a scoping review (2019)," *World Health Organization. http://www. euro. who. int/en/publications/abstract s/what-is-the-evidence-on-the-role-of-the-artsin-improving-health-and-wellbeing-a-scopingreview-2019*, 2019.

[3] G. D. Cohen, *The mature mind: The positive power of the aging brain*. Basic Books (AZ), 2005.

[4] A. Creech, K. Larouche, M. Generale, and D. Fortier, "Creativity, music, and quality of later life: A systematic review," *Psychology of Music*, p. 0305735620948114, 2020.

[5] H. Zeilig, V. Tischler, M. van der Byl Williams, J. West, and S. Strohmaier, "Co-creativity, well-being and agency: A case study analysis of a co-creative arts group for people with dementia," *Journal of Aging Studies*, vol. 49, pp. 16–24, 2019.

[6] V. P. Glăveanu, "Rewriting the language of creativity: The five a's framework," *Review of general psychology*, vol. 17, no. 1, pp. 69–81, 2013.

[7] J. C. Kaufman and R. A. Beghetto, "Beyond big and little: The four c model of creativity," *Review of general psychology*, vol. 13, no. 1, pp. 1–12, 2009.

[8] B. Groot, L. de Kock, Y. Liu, C. Dedding, J. Schrijver, T. Teunissen, M. van Hartingsveldt, J. Menderink, Y. Lengams, J. Lindenberg, *et al.*, "The value of active arts engagement on health and well-being of older adults: A nation-wide participatory study," *International journal of environmental research and public health*, vol. 18, no. 15, p. 8222, 2021.

[9] Y. Liu, B. Groot, L. de Kock, T. Abma, and C. Dedding, "How participatory arts can contribute to dutch older adults' wellbeing–revisiting a taxonomy of arts interventions for people with dementia," *Arts & Health*, pp. 1–16, 2022.

[10] A. Pease, M. Ackerman, N. Pease, and B. McFadden, "A roadmap for therapeutic computational creativity," in *13th International Conference on Computational Creativity*, 2022.

[11] K. Compton and M. Mateas, "Casual creators.," in *ICCC*, pp. 228–235, 2015.

[12] E. Kramer, "The art therapist's third hand: Reflections on art, art therapy, and society at large.," *American Journal of Art Therapy*, 1986.

[13] P. Gemeinboeck and R. Saunders, "The performance of creative machines," in *Cultural Robotics: First International Workshop, CR 2015, Held as Part of IEEE RO-MAN 2015, Kobe, Japan, August 31, 2015. Revised Selected Papers 1*, pp. 159–172, Springer, 2016.

[14] S. Deterding, J. Hook, R. Fiebrink, M. Gillies, J. Gow, M. Akten, G. Smith, A. Liapis, and K. Compton, "Mixed-initiative creative interfaces," in *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 628–635, 2017.

[15] L. Bray and O. Bown, "Applying core interaction design principles to computational creativity," *Proceedings of the 7th International Conference on Computational Creativity, ICCC 2016*, pp. 93–97, 2016.

[16] O. Bown, K. Grace, L. Bray, and D. Ventura, "A speculative exploration of the role of dialogue in human-computerco-creation.," in *ICCC*, pp. 25–32, 2020.

[17] J. S. Gero and U. Kannengiesser, "The function-behaviour-structure ontology of design," *An anthology of theories and models of design: philosophy, approaches and empirical explorations*, pp. 263–283, 2014.

[18] A. Kantosalo, P. T. Ravikumar, K. Grace, and T. Takala, "Modalities, styles and strategies: An interaction framework for human-computer co-creativity.," in *ICCC*, pp. 57–64, 2020.

[19] M. Ouzzani, H. Hammady, Z. Fedorowicz, and A. Elmagarmid, "Rayyan—a web and mobile app for systematic reviews," *Systematic reviews*, vol. 5, pp. 1–10, 2016.

[20] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, and t. PRISMA Group*, "Preferred reporting items for systematic reviews and meta-analyses: the prisma statement," *Annals of internal medicine*, vol. 151, no. 4, pp. 264–269, 2009.

[21] T. Lubart, D. Esposito, A. Gubenko, and C. Houssemand, "Creativity in Humans, Robots, Humbots," *Creativity*, vol. 8, no. 1, pp. 23–37, 2021.

[22] S. Ali, T. Moroso, and C. Breazeal, "Can children learn creativity from a social robot?," *C and C 2019 - Proceedings of the 2019 Creativity and Cognition*, pp. 359–368, 2019.

[23] S. Ali, N. Devasia, H. W. Park, and C. Breazeal, "Social robots as creativity eliciting agents," *Frontiers in Robotics and AI*, vol. 8, p. 673730, 2021.

[24] P. Alves-Oliveira, P. Arriaga, M. Cronin, and A. Paiva, "Creativity encounters between children and robots," *ACM/IEEE International Conference on Human-Robot Interaction*, pp. 379–388, 2020.

[25] P. Alves-Oliveira, P. Arriaga, A. Paiva, and G. Hoffman, "Guide to build YOLO, a creativity-stimulating robot for children," *HardwareX*, vol. 6, 2019.

[26] P. Alves-Oliveira, S. Gomes, A. Chandak, P. Arriaga, G. Hoffman, and A. Paiva, "Software architecture for YOLO, a creativity-stimulating robot," *SoftwareX*, vol. 11, 2020.

[27] M. Elgarf, N. Calvo-Barajas, P. Alves-Oliveira, G. Perugia, G. Castellano, C. Peters, and A. Paiva, "'And then what happens?' Promoting Children's Verbal Creativity Using a Robot," *ACM/IEEE International Conference on Human-Robot Interaction*, vol. 2022, pp. 71–79, 2022.

[28] M. Elgarf, S. Zojaji, G. Skantze, and C. Peters, "CreativeBot: a Creative Storyteller robot to stimulate creativity in children," *ACM International Conference Proceeding Series*, pp. 540–548, 2022.

[29] M. Elgarf, G. Skantze, and C. Peters, "Once upon a Story: Can a Creative Storyteller Robot Stimulate Creativity in Children?," *Proceedings of the 21st ACM International Conference on Intelligent Virtual Agents, IVA 2021*, pp. 60–67, 2021.

[30] L. Hubbard, Y. Chen, E. Colunga, P. Kim, and T. Yeh, "Child-Robot Interaction to Integrate Reflective Storytelling into Creative Play," *ACM International Conference Proceeding Series*, 2021.

[31] P. H. Kahn, K, T. a, H. Ishiguro, S. Shen, H. E. Gary, and J. H. Ruckert, "Creative Collaboration with a Social Robot - Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing," *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pp. 99–103, 2014. Place: New York, NY, USA Publisher: Association for Computing Machinery Section: 0.

[32] P. Alves-Oliveira, S. Tulli, P. Wilken, R. Merhej, J. Gandum, and A. Paiva, "Sparking creativity with robots: A design perspective," in *14th Annual ACM/IEEE International Conference on Human Robot Interaction (HRI)*, Jan. 2019.

[33] F. Fabiano, H. Pelikan, J. Pingen, J. Zissoldt, A. Catala, and M. Theune, "Designing a co-creative dancing robotic tablet," *CEUR Workshop Proceedings*, vol. 2160, 2017.

[34] D. Hinwood, J. Ireland, E. Jochum, and D. Herath, "A proposed wizard of OZ architecture for a human-robot collaborative drawing task," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 11357, pp. 35–44, 2018.

[35] Y. Lin, J. Guo, Y. Chen, C. Yao, and F. Ying, "It Is Your Turn: Collaborative Ideation with a Co-Creative Robot through Sketch," *Conference on Human Factors in Computing Systems - Proceedings*, 2020.

[36] J. Pedersen, K. Christensen, D. Herath, and E. Jochum, "I Like the Way You Move: A Mixed-Methods Approach for Studying the Effects of Robot Motion on Collaborative Human Robot Interaction," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 12483, pp. 73–84, 2020.

[37] C. Gomez Cubero, M. Pekarik, V. Rizzo, and E. Jochum, "The Robot is Present: Creative Approaches for Artistic Expression With Robots," *Frontiers in Robotics and AI*, vol. 8, 2021.

[38] R. Twomey, "Three Stage Drawing Transfer: Collaborative Drawing Between a Generative Adversarial Network, Co-robotic Arm, and Five-Year-Old Child," *Proceedings of the ACM on Computer Graphics and Interactive Techniques*, vol. 5, no. 4, 2022.

[39] M. Cooney and M. Menezes, "Design for an art therapy robot: An explorative review of the theoretical foundations for engaging in emotional and creative painting with a robot," *Multimodal Technologies and Interaction*, vol. 2, no. 3, 2018.

[40] M. Cooney and P. Berck, "Designing a robot which paints with a human: visual metaphors to convey contingency and artistry," in *ICRA-X Robots Art Program at IEEE International Conference on Robotics and Automation (ICRA), Montreal QC, Canada*, p. 2, 2019.

[41] M. Cooney, "Robot Art, in the Eye of the Beholder?: Personalized Metaphors Facilitate Communication of Emotions and Creativity," *Frontiers in Robotics and AI*, vol. 8, 2021.

[42] S. Shaik, V. Srinivasan, Y. Peng, M. Lee, and N. Davis, "Co-creative Robotic Arm for Differently-Abled Kids: Speech, Sketch Inputs and External Feedbacks for Multiple Drawings," *Advances in Intelligent Systems and Computing*, vol. 1290, pp. 998–1007, 2021.

[43] S. Chung, "Sketching symbiosis: Towards the development of relational systems," in *The Language of Creative AI: Practices, Aesthetics and Structures*, pp. 259–276, Springer, 2022.

[44] R. Saunders and P. Gemeinboeck, "Accomplice: Creative robotics and embodied computational creativity," *AISB 2014 - 50th Annual Convention of the AISB*, 2014.

[45] R. Saunders and P. Gemeinboeck, "Performative body mapping for designing expressive robots," *Proceedings of the 9th International Conference on Computational Creativity, ICCC 2018*, pp. 280–287, 2018.

[46] M. Sola and V. Guljajeva, "Dream Painter: Exploring creative possibilities of AI-aided speech-to-image synthesis in the interactive art context," *Proceedings of the ACM on Computer Graphics and Interactive Techniques*, vol. 5, no. 4, 2022.

[47] S. Ali, H. Park, and C. Breazeal, "A social robot's influence on children's figural creativity during gameplay," *International Journal of Child-Computer Interaction*, vol. 28, 2021.

[48] A. Kantosalo and H. Toivonen, "Modes for creative human-computer collaboration: Alternating and task-divided co-creativity," *Proceedings of the 7th International Conference on Computational Creativity, ICCC 2016*, pp. 77–84, 2016.