Brushstrokes of Autonomy: Exploring Artistic Expression for People with Motor Impairments through an AR-Guided Robotic Arm

João Ferreira*
jpferreira@lasige.di.fc.ul.pt
LASIGE, Faculdade de Ciências, Universidade de Lisboa
Lisboa, Portugal

Leonardo Bizzaro*
leonardo.bizzaro.1@studenti.unipd.it
LASIGE, Faculdade de Ciências, Universidade de Lisboa
Lisboa, Portugal
Università degli Studi di Padova
Padova, Italy

Hugo Simão*
Beatriz Nogueira
Isabel Neto
LASIGE, Faculdade de Ciências, Universidade de Lisboa
Lisboa, Portugal

Daniel Jimeno-Huete
Sara Reina-Gutiérrez
Antonio Oliviero
FENNSI Group, Hospital Nacional de Parapléjicos, SESCAM
Toledo, Spain

João Bimbo
João Guerreiro
Tiago Guerreiro
LASIGE, Faculdade de Ciências, Universidade de Lisboa
Lisboa, Portugal

Figure 1: A participant with an upper-limb motor impairment uses an augmented reality (AR) head-mounted display (HMD) to draw on a virtual canvas, which is reproduced by the robotic arm on paper using acrylic markers, following the same strokes (left). The resulting pieces (right) reflect participants' personal artistic expression made physically present through the system.

Abstract

People with upper-limb motor impairments often face significant barriers to creative self-expression, particularly in activities like drawing that rely on fine motor control. We explore how a hybrid system combining augmented reality and robotic actuation can support engagement with expressive practices. Through head and voice-based interaction, fourteen participants with upper-limb motor impairments, due to spinal cord injuries, created virtual drawings that were physically rendered by a robotic arm. They engaged in two temporal conditions, live and deferred robot execution, used as probes to explore different facets of agency, authorship, and embodiment. Our qualitative analysis reveals how participants reconnected with long-lost creative practices, used drawing to revisit

*These authors contributed equally to this work.

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memories and identities, and envisioned broader societal contributions. Many experienced the robot as an extension of their body, reinforcing a strong sense of ownership and intentionality. We contribute a rich account of how assistive technologies can enable creative agency and suggest design considerations for moving beyond utilitarian goals.

CCS Concepts

• **Human-centered computing → Accessibility**.

Keywords

Self-expression, Motor Impairments, Assistive Robotics, Augmented Reality, Drawing.

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1 Introduction

Creative practices such as drawing or painting are often inaccessible to people with upper-limb motor impairments as they typically require fine motor control and precise hand movements [56]. However, art and other forms of self-expression are deeply tied to how we connect with ourselves and others [69], helping to support a person's identity formation, autonomy, and emotional well-being [39]. They also enable people to communicate emotions and experiences beyond language or physical barriers, reflecting a deeper sense of personal freedom [49]. Despite the importance of creative expression, the motor demands of activities like drawing and painting can constrain how people with upper-limb motor impairments, such as those resulting from spinal-cord injuries, can participate.

Prior research has leveraged technology to support people with motor impairments in controlling devices and executing actions, but most efforts have focused on utilitarian tasks. Assistive robotics has gained prominence in this space, with a large body of work aiming to support people in activities of daily living (ADLs), such as dressing, hand washing, and food preparation [5, 26, 42]. These works usually rely on alternative control methods, such as eye- or head-tracking, with Augmented Reality (AR)–based input increasingly explored as a complementary approach that also provides feedback to users [6, 57]. However, these systems are generally designed to maximize functional independence, emphasizing task efficiency, reliability, and physical support [26, 64]. Some exceptions have begun to explore broader forms of engagement, such as leisure, social participation, and remote embodiment [4, 37, 63]. Still, within the limited body of work exploring drawing or writing [23], prior approaches have emphasized the technical feasibility of direct robotic teleoperation, overlooking how such interactions support self-expression, agency, and the meaningful experience of creating.

In this paper, we investigate how people with upper-limb motor impairments experience artistic self-expression through the development and experimentation of EXPRESS-AR, a hybrid system combining AR and robotic actuation. This system allows users to draw in an AR environment using head and voice input, and renders the drawing through a robotic arm (Figure 1). We use robotic actuation to produce tangible, physically grounded outputs, as prior work shows that material traces enhance creative ownership compared to digital-only representations [21, 32, 82]. We conducted a study with 14 participants with spinal cord injuries (with both upper- and lower-limb motor impairment), who experienced the AR-guided robotic system, aiming to understand how such a setup supports creative agency, emotional connection, and sense of authorship. To further explore these dimensions, participants engaged in two temporal conditions: live and deferred robot execution. This manipulation draws on prior work showing that temporal contiguity between action and outcome is important for perceived agency [55, 77], allowing us to explore how timing influences control, ownership, and authorship. Following the drawing sessions, we conducted semi-structured interviews to understand participants' reflections on the system and its broader implications. In particular, we wanted to answer the following research questions:

- **RQ1**: How do people with upper-limb motor impairments experience self-expression through AR-guided drawing and robotic execution?
- **RQ2**: How does immediate physical drawing impact users' perceived agency and connection to their creative output?
- **RQ3**: What opportunities and concerns do users perceive in using AR and robotics to support self-expression?

Our findings indicate that participants approached the system with a range of expectations, varying from curiosity to skepticism. However, most participants viewed it as an empowering tool for engaging in creative activities. Drawing became more than a technical task; it often helped individuals reconnect with memories, identities, and places that felt out of reach. Many participants expressed a strong sense of ownership and control, with some feeling as if the robot was an extension of their own body. Ultimately, participants considered potential uses for the system beyond artistic expression, envisioning it as a means for rehabilitation, leisure, or engaging in activities of personal or social value.

The primary contribution of this work is an exploration of how assistive technologies can support artistic self-expression for people with upper-limb motor impairments, offering insights into users' experiences of agency, authorship, and emotional significance. To facilitate this exploration, we developed a system integrating AR and assistive robotics, a technological probe that allowed people to draw independently, demonstrating how such tools can move beyond functional assistance to support creative self-expression.

2 Related work

We ground our study in two main areas of prior work: assistive robotics for people with motor impairments, and technologies that support self-expression and creative autonomy.

2.1 Assistive Robotics for People with Motor Impairments

People with motor impairments often face challenges in performing both activities of daily living (ADLs), such as eating, dressing, or bathing, and instrumental activities of daily living (IADLs), such as shopping, housekeeping, and other forms of community participation [46, 59, 65]. These challenges not only affect physical independence and the agency to influence the world and the surrounding environment [27, 54], but are also strongly linked to reduced social participation, increased reliance on caregivers, and diminished life satisfaction [2, 34].

Assistive robotics has emerged as a promising field to address these challenges. Early approaches [20] explored mobile robotic units to support manipulation tasks in domestic environments. More recent work demonstrates the ability of robotic arms and platforms to support people with upper-limb motor impairments in tasks like reaching and grasping [5, 26, 42]. These systems are often controlled via modalities like gaze or head movement, reducing physical strain and enabling more natural, cognitively light interactions [72].

Recent advances in AR have further expanded the potential of assistive robotics by enabling rich, high-dimensional interaction with reduced physical effort. AR can enhance spatial awareness, provide real-time feedback, and support head-, gaze-, and voice-based control, allowing users to plan and execute complex tasks more fluidly [29, 57, 75]. These features are particularly useful for people with limited or no arm/hand mobility, enabling them to control devices and execute actions with natural, intuitive inputs.

However, despite this progress, the vast majority of assistive robotic systems remain focused on utilitarian goals, restoring functionality for essential tasks like feeding or grooming. While this is critical, such framing often overlooks other important dimensions of human experience, including emotional, creative, and social needs. Creative autonomy and self-expression remain underexplored in this domain, despite their established importance for well-being, identity, and inclusion. In this work, we explore how assistive robotics might be repurposed to support self-expression and authorship, expanding the design space beyond daily utility.

2.2 Technology-Supported Self-Expression and Creative Autonomy

Self-expression is a fundamental component of autonomy, identity, and self-worth [22, 47], yet technology that enables embodied, creative expression for people with upper-limb motor impairments is still rare [17, 60, 68, 80]. Most existing systems focus on digital modalities (e.g., screen-based art, laptop/computer-based systems, and speech output) [31, 61], which can lack the physicality and tangible feedback that contribute to a sense of authorship and creative ownership [62, 78].

Although technologies for accessible creative expression can reduce physical barriers and widen access to creative practices, they can also introduce new forms of effort and constraint. Digital artists with upper-limb motor impairments report pain, discomfort, fatigue, and time-consuming workarounds that can interrupt creative flow and reduce motivation [15]. These experiences highlight a design tension that assistive systems should reduce physical effort while preserving users' meaningful control over the creative process. Research on sense of agency suggests that higher levels of automation or weaker coupling between users' actions and system outcomes can diminish perceived agency [7, 55]. Work on hybrid fabrication further suggests that involving users in material processes can foreground agency and control by clarifying the relationship among intention, action, and artifact [21].

Several recent studies have explored how robotic systems might support artistic expression [13, 19]. Prior work argues that while computers have long shaped artistic practice, the role of robots in art-making has only recently received sustained attention. Robots are framed as embodied, material, and co-present creative tools that can open new pathways for the performing [40, 41] and visual arts and broaden how researchers think about embodied interaction.

Barbareschi et al. [4] enabled a DJ with Amyotrophic Lateral Sclerosis to control robotic arms to enhance self-expression. Zhou et al. [81] combined LLMs and robotic gestures to support emotional expression through body language. Cubero et al. [19] showed how real-time robotic drawing can shift perception from a "printing machine" to a creative "colleague," while Karimov et al. [43] explored robotic arms in artistic practices such as painting and restoration. Together, these works highlight growing interest in robotics as a means to expand creative possibilities.

More work is needed that centers the lived experience of people with upper-limb motor impairments and examines how physically instantiated outputs shape their sense of authorship, agency, and social connection. Prior systems have explored alternative input modalities, including eye-tracking for writing and drawing [23, 70], but often focus on reproducing predefined content rather than supporting open-ended creation.

Our work addresses this gap by enabling users to generate original artwork through multimodal input (head and voice) and experience it as a tangible, embodied output via robotic actuation. Beyond feasibility, we investigate how effort, user control, the timing of robotic execution, and the tangible materialization of creative outcomes shape agency, authorship, motivation, and inclusion.

3 Methods

To investigate how people with upper-limb motor impairments experience artistic self-expression, we developed a hybrid system combining AR and robotic actuation. The system allows participants to create virtual drawings that are reproduced on paper by a robotic arm. Participants engaged with the system under two reproduction conditions, live and deferred, and their experiences and perceptions were assessed through a combination of interviews and questionnaires. The following subsections describe the system architecture and functionality, the research team's positionality statement, participant recruitment, study design, and data collection methods.

3.1 The EXPRESS-AR System

To explore how people with upper-limb motor impairments might regain expressive autonomy through creative physical output, we developed **EXPRESS-AR**, a hybrid system that combines AR with robotic actuation (Figure 2). EXPRESS-AR enables people with upper-limb motor impairments to independently produce **physical**

drawings on paper, controlling the system using head movement and voice commands. This choice is motivated by prior work emphasizing the role of materiality and physical traces in shaping creative ownership. Unlike digital outputs, tangible artifacts retain a visible connection between the generative process and the final result, impacting meaningful engagement [19, 21, 82]. Robotic actuation enables this form of hybrid fabrication, producing physically grounded outcomes that support users' sense of authorship and agency [67].

We conducted a pilot study to assess the feasibility of the control system, the head-tracking interaction, and to also understand the range of movement the system needed to support a drawing task while ensuring a comfortable experience to the user. This pilot study included four people with spinal cord injuries (with low- and upper-limb motor impairments) and two occupational therapists. All six participants performed free-drawing tasks in which they could draw anything they wished using only the AR application (the robotic arm was not used). Furthermore, it also motivated the adoption of minimal voice commands and prompted simplifications to the visual feedback and overall drawing workflow.

Below, we describe the system's core components: the AR interface for control, the physical setup for holding drawing tools, and the robotic execution module. All these components are available at <https://github.com/jpplf50/PaintWithHead-XR/tree/AR-Version>[1].

AR Control Interface. The first component of EXPRESS-AR is an AR application in which users can draw and paint virtually (Figure 2.a). The user wears a Meta Quest 3 headset and, using the device's video passthrough, can simultaneously see the virtual interface on the left and the physical setup (including the robot, paper, and markers) on the right. The virtual and real canvases are separated, i.e., not overlaid.

Interactions are entirely hands-free; no manual input or physical gestures are used. Instead, a laser pointer originating from the head-mounted display indicates where the user is pointing their head, using head-gaze to drive the cursor. This interaction operates in two distinct states based on whether the virtual brush is lifted or lowered. When the brush is lifted, head-gaze acts as a cursor to select colors or controls via an interface located next to the virtual canvas. This selection is performed via dwell time, as users rest their gaze on an option for 2 seconds to confirm their choice, during which a small progress circle provides visual feedback. When a new color is selected, the system temporarily pauses drawing and displays a red message indicating that the robot is changing colors. When the brush is lowered, head movements directly control the drawing tip's position on the canvas. Toggling between these states is controlled solely by voice commands. Participants verbally dictate when to start and stop drawing using the words "Start" and "Stop". The laser pointer is displayed during selection mode to aid precision but is automatically hidden when drawing mode is activated.

Robotic Arm. Physical reproduction of the drawing is achieved by a Franka Emika FR3 robotic arm (Figure 2.b). The robot receives drawing coordinates through a ROS1-based architecture. A velocity-based controller processes these poses into commands in real time, using filters to reduce unintended motion from minor head movements.

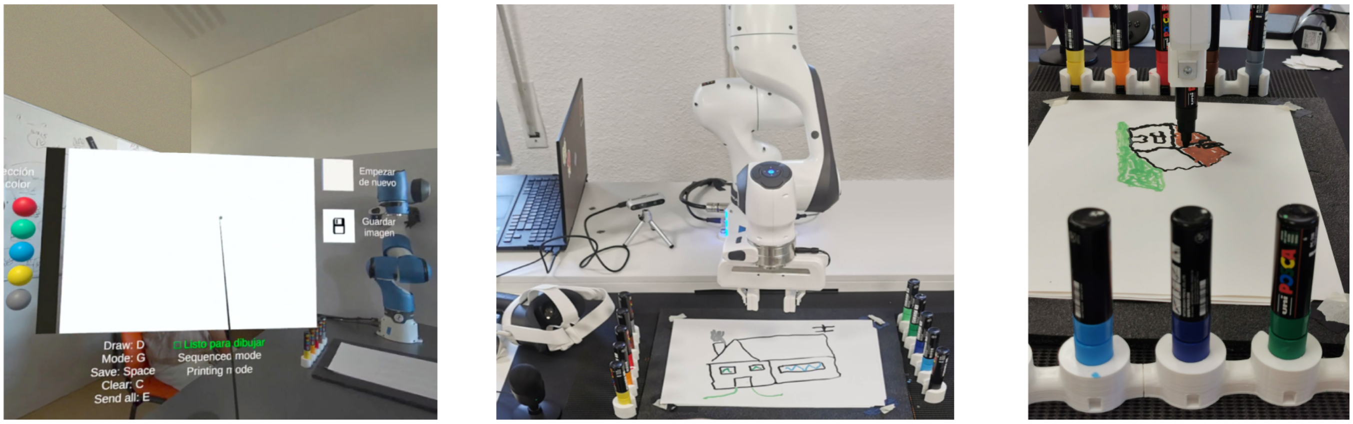
This architecture was designed to support both live synchrony and deferred execution. Temporal contiguity (i.e., the timing between an action and its feedback) is known to impact a user's sense of agency [55, 77], with synchronous responses supporting a more embodied, "self-extension" experience [45], and delays potentially shifting perception toward an external or delegated agent [7, 18]. The rationale for including both live and deferred execution was to provide participants with two distinct experiences of agency during creative expression. By varying whether actions were reflected immediately or executed later by the robot, we sought to elicit reflections on the role of control, action–outcome coupling, and immediacy in shaping experiences of self-expression. While the virtual drawing phase is faster in the deferred condition because it is not interrupted by physical marker changes, the overall end-to-end experience takes longer since the robot only begins drawing after the user finishes.

Physical Canvas. The physical output is produced onto an A3-sized sheet of watercolor paper, positioned 48 cm away from the robot base (measured from the middle of the sheet) and centered in its working area (Figure 2.c). This grounding of virtual interaction in a tangible medium leverages the "physicality" of the outcome to provide an embodied record of the user's agency [32, 67]. Beneath the sheet, we placed a semi-rigid foam layer to absorb the impact from the marker tip during drawing. Warm colors were positioned to the left of the paper, and cool colors to the right, using quick-drying 7mm Posca acrylic markers. Markers were stored tip-down in custom 3D-printed holders. Each holder stored five markers with added weight for stability, further reinforced by an anti-slip mesh underneath. To ensure a secure grip, we also 3D-printed finger add-ons forming a negative mould of the marker's shape.

3.2 Positionality Statement

We recognize that our experiences and positionality shape how we design, conduct, and interpret this research. Our team is based in three Western countries and comprises researchers with training in Computer Science, HCI, accessible computing, robotics, rehabilitation, and medicine. The team includes a range of experience levels, from researchers with over a decade of work in HCI and accessible computing to students with one to three years of experience in HCI, HRI, or robotics. Several members have collaborated closely with people and communities with disabilities across projects in accessibility, rehabilitation, and aging. We also note that this particular work emerged within a broader collaborative project with a focus on assistive robotics for people with upper-limb impairments, involving occupational therapists and frequent, often informal, contact with people with spinal cord injuries. These ongoing interactions shaped the questions we asked, the design of the system, and the exploratory orientation of the study. We approach this research as an effort to broaden access to creative practices and to foreground participants' agency and values.

[1] Available as supplement material.



a) b) c)

Figure 2: EXPRESS-AR is composed of three distinct components: a) AR control interface, b) Robotic arm, c) Markers and 3D printed platforms

3.3 Participants

Fourteen participants (8 men, 6 women) were recruited by hospital therapists from a specialized spinal cord injury rehabilitation hospital in collaboration with the research team (Table 1). Inclusion criteria required upper-limb motor impairments and the cognitive capacity to interact with an augmented reality interface, as determined by clinical staff. The cohort exhibited a broad range of upper-limb motor abilities, ranging from no arm or hand movement to limited movement without fine-motor dexterity. Although recruitment focused on upper-limb impairments, all but one participant (P1) also had lower-limb motor impairments.

Participants were 18 to 72 years old (M = 51.4, SD = 12.9), with time since injury ranging from 3 months to 6 years (M = 14.7 months, SD = 20.6). The majority (n = 11) have lived with their injury for less than 1 year, and all (n = 14) injuries were persistent, not temporary. This can be explained by the recruitment being conducted at a rehabilitation-focused hospital, where most patients are in the early stages of post-injury recovery. Injury levels spanned from vertebrae C2 to C6, with impairment severities classified across ASIA Impairment Scale (AIS) grades A–D.

Three participants reported prior experience with creative hobbies (e.g., painting, crafts) (P5, P8, P12), and one (P10) had a professional background as an architect. Eight participants reported prior experience with robots, primarily through rehabilitation robots (n = 6) or household robots such as Roomba (n = 2), while the others had no prior exposure.

3.4 Study Design

The study was structured into four phases, totaling 90 minutes, conducted individually with each participant. All participants produced two paintings, with subjects including natural elements (e.g., trees, landscapes, flowers), personal themes (e.g., heart), or cultural references (e.g., "Pink Floyd"). The research protocol was approved by the ethics committee of Faculdade de Ciências da Universidade de Lisboa. All participants agreed to participate and could quit at any time.

Table 1: Participants in the study. From left to right, columns contain participant ID, age, gender, the level of their injury according to ASIA Impairment Scale (AIS), how long participants have been living with their injury, if they had previous experience with art either professionally or as a hobby before injury, and if they had any experience with robots.

Participant	Age	Gender	Injury Level	Since Injury	Artist	Robot Experience
P1	56	M	AIS D, level C2	3 months	No	No
P2	55	F	AIS C, level C6	1 year	No	Yes (Roomba)
P3	18	F	AIS C, level N/A	5 months	No	No
P4	53	M	AIS A, level C4	8 months	No	No
P5	63	F	AIS D, level C5	1 year	Yes	Yes (Roomba)
P6	72	M	AIS D, level C4	5 months	No	Yes (Rehab)
P7	46	M	AIS C, level C4	6 months	No	No
P8	65	F	AIS D, level C4	10 months	Yes	Yes (Rehab)
P9	47	M	AIS C, level C4	9 months	No	Yes (Rehab)
P10	40	M	AIS A, level C5	6 years	No	Yes (Rehab)
P11	43	M	AIS C, level C2	3 months	No	No
P12	57	F	AIS B, level C4	7 months	Yes	No
P13	47	M	AIS A, level C3	3 months	No	Yes (Rehab)
P14	62	M	AIS D, level C3	3 months	No	Yes (Rehab)

Phase 1: Pre-Interaction. Each study session began with participants attending an initial briefing session where the study's purpose and procedures were explained. At this stage, we only informed participants that the study involved a drawing activity, without providing further details about the system. The briefing took place in a room where neither the robot, the head-mounted display, nor any other apparatus was visible, to avoid influencing their expectations about the setup. After giving their consent, they completed a demographic and background questionnaire, followed by a brief pre-interaction interview. During the interview, participants were asked about their prior experience with assistive technology and their expectations and concerns about participating in a drawing activity.

Phase 2: AR Interaction - training session. After discussing the perceived expectations of the study, the researchers, assistive staff, and participant proceeded to the main room, which contained the robotic arm, AR prototype, and drawing setup. Participants began with a brief training session lasting between one and twelve minutes (M = 05:42, SD = 03:39), during which they were introduced to how the AR interface worked while the robotic arm was not activated. We separated the two components so participants could focus on learning the AR interface (the only part they directly controlled), since most had no prior experience with AR. This also allowed for a shorter, more focused training session. This initial training was also valuable for assessing whether each participant could interact effectively with the system without experiencing nausea or motion sickness, which are common limitations of VR and AR applications [50].

Phase 3: Multimodal Interaction with the Robotic Arm. Following training, each participant completed two drawing tasks under different robotic reproduction conditions. In the first condition, labeled "live," the robot replicated the participant's drawing in real time. In the second condition, referred to as "deferred," the robot rendered the entire drawing only after completing the digital version. These conditions aimed to probe potential differences in how participants perceive the interactions and the impact on self-expression. The order of these conditions was counterbalanced across participants to control for order effects. In all drawing tasks, participants were asked to "draw whatever they liked", with no other instructions that could influence their drawings.

Each condition lasted up to 15 minutes, and after each session, participants completed a quantitative questionnaire specific to that condition. Live sessions lasted between 1:02 and 15:00 minutes (M = 08:39, SD = 04:06), while deferred sessions ranged from 3:00 to 12:00 minutes (M = 06:19, SD = 03:05). Participants were encouraged to be in charge of the drawing (i.e., they would decide when the drawing was finished), which explains some sessions lasting as little as one minute, while others lasted the full fifteen minutes. A short break was offered between tasks if needed. The physical artworks created during each condition were given to the participants afterward, with one piece of their choice framed.

Phase 4 Post-Interaction Reflection and Feedback. Finally, after completing all conditions and quantitative questionnaires, a semi-structured interview was conducted to allow participants to reflect on their experiences using the system, their perceived sense of control, autonomy, and engagement, any challenges they faced, and suggestions for improvement (protocol and interview guides available as supplementary material).

A therapist was always present to accompany participants, helping to bridge communication barriers and acting as a participant's advocate. Two to three researchers were present, alongside the therapist, throughout the study.

3.5 Data Collection and Analysis

Sessions were audio-recorded and transcribed, with videos captured to support field notes. Participants were assigned ID codes, and all personal information was removed to ensure anonymity. This data was then analysed following a codebook thematic analysis approach, which combined a structured coding procedure and reflexive interpretation [11, 12]. We used a mixed deductive-inductive approach, in which the first author generated initial codes (e.g., creativity, agency, drawing quality) after becoming familiar with the data. This first codebook was shared and discussed within the research team. To align coding perspectives, the first three interviews were independently coded by three authors, followed by discussion to refine, merge, and define codes. This first analysis resulted in new codes (e.g., artistic context, effort). Interpretative differences were resolved through consensus discussions among the three researchers, including the other team members when needed. The initial codebook, including codes, definitions, and example quotes, was revised and validated by the team. All interviews were then coded by these three authors and organized on a Miro board to facilitate collaborative discussion. Finally, codes and associated quotes were grouped into higher-level themes, which were iterated through multiple team discussions, including brainstorming sessions, to rearrange ideas and build connections among themes.

Additionally, after each drawing task, participants completed a set of questionnaires that measured their experience, including the Sense of Agency Scale [76] and the Short Scale of Creative Self (SSCS) [44]. The system also logged all interaction data during the session, including drawing duration, task completion, condition type, and input behavior. The drawings were saved as images (PNG) and as JSON files containing all the information for each drawing (number of strokes, colors, and pixel coordinates). This JSON can be loaded into the system, allowing the drawing to be continued or redone. All data was pseudo-anonymized using participant identifiers.

4 Findings

Participants approached the study with diverse expectations. Most were curious and eager to experience virtual reality, while others were uncertain about what the system would enable or questioned its purpose. For example, P7 initially assumed that the robot, rather than the participant, would create the artwork. Despite these differences, most participants entered the experience with optimism and a willingness to explore.

Our findings show how participants' perceptions evolved as they interacted with the system. We describe how they experienced agency throughout the creative process, interpreted the relationship between their physical actions and the robot's output, and reflected on the broader significance of technologies that enable artistic expression.

4.1 Creating Again

Many participants brought expectations regarding being able to self-express once again. P10, an architect, wanted to *"enjoy drawing (house) blueprints again"* and was *"excited because I'll be able to create again."* Others wished for the chance to recover a sense of lost creative freedom. For example, P14 hoped, *"that I can draw something just by looking,"* and P12 simply wished *"that my drawings turn out well."* Two participants (P5, P8), who had been consistently painting before the accident, explicitly expressed frustration at being unable to continue their artistic practice: *"I'm very frustrated. Very. Yes, I'd like to (paint), but right now I'm frustrated and I haven't painted anything, I haven't even thought of anything."* (P5). Also, P8 mentioned painting as something she can not face anymore. However, she faced our system as a new tentative try, stating, *"Let's see, facing drawing again"* (P8). For these two participants, their injuries have led them to discard painting from the range of potential endeavors.

Although the participants' expectations ranged from excited to hopeful, neutral, or unsure, the hands-on experience with the system was mostly seen as optimistic, a new opportunity, and empowering. As they explored further, confidence grew. P4 reflected, *"I thought it was me doing it with my hand, and it has been with my mind and my eyes. (. . .) It's better than I thought it would be."* For many, expectations were described as *"somewhere in the middle, not too high, not too low"* (P14), but were ultimately exceeded. P10 felt their hopes were fulfilled *"to a very high degree,"* while P11 concluded, *"It more than met my initial expectations."* P9, who had doubted at first, acknowledged, *"because I thought it wouldn't work, that it wouldn't turn out the way I had drawn it, but it turned out exactly right."* Even P7, who initially questioned the value of the technology, eventually admitted that their expectations for the future were *"high too, they're good."* P8 very enthusiastically said: *"Spectacular! (...) I felt very free, and I felt like painting again."*

For some, the experience went beyond technical success and touched deeper questions of agency. P6 described it as *"superior,"* adding, *"I think it's very good that the robot helps you see things and do things that many people who can't do anything with their hands can do."* P11 also captured this feeling: *"In the end, people who can't move at all or can't move their arms like me (. . .) find it very interesting. (. . .) I would say that, in the end, it's a rush to see that you can do things."* Experiencing agency through the system was often described as joyful and fulfilling. P4 expressed, *"I feel happy and content to have done it,"* while P2 added, *"It was a lot of fun. I had a great time."* Others described the experience simply as *"very enjoyable"* (P1) or *"curious and good"* (P7). For P10, facing the return to drawing after many years carried particular weight: *"being able to create with the robot? It's amazing, it's something amazing. (. . .) I hadn't drawn for six years and today I drew again."* Even P11, who does not perceive himself as being artistic towards painting, expressed *"being able to do things, being able to paint, being able to do the same thing again. I don't paint, but there are people who paint really well, and they can paint again"* (P11).

For a few participants who did not consider themselves artistic or creative, their reactions to the system were more varied. P9, while recognizing the system's success, still felt unsure about its immediate value for himself: *"Honestly (...) I don't know what it could offer me right now (...) in terms of progress and all that. Maybe tomorrow, but right now, no."* Others compared the experience with past drawing experiences when they could use their arms. For instance, P12 compared the experience with past abilities: *"With my hand, I think I drew better, but with the glasses and moving my head (...) I drew them well."* For some participants, a sense of artistic possibility emerged, as P10 reflected: *"I can draw with a robot, and I can create (...) I thought I couldn't do these things."* The experience led some participants to talk about returning to activities they had stopped after injury: *"Until now, I hadn't wanted to do something I really liked. I was really afraid. But now? Well, this has made me really want to paint again"* (P8).

4.2 Drawing with Meaning

For many participants, drawing was more than just an activity; it was a way to express themselves. Their artwork reflected their personal stories, relationships, passions, and memories. As P2 explained, *"You can express many things with drawing. Your mood, your joy, many things. With a lot of creativity and imagination, you can express a lot."*

Some drawings represented what was happening in their lives at that time. P7 chose to draw a house (Figure 3.a) because *"it was a project I have in mind right now,"* while P10, who had worked as an architect (Figure 3.b) before the injury, explained, *"I wanted to make the blueprint [of a house] in perspective. Then the facade of the house."* Similarly, P2, who had previously worked as a cook, proudly described her creation (Figure 3.c): *"The paella is very nice, the tree is hideous [the other drawing]. But the paella is very cool, it turned out very round."* Others drew inaccessible places that they used to enjoy, such as nature. These drawings helped them reconnect with places or activities they could no longer reach. P3 described painting the sea as particularly powerful (Figure 3.d), because, with watery eyes, she explained it's a place she feels sad she can not access easily: *"When I was painting the blue of the sea, the little bit of sea I did, I felt good."* P8 recalled an unfinished landscape painting before their injury, while P4 sketched a truck (Figure 3.e) to remember his profession as a truck driver. These moments show how creating helped participants reconnect with memories and identities that felt lost.

The drawings also illustrated strong connections between relationships and personal identity. For example, P6 expressed that his ship and heart were intrinsically tied to his sense of self and his love for his wife: *"I like to travel by boat. . . I also like fishing (...) [I drew] the heart because of my wife."* Similarly, P13 created a heart illustration dedicated to his wife, while P7's drawings intertwined personal interests with those he shares with his partner (Figure 3.f). For these participants, drawing was a meaningful way to honor and bring significant relationships into view. One of the participants, P13, wrote in the drawing *"LAUGHING AT LIFE,"* (Figure 3.g) as a form of acceptance of his new reality. Another participant, P14, drew an abstract painting (Figure 3.h). When asked why, he replied: *"I made an abstract piece because that is my life right now. . . abstract."*

Interestingly, many participants spontaneously mentioned their drawings as childish and basic, but not out of embarrassment. P10 admitted, *"The drawing itself is very childish to me, but I have to admit that it's really cool, that it's a way to create and do amazing things."* P4 and P7 expressed that even if childish, they were happy and

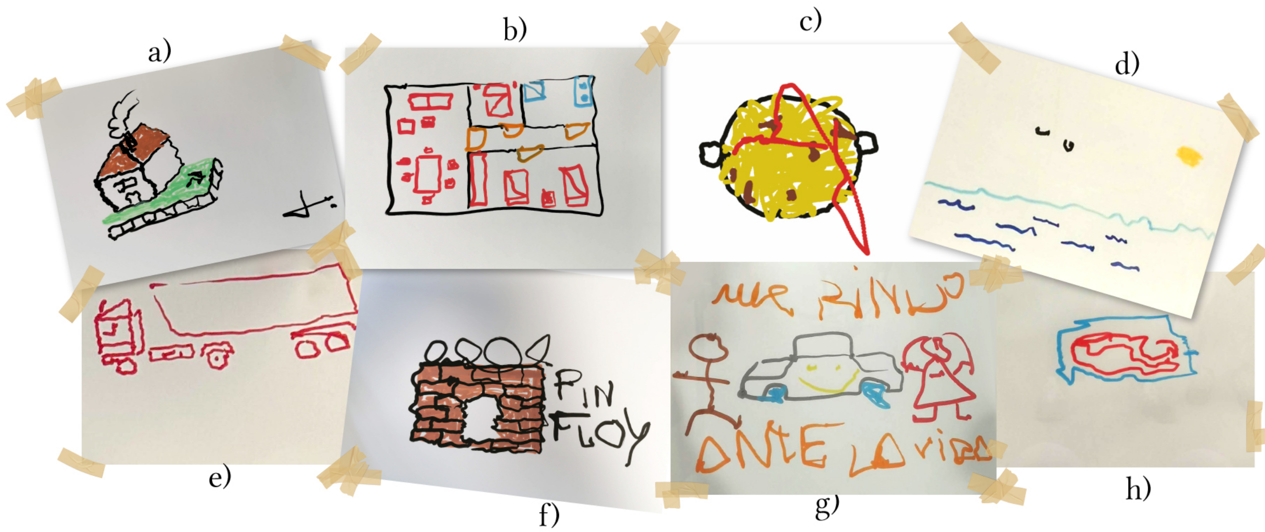


Figure 3: A collection of drawings made by participants using EXPRESS-AR. a) P7 drew a house as it was a plan on their mind, b) P10, as a former architect, drew a blueprint, c) P2, a cook, drew a paella, d) P3 drew the sea since it was inaccessible, e) P4 drew a truck as a former truck driver, f) P7 and their wife loved Pink Floyd, g) P13 wrote "Me rindo ante la vida" (laughing at life), h) P14 drew an abstract drawing as their life was abstract.

curious to draw again, while P11 said childish is positive because he's not able to draw something artistic like renowned artists do (citing Picasso). Other participants, who initially stated they were not great at drawing, such as P11, reflected that they drew *"Like I was 5 years old. It reminded me of how badly I used to paint when I was little and how badly I've been painting as an adult."* P1 even dismissed their work as *"a disaster when it comes to painting,"* yet still recognized that it represented their skills and efforts. However, for most, such as P4 expressed, this sense of imperfection did not detract from the significance of the act - *"Even if it's a childish drawing, it's a drawing I made myself."*

Most participants were not prioritizing technical skills or how technical the drawing was, but what it made them express and communicate. It became a means of reclaiming expression, revisiting significant places, and giving shape to relationships and memories. Even when the drawings appeared simple or imperfect, their value lay in what they represented: an opportunity to express identity and reconnect with what mattered most.

4.3 Embodied Expression

A key theme in participants' accounts was the embodied feelings they developed toward the robotic arm. For many, the robot was not experienced as an external tool but as an extension of their own body, allowing their ideas and movements to take physical form. P9 explained, *"I could consider it a third arm of my body… it was as if my arm was drawing."* Many people shared this feeling of blending or merging. P6 described the immersive experience in a way that stood out the most: *"I was in the glasses as if I were the robot doing it."*

The sense of embodiment was linked to a perception of autonomy, with participants noting that the robot did not act independently, but consistently reflected their intended actions on the paper. As P2 put it, *"The arm helps you express what you want to do, but you do what you want. Whether it turns out well or badly."* Similarly, P4 stressed that the drawing came *"from my imagination and by myself, from what came to me."* What was produced on paper was consistently described as their own drawing, not the robot's.

Participants valued how closely the system mirrored what they had envisioned. P7 reflected, *"I just asked it [the robot] by drawing it. Then it was captured [the drawing], exactly the same as what I drew [in AR]."* Even when errors occurred, such as forgetting to give a command, they were attributed to personal mistakes rather than technical failures. As P4 explained, *"Sometimes I forgot to say stop and I went on (...) but it was because of my impulsiveness to go faster."*

This combination of body and robot was both functional and emotional. Participants experienced satisfaction in being able to express themselves despite physical limitations. P8 summarized this clearly: *"It made me happy. I felt it captured what I wanted, which is what it's supposed to do when you can't use your arms."* For some, like P14, the experience exceeded imagination: *"I was thinking that it was so surreal being able to make a drawing with your head."* One key aspect of combining the human body with the robotic arm output was the fact that their creations became tangible, easy to carry, and easy to proudly display, with some participants expressing that they would hang them on their walls, as stated by P8: *"It's important to have a physical paper, because you can feel it, while the virtual drawing you can only see it"*.

Through this embodied interaction and the materialization of the outcome, the robot was described less as a device and more as an extension of their own presence and agency, enabling them to draw through it. This sense of physicality was central to how they experienced authorship and expression.

4.4 Authorship and Fidelity

A key consideration in participants' reflections was authorship: who was truly responsible for the drawings: the system or themselves? Across accounts, participants consistently emphasized that they were the authors and that the robot merely enacted their intentions.

Participants stated that having the robot draw a physical version did not reduce their sense of ownership over the drawings. As P2 noted simply, *"I drew the pictures myself. I don't care if the robot draws at the same time as me. I did the drawings."* Likewise, P9 mentioned they were in complete control, *"Man, honestly, there's a lot of control (...) over what I was seeing."* For P11, live drawing reinforced this sense of authorship: *"It's more like you're really doing it yourself (...) the more realistic feeling is in real time."*

Beyond authorship, participants reflected on responsibility when things did not go as planned. P1 expressed a general idea that *"it's only the artist's fault if the final result is not good."* In these cases, mistakes were often attributed to their lapses rather than technical flaws. P1 explained, *"It's my own mistake (...) I was already thinking about something else, that's not a system error, (...) it's human error. Therefore, I had total control."* P4 similarly described partial but sufficient control: *"Well, I had quite a lot of control, although not completely, but I did control the situation."* Even P3, who had limited neck mobility, acknowledged that lack of precision might be associated with their own body rather than the system: *"But it's also because I don't have full control of my neck, so that could be why."* However, P1, as well as other participants, understood that their drawings' *"errors belong to me, not to the system. If a person trains with that, you can achieve big results."*

Participants emphasized the fidelity of the drawings as a crucial factor in their sense of authorship. Observing their ideas and values on paper strengthened their ownership of the drawings. P7 recalled, *"After seeing the drawing, he [the robot] drew it just as it was."* With the same sentiment, P1 celebrated, *"The drawing is phenomenal, very beautiful. It corresponds perfectly to what I did. That's fantastic."* P11 even described the outcome as *"a work of art… magnificent."* A few noted that with more practice, they could improve their technique and outcome: *"I need to improve"* (P7); *"I would practice first to make it nicer"* (P2).

Authorship was about accepting responsibility over the drawing in the present and about imagining future artistic practices. Participants felt their creations were truly theirs, regardless of whether they were imperfect, accurate, or surprisingly artistic. During our session, they thought the system gave them the control and accuracy needed to support their imagination and drawings.

4.5 Temporal Execution

Participants discussed the two modes of interaction with the system: live and deferred.

Many participants preferred the live mode because they felt it gave them more control. They described it as more immediate and better aligned with their intentions. P11 noted, *"When you're doing it at the same time, you notice and see the control in real time more."* Similarly, P9 emphasized, *"In real time, I was seeing what I was drawing (...) my feeling is that there was much more control."*

Live mode was also often described as more *"real"* and engaging. P4 remarked, *"While you draw and the robot draws, it seems more real, more creative."* P1 added that it created a stronger sense of authorship: *"You feel it's more yours than if it's 'printed' at the end."* Many participants noted that watching the drawing come to life enhanced their immersion and satisfaction, with P11 calling it *"a greater sense of reality that you're doing it yourself at that moment."* However, some participants expressed less control in the live drawing, as it is more prone to mistakes. For instance, P2 considered her live drawing worse than the deferred version.

The deferred mode also offered benefits. Some participants liked the clarity of seeing a final, clean result without the distraction of ongoing movement. For instance, P3 thought the deferred option best represented her drawing. Painting or drawing is often a moment where the person can unfocus on reality and get absorbed in the moment. For these reasons, P8 (former artist) preferred the deferred version because it gave them a lot of quietness and peace. Another example was P12, which utilized the deferred mode to be very focused in silence and involved while the drawing later emerged through the robot. However, this slowness for others could feel too slow or tiring to watch. P1 commented, *"Watching the robot draw (...) is really boring… it takes 20 minutes. It bores me to death."*

These reflections emphasize that the temporal execution can be an important design choice that influences some participants' feelings of authorship (but not all). While it also influences their sense of control and satisfaction with the system, it is highly dependent on each person's perception and preference.

4.6 Beyond Self-expression

While drawing was often regarded as a means of personal expression, during the study, participants also recognized the potential of systems like EXPRESS-AR beyond creativity, opportunities for rehabilitation, skill development, employment, and broader social impact.

Participants compared the system to other assistive technologies they had used in their recovery, and even for those, there is a learning curve. P14 explained this by drawing a parallel with the hospital robotic exoskeleton, *"It's just like the robot for walking, (...) I never thought I could learn to walk with it, and I'm learning."* The act of painting was not only seen as a form of expression, but it could also be part of physical and cognitive progress. As P4 described, *"You feel really creative, it gives you the opportunity to move your arms (...), even if you couldn't move them, you'd still feel super happy to be creative through your eyes."* In this sense, drawing was imagined not only as artistic expression but also as a rehabilitative exercise. A reflection from the pilot study further illustrates the potential of this technology for rehabilitation. One participant saw it as a way to track recovery, comparing early and later drawings to make progress visible. The participant later added, *"It has been especially helpful to see my state of health and progress since the lesion."*

Participants viewed the system as a helpful tool for accomplishing tasks, even related to past professions. P10, who was an architect before the lesion, was clear: *"With this system, you can work and get things done (...) drawing blueprints (...) in a way that allows me to work and create."*

Potentially applying the system to tasks beyond leisure painting was compelling for participants with certain professional backgrounds. Additionally, creative expression was imagined to be transformed into something more practical, even professional. P11 suggested, *"It would be a hobby to consider (...) or as a way to make a living."* Like several other participants, P11 had many previous hobbies, such as riding a motorcycle, but after the accident, some saw painting as a new opportunity. P2 echoed this possibility as being advantageous to several people, commenting, *"My goodness, you would have a school [school class, with this system], because there are so many people who don't have hands at all [metaphorically speaking]."* For these participants, creating art was more than just expressing themselves. It helped them find new ways to be included, learn new things, and earn money.

However, for these further artistic explorations or even extended uses to be materialized, P8 mentioned that the research team and the robotic system would have to be available over time. P8 insisted, *"You have to stay here now to help people."* Similarly, P2 imagined the system as a way of creating opportunities for other people who can't use their arms: *"This would be wonderful. I would like it here (at the hospital)."*

These accounts show how the system encouraged participants to see beyond the act of drawing. For some, it was connected to recovery and mobility. For others, it related to work, art, or contributing to society. Even when participants downplayed their creativity, they often viewed the system as an empowering resource for people with motor impairments. Systems that merge human action and intention to agency through a robotic arm have the potential to restore a sense of agency, promote productivity, and foster new spaces for inclusion.

4.7 Complementary Quantitative Analysis

Complementing the qualitative findings, we examined quantitative indicators of task engagement. Participants used a comparable number of strokes across conditions (Deferred: M= 20.50; Live: M = 14.57) and covered similar drawing distances (Deferred: M = 20,832 px; Live: M = 15,836 px). The amount of colors selected was also consistent (Deferred: M = 4.14; Live: M = 4.00). Paired-samples t-tests showed no statistically significant differences between conditions between both temporal settings (e.g., stroke count: $t = -1.67$, $p = .12$).

Additionally, we analyzed questionnaire data to gain an overall view of participants' experiences with both interaction modes. Participants reported relatively high levels of positive agency (SoPA) and moderate levels of negative agency (SoNA) across both conditions. In the deferred condition, SoPA scores averaged $M = 5.64$ $(SD = 1.27)$, while in the live condition, they averaged $M = 5.77$ $(SD = 0.78)$. For SoNA, deferred scores averaged $M = 3.33$ $(SD = 1.73)$ and live scores averaged $M = 3.30$ $(SD = 1.51)$. Paired-samples t-tests showed no significant differences between conditions for either subscale: SoPA, $p = .76$, 95% CI $[-0.78, 1.04]$; SoNA, $p = .93$, 95% CI $[-0.82, 0.76]$.

Descriptive statistics also showed that participants reported relatively high creative self-beliefs across conditions, with mean scores consistently above the midpoint of the 5-point scale. Creative Personal Identity (CPI) scores averaged 3.84 (SD = 1.39) in the deferred condition and 3.73 (SD = 1.20) in the live condition, while Creative Self-Efficacy (CSE) scores averaged 3.98 (SD = 0.92) in the deferred condition and 3.89 (SD = 0.72) in the live condition. Paired-samples t-tests showed no significant differences between the live and deferred conditions for CPI ($p = 0.74$, $d = -0.08$) or CSE ($p = 0.72$, $d = -0.11$). Effect sizes were negligible, and the 95% confidence intervals included zero in both cases, suggesting no reliable effect of condition on participants' creative self-beliefs.

Overall, the quantitative results aligned with participants' reflections: both live and deferred conditions supported strong agency and creative self-efficacy, though in different ways, with the analysis showing no significant differences between modes.

5 Discussion

We begin the discussion by addressing the research questions that guided our study design, followed by broader lessons learned derived from our findings.

How do people with upper-limb motor impairments experience self-expression through AR-guided drawing and robotic execution? Participants experienced EXPRESS-AR as a way to re-enter creative expression, whether by reconnecting with practices they had set aside after injury or by exploring drawing as a novice. Creative output carried emotional weight, often tied to memories, relationships, and identity. Instead of judging their drawings by technical quality, participants emphasized authorship: even imperfect strokes "felt like mine". This sense of ownership emerged because the robot was experienced less as a surrogate actor and more as a channel for their intentions, echoing prior work on embodiment and mediated agency [48, 55]. Thus, the system supported the mechanics of drawing and the broader goal of reclaiming expressive possibilities that participants associated with autonomy and participation in everyday life [35].

How does immediate physical drawing impact users' perceived agency and connection to their creative output? Participants described the live condition as heightening their sense of "acting in the moment", with real-time reproduction strengthening the coupling between intention and visible outcome. It aligns with work showing that temporal contiguity is a key cue for agency [33, 38, 55, 77]. However, authorship remained high in the deferred mode as well. Participants still recognized the drawings as their own when the system precisely enacted their intentions, echoing findings that agency can persist despite temporal delays [79]. Interestingly, some valued the deferred mode precisely because it reduced visual distraction and supported quieter, more reflective engagement.

What other opportunities and concerns do users perceive in using AR and robotics? Participants focused on the opportunities the system created: reviving expressive practices, strengthening emotional communication, and reconnecting with aspects of identity. They also imagined vocational and social applications extending beyond leisure. Some valued the drawings as tangible markers of progress, contrasting them with traditional rehabilitation exercises. This reinforces prior findings that creative work can support motivation and self-reflection in therapy [52], while highlighting the importance of integrating such systems thoughtfully into rehabilitation contexts.

5.1 Enabling more with Assistive Robotics

Most advancements in assistive robotics have focused on feeding devices and robotic arms for reaching and grasping, particularly for activities of daily living (ADLs). This ensures that individuals with severe motor impairments can eat, dress, or bathe with greater independence [5, 42]. This focus is essential, as fulfilling basic needs is vital for survival and independence. However, the utilitarian perspective on assistive robotics overlooks other important aspects of human life. Activities often dismissed as "extra", such as hobbies, leisure, or creative expression, are central to psychological well-being, identity, and social participation [34, 51].

Expectations for self-expression were typically low among our participants, since most of the technology they encountered was limited to restoring functionality (i.e., rehabilitation robots). This mirrors broader trends in the field, where assistive robots are normally not designed to enable play, creativity, or hobbies, despite their importance for mental health and recovery [26, 27].

Our findings indicate that when given the opportunity, participants engaged in drawing and began exploring new possibilities for themselves. For some, this involved reconnecting with past activities such as painting or architecture. For others, it opened the door to envisioning new hobbies and professional goals, or to setting personal challenges for self-improvement over time. This echoes work on inclusive design, highlighting how technologies beyond functional recovery can foster identity, joy, and social meaning [30].

Participants noted that rediscovering creative outlets significantly impacted their mental well-being. Feelings of powerlessness often gave way to surprise, satisfaction, and renewed engagement. This suggests that technologies facilitating expressive non-utilitarian tasks may contribute to psychological rehabilitation, aligning with previous work showing the benefits of meaningful activities [1, 58].

By combining AR interfaces with a robotic arm, participants could actively create and materialize their ideas. This shift towards self-expression highlights an important design space in assistive technology. We call attention to HRI scenarios that move beyond utilitarian goals and encourage researchers to broaden the scope of what these technologies are designed to support. This includes co-defining use cases with people with disabilities, centering their voices in identifying values, needs, and ambitions [63, 71].

5.2 The Tradeoffs of Automation

Modern robotics and artificial intelligence research tends toward automation, aiming to make systems more efficient. Interestingly, most participants in our study assumed responsibility for their own errors and considered them marks of self-expression and ownership. They emphasized the importance of controlling the creative process. This sense of agency was central to how the results were regarded. In automated systems, people often feel detached from outcomes, as decision-making and agency shift from them to machines, limiting human involvement [3, 66]. The risks of excessive automation have been widely recognized in fields such as aviation and driving, where automation can shift responsibility and diminish the user's sense of agency [14, 24, 25].

When automation displaces action, users can feel alienated from outcomes, leading to decreased trust and a weaker sense of accountability [53]. This is consistent with more recent findings on creativity support tools, where users report that a sense of agency is essential for feeling ownership over their outputs [74].

Research on shared autonomy shows that allowing users to modulate the level of technological assistance can preserve agency while reducing effort [79]. For instance, Hirabayashi et al. [36] developed a photography system for visually impaired users using an omnidirectional camera combined with post-production AI cropping. The system automates technical tasks like framing and cropping, yet crucially, users choose what to include in the final image. This mirrors how our participants found some automation acceptable in the form of smoothing lines and auto-filling shapes, and highlights opportunities for work that automates the provision of adaptive just-in-time tools rather than automating the outcomes [10].

These examples show that the impact of automation on human agency depends not on its existence but on how it is understood and deployed. We argue that, when connected to tasks that support execution, it can enhance human intention rather than undermine it. By placing this automation in a supportive rather than a controlling role, our approach reinforces a design philosophy that amplifies human creativity rather than replacing it [9].

Automation is not always the optimal goal, especially in contexts where personal agency, expression, and authorship are central. In such cases, overly automated systems may inadvertently strip users of the very experiences they are intended to support. We advocate for a nuanced understanding of how to balance system autonomy with human agency in ways that are sensitive to individual preferences, tasks, and contexts. This balance is unlikely to be one-size-fits-all. Instead, it calls for flexible systems that enable personalization and contextual adaptation, empowering users to shape the role automation plays in their interactions.

5.3 Navigating the Ethics of Brief but Lasting Experiences

In our study, participants gained temporary access to a system that allowed them to draw, express themselves, and reconnect with activities (for some) that had long been thought inaccessible. This impact, while positive, brings important responsibilities.

Despite careful efforts to set appropriate expectations, both for participants and within the research team, we were still surprised by the overwhelming emotional responses from some participants. Several expressed a strong desire to continue using the system beyond the study, with some asking if the robot and headset could stay in the hospital permanently. While this speaks to the value and relevance of the intervention, it also highlights a persistent ethical dilemma in accessibility research: introducing meaningful tools and then removing them at the end of the study.

Our experience echoes recent work on emotional sustainability in HRI, which shows that endings can be tough because participants may form attachments, feel the loss of a system, and leave researchers with responsibilities that continue beyond data collection [28, 73]. "Touch-and-go" research risks leaving participants feeling abandoned or disappointed. From this perspective, accessibility studies should plan for a positive impact on users with care, continuity, and a planned exit [8, 16]. We underscore the importance of continuous engagement, in which researchers remain present in the lives of the communities they work with, before, during, and after the study [73].

To mitigate the transience of our intervention, we adopted several strategies. First, each participant received a framed copy of a selected drawing (a physical, lasting artifact of their creative agency). Second, we are making the VR painting application independently available, decoupled from the full robotic setup. This lightweight version of the system, supporting head-gaze and voice-based drawing, saving, and revisiting artwork, is open-source, easy to deploy, and designed to run on accessible AR/VR hardware. While not as tangible as the robotic drawing, it sustains access to the expressive core of the experience.

Beyond technical solutions, we emphasize the value of team composition and internal reflection. Emotional moments were shared not just by participants but also by researchers, who found themselves unexpectedly moved by what the experience meant to users. Debriefing sessions among the research team proved essential, allowing for emotional processing and strengthening ethical reflexivity. The interdisciplinary nature of our team, spanning technical, clinical, and social backgrounds, was instrumental in ensuring a supportive environment for both participants and ourselves.

Ultimately, impactful accessibility experiments require more than thoughtful design; they demand thoughtful infrastructure. We advocate for research practices that are grounded in care, designed with continuity in mind, and open to co-shaping futures that do not end when the study does.

5.4 Limitations

The participant population was exclusively drawn from a rehabilitation hospital specializing in spinal cord injuries. This specific context likely influenced both the recruitment process and the participants' experiences with technology, creativity, and rehabilitation. Moreover, this limitation was exacerbated by the fact that several participants had sustained their injuries within the past year, meaning they were still in relatively early stages of adjustment and recovery. Consequently, the findings may not directly apply to individuals with motor impairments in other contexts, such as those living independently, in long-term care, or in non-clinical environments. This is especially important, as individuals living with injuries for a longer time might already have approaches to self-expression. The relatively small sample size should also be acknowledged. While it generated rich qualitative insights, it limited the statistical power of the quantitative analyses, potentially leading to some effects going undetected.

Furthermore, our system's interaction design, in addition to head gaze, relied on voice commands. This modality was informed by an initial pilot study and proved suitable for our specific sample, as all participants retained the ability to interact vocally. However, we recognize that this limits the system's accessibility for individuals with speech or severe respiratory impairments. Future research should explore alternative or multimodal input methods (e.g., eye-tracking, sip-and-puff, or adaptive switches) to accommodate populations unable to interact by voice.

In addition, we acknowledge that participant feedback in this study was predominantly positive. We attribute this partly to the novelty of the system and to the meaningfulness of engaging in a form of self-expression that many had not accessed since their injury. Because this study was designed as an early elicitation and feedback session, it successfully captured participants' immediate reactions and initial requirements. However, short-term encounters can highlight enthusiasm while obscuring longer-term challenges. We therefore note the need for future longitudinal studies in more diverse settings (e.g., homes or rehabilitation centers) to examine sustained engagement, identify potential sources of fatigue or discomfort, and assess whether minor issues evolve into barriers to continued use once the novelty disappears.

6 Conclusions

This study examined how combining AR and robotic actuation can enable new forms of expression for people with upper-limb motor impairments. Using a novel system that allows users to draw with head and voice input, we investigated how participants with upper-limb motor impairments engaged with physical creative output and how different drawing dynamics shaped their sense of agency. Our findings highlight that creative practices, which have been receiving less attention in assistive technology research, can play a powerful role in restoring confidence, reconnecting with identity, and imagining new forms of contribution to society. Participants described the system as enabling more than expression; it offered validation, emotional resonance, and a renewed sense of capability. These results invite a broader view of assistive technologies, one that includes self-expression and authorship as essential goals.

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