“Why would you persist through the pain?” Understanding Pen-Based Gestures for Artists Living with Upper Limb Motor Impairments

ANONYMOUS AUTHOR(S)

Digital art-making can be transformative for people living with disabilities. However, accessibility challenges force artists to use lengthy workarounds and interrupt their creative processes. We employed a Research-through-Design approach with six digital artists with upper limb motor impairments. First, we co-designed a stylus artifact capable of detecting pen-based gestures. In a second phase, we deployed this artifact as a design probe to gain insights into how artists adapt their workflows. We found that artists rely on resilient processes that took a long time to form, and they manage to keep a balance between their creative immersion and physical discomfort. The probe revealed that adopting new interactions was often easier than changing existing workflows, with artists often prioritizing control and authorship. We discuss the potential for customizable interactions to reduce cognitive and physical loads and digital art embodiment. Finally, we share design recommendations for developing future accessible artistic technologies.

CCS Concepts: • **Human-centered computing** → **Accessibility**; **Empirical studies in accessibility**; **Graphics input devices**; **Empirical studies in HCI**.

Additional Key Words and Phrases: Digital Artists, Graphic Input Devices, People with Disabilities, Upper Limb Motor Impairment, Disability Art

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1 Introduction

Creating art presents opportunities for individuals with disabilities for self-expression, social integration, and economic independence [14, 58]. Visual arts play a critical role in identity formation [86], offering avenues for cultural engagement [10], and allowing for the expression of individuality, increasing self-efficacy and independence [71, 75]. Research has shown that art-making helps to manage intrusive thoughts and enhance control and confidence [78]. Art is a social integrator that forges connections and fosters community [14, 56, 58]. The economic opportunities it brings support individuality and autonomy [64, 75, 80, 82]. Shifting the narrative from ‘incapable’ to ‘capable’ can help society recognize the contributions of people of diverse abilities in the arts [95].

However, digital artists who live with upper limb motor impairments (ULMI) find significant barriers to overcome when creating art [29, 72], often needing to develop lengthy workarounds or adapt their creative methods based on the limited tools they find accessible [74, 75]. Prior studies have observed a trend of artists with ULMI preferring mainstream input devices [29], possibly due to the new accessibility configuration options available.

While technology can offer ways to compensate for the limitations in individuals’ motor skills [92], Human Computer Interaction (HCI) research has at times neglected the need artists have, often mainly focusing on improving productivity [43, 55]. To be able to produce art, artists need to navigate through several stages from inspiration to finalizing a piece in a deep state of concentration [24, 56]. Artists living with ULMI face accessibility challenges which impact creative processes, and the agency over tools shapes their identities [27]. Addressing this gap requires research approaches that can explore the lived experiences and nuanced practices of artists, rather than focusing solely on performance metrics.

The accessibility of digital input methods that are applied to artistic processes is an area that remains underexplored [28, 29], with digital artists with disabilities still experience pain and fatigue that cause interruptions, limiting or abandoning work [30]. Enhancing accessibility features in digital art platforms, such as supporting alternative input devices and customization options, is essential for enabling artists with motor impairments to fully participate in creating art [35].

In this context, the intersection of digital art creation and accessibility is increasingly important for HCI. To explore these complex interactions, we adopt a Research-through-Design (RtD) approach [97]. Specifically, we engaged in a two-phase process of making to generate insights [81]. We first co-designed a functional stylus prototype, which we then deployed as a design probe [44] to elicit rich data about artists' lived experiences. Our RtD inquiry is guided by the following questions:

RQ1 *How can pen-based gestures be designed to better support the creative processes of digital artists with ULMI?*

RQ2 *How do digital artists with ULMI experience and utilize the customization of pen-based gestures?*

RQ3 *How does interacting with a customized stylus shape artists' relationship with their tools and creative practice?*

After the study concluded, we analyzed the data collected from the co-design sessions, our semi-structured interviews, the information logged by our design probe, and the video recordings of the participants creating art. We found that the input devices offer affordances that shape the stylistic choices and workflows of digital artists living with ULMI, like sketching or colouring, and they use many tools to produce fine details in their more advanced creative processes. We also note how some limitations restrict their creative choices, like interruptions due to pain or fatigue, which lead to abandoning work. We also share how artists saw their artistic processes as complex and not easily modifiable. They linked their concentration level to physical strain, finding pen-based gestures easier to remember than initially expected. We discuss how participants thought new interactions, such as pen-based gestures, could help streamline existing artistic processes and reduce the cognitive/physical load. We explore the relationship artists establish with their tools and artistic practices. Finally, we outline the study's limitations and propose avenues for future research.

2 Related Work

2.1 Creative Processes of Visual Artists

To understand the experiences of artists, including those with disabilities, we examine the creative process itself. The 4Ps framework [79] was an early model for creativity that identified four key elements: Process, People, Press, and Product. Many scholars have since deconstructed and built upon the 4Ps, including the Process element that is central to our study. Scholars generally agree that the creative process is complex, with some modelling it as a series of distinct stages [7, 65]. Artists must navigate these stages sequentially to bring their artwork to completion [13, 32]. In this work, we mostly adopt the stage-based framework discussed by Botella et al. in their analysis of artistic creative processes [15].

However, we acknowledge that creative production is a highly nonlinear process. While Botella et al. describe multiple phases, we synthesize these into three key stages for our study: ’Initialization,’ ’Expansion,’ and ’Finalization.’ Their framework also identifies several factors that facilitate or hinder movement between these stages, such as personal characteristics, domain, experience, and emotional state. For example, managing difficult emotions is vital for completing artwork.

Artists need to be deeply concentrated to achieve mastery during their creative stages. We use the term ’creative stage transitions’ to refer to the moments when an artist moves between distinct phases of their work, such as from initial sketching to detailed refinement or coloring, which we later frame as ’Initialization,’ ’Expansion,’ and ’Finalization’ (see Fig. 2). Csikszentmihalyi called these feelings of effortless control and loss of self-consciousness ’flow’ [31]. While measuring flow remains debated, the concept is widely accepted [70], and is often understood as a dynamic path navigated between challenges and skills [56, 70]. In other words, artists may stretch beyond their abilities while coping with outcome uncertainty [9]. We will use this perspective to interpret our findings, since artists perceive flow as a prerequisite for and an effect of their creative work, learning, and organization [24].

Artists navigate their creative processes influenced by diverse internal and external factors [90]. Nicholas et al. call for more research into tools that support artists emotionally and facilitate focus on the creative process [73]. By examining the impact of a customized stylus on the artists with ULMI, our work explores one potential avenue for developing such supportive technologies.

2.2 Accessible Artistic Input Devices

We should not neglect the role of the body and the physical world during the creative processes [55]. Early findings about digital artists’ input devices indicated that disabled people do not commonly use mainstream technologies and software [50]. However, Creed’s work indicates that most people with a motor impairment use input devices such as a mouse, trackball, or a digitizer tablet with software to create and edit graphics [28, 30]. Creed hypothesizes this is a trend, given that mainstream products are more affordable and include accessibility features and a wider choice of devices, such as mobile platforms [29]. The work of Cossovich et al. also confirmed this tendency to use customized mainstream products and the difficulties related to finding the right artistic technology [25].

As new digital tools increasingly involve customizing mainstream devices to be used by a wider range of abilities [28–30], a useful concept for analyzing these systems is ’integrality’. As described by Jacob et al., integrality moves beyond considering hardware and software as separate components [57]. We use this perspective because it brings a holistic approach that examines the input device, its control structure, the interactive tasks performed, and how these elements interrelate.

HCI researchers have spent significant efforts improving the accessibility of input devices that allow the moving of the pointer for people with physical impairments [38, 77]. For example, there are several accessibility enhancements of input devices and applications using eye gaze for drawing [54], pen-based applications for menu selection [69], and inputting text [94].

Most of the work has focused on performance on productivity, but there is a growing recognition of the unique challenges digital artists face when living with motor impairments [72]. Designers of artistic tools might find it tempting to think only about physical and functional limitations because they represent actionable challenges that bring measurable results [66]. Creed showed that digital artists with motor impairments engage beyond the available tools, even adapting their art as their disabilities change, but fatigue and frustration were obstacles to finalizing artwork [29].

While the HCI accessibility research community is growing interested in new input methods for artistic production, there has not been a specific focus on artists' creative processes.

2.3 Customizable Input Devices

HCI researchers have successfully customized computer interfaces across various domains for better access [3, 5, 20]. Ability-Based Design has enabled such work by guiding researchers and designers to adapt technology to the user's abilities rather than requiring the user to conform to predefined constraints [93]. Our research embraces this approach, seeking customizable input devices that are not merely accessible but actively support individual creative workflows.

Many customization techniques used in recent HCI research are potentially applicable to artistic input devices. For example, digital fabrication techniques allow users to design customized, more ergonomic physical adaptations [1, 17, 19, 52, 60, 68]. These customizations often lead to better adoption rates among people with disabilities [18, 51, 53, 88].

Beyond physical form, customizing interaction itself is crucial. Video gaming offers compelling examples where adaptive technologies like remappable controls and adaptive controllers enable full engagement for individuals with ULMI [2, 45, 96]. These successes suggest similar strategies for adaptable interaction could benefit digital artists as well.

Researchers have also customized core device functions. Examples include using programmable buttons or macro pads [59], creating novel tactile interfaces [17], and employing physical computing in co-designing accessible input devices [25, 26].

By using different sensors such as accelerometers and gyroscopes, input devices can accurately detect hand gesture detection [47, 48] and enhance pen-based interactions [37, 85, 87, 88]. We also know from the experiences from sign language interpreters that some hand gestures are rated as more comfortable than others when used for as an HCI input [76]. Our implementation of customizable gesture detection builds upon prior work, including studies using artificial intelligence (AI) for robust pen-based interaction analysis [67].

2.4 AI, Agency, and Creative Support

Building on customization, AI offers further potential for enhancing adaptive interfaces, sometimes termed Accessibility 2.0 [61]. AI algorithms can potentially filter, complement, or predict user input [63], aiming to improve interaction for people with disabilities. Successful examples include enhanced pointing for users with tremors [94], adaptive interfaces for older adults [8], and personalized gesture recognition systems that improve intuition and accessibility [4, 39].

While general AI applications for disability require further exploration [84], these concepts are emerging in artistic contexts. Examples include using Generative AI (GenAI) to create visual artworks with alternative input methods such as text prompts [11], wheelchairs [10], body movements [34], or voice [49]. However, introducing GenAI to act as a co-creator raises critical questions about agency, artistic control, and ownership of the resulting artwork [12, 62]. Creativity should not be separated from practice, with 'magical language' [22] that spotlights the technical tool capabilities can obscure daily practices of creative work [55]. Elaborating on this complexity, Bennett et al. emphasize that designing accessible GenAI tools necessitates accounting for the surrounding creative processes and interdependencies, prompting reflection on what counts as art and who counts as an artist [11].

While past HCI studies of artistic tools often focused on productivity metrics [6], pioneers like Shneiderman argued that computing's focus should shift towards empowering human creativity [83]. These ideas motivate the development of Creativity Support Tools (CSTs), including input devices such as the adaptive stylus we chose for our study [41]. CSTs should democratize creativity instead of supplanting it by automation [55]. Understanding how to balance usability and facilitation effectively requires further in-vivo investigation [36, 40, 42], which aligns directly with our Research-through-Design (RtD) approach that creates and deploys a novel artifact as the primary means of generating situated knowledge [91, 97]. This is especially relevant with the new capabilities AI can introduce, raising questions about user agency and control challenges relevant to the interactions observed in our study.

3 Methods

To investigate the creative workflows of digital artists with ULMI, we adopted a Research-through-Design (RtD) methodology [97]. This approach uses the design of novel artifacts as a means to generate new knowledge and insights about complex human experiences [91]. We integrated elements of co-design (making "with") [81] in order to position both ourselves and our participants as peers engaged in dialogue. Our study worked with six digital artists living with ULMI to examine their creative workflows, digital tool interactions, and the potential of new adaptive technologies. The study proceeded in two phases. Phase 1 involved co-designing an artifact capable of detecting pen-based gestures with two expert artists living with ULMI. Phase 2 evaluated the design probe, developing it into a more functional prototype. The second phase continued involving the initial two participants, plus four additional artists with ULMI of varying expertise. This section details our RtD process, including recruitment, participant demographics, study procedures, and data analysis methods.

Before data collection, we obtained ethical approval from our institution's Ethics Review Board. Participants provided informed consent before each session. We recorded audio and video of their hands manipulating the stylus and their on-screen activity, supplemented by observational notes. Artists received C$25 per hour in e-gift cards as compensation. Interviews were conducted in English or Spanish, depending on the participant's preference, and later translated if necessary.

3.1 Recruitment

We recruited participants who reported using graphic input devices to draw or edit graphics during their regular tasks, for producing amateur or professional artwork for at least three hours per week, and who self-reported living with ULMI. We excluded artists who only used analog methods (brushes, pens, etc.). We designed a list of common impairments that could help participants match their experiences with our eligibility criteria, for instance:

- Pain in your hand, arm, or joints while drawing
- Feeling tired or fatigued after drawing for a while
- Struggling to hold or control a pen or brush
- Shaky or unsteady hands when drawing
- Trouble with precision and fine details in your artwork
- Limited movement in your arms or fingers
- Finding it hard to apply the right pressure while drawing
- Difficulty coordinating movements for detailed work
- Frequently needing to take breaks because of discomfort
- Having to use special tools or grips to draw

We set these criteria to focus on users already familiar with the digital medium. This allowed us to isolate challenges related to the accessibility of the input device itself, rather than confounding our findings with the general learning curve of digital art software.

Our recruitment approach incorporated posters, email correspondence, and social media platforms to reach potential participants who met the inclusion criteria. We recruited most of our participants via direct emails to art institutions, personal acquaintances with researchers, disability advocates, and art on art-oriented networks such as Instagram.

3.2 Participants

The digital artists who participated in our study presented diverse artistic backgrounds and accessibility needs, drawing and editing graphics between 12 and 30 hours weekly. All of them resided in Ontario, Canada. We have included participant demographic information in the Appendix section, in Table A.1.

Three participants were highly active digital artists who regularly used a stylus. P1 (F, 24), experiencing wrist pain from carpal tunnel syndrome, shifted from commissioned illustration to cosplay but still draws extensively using an XPS stylus and Clip Studio[1]. P2 (M, 56), with limited motion due to cerebral palsy, prefers digital drawing using an Apple Pencil with Illustrator[2] and Sketchbook[3], finding it more accessible than traditional media. P3 (F, 18), a student, draws for stress relief and occasional commissions with a Wacom pen and Clip Studio, despite needing breaks due to fatigue and stiffness. P1 and P3 are active in online art communities.

The remaining participants included two designers and a hobbyist. They were familiar with using a stylus, but they preferred other input devices. P4 (M, 53), with fine motor challenges from spina bifida, works as a graphic designer, primarily using a trackball with Figma[4] and Wix[5]. P5 (M, 44), a product designer with chronic joint pain, sketches prototypes using a mouse or touchpad with Paint and 3D software. P6 (F, 75), a retired hobbyist with MS, illustrates stories for her granddaughter using Canva[6] with a mouse when mobility allows.

3.3 Procedure

Our RtD process was structured following the generative and evaluative phases of making outlined by Sanders and Stappers [81]. These two distinctive phases were a first co-design phase to develop a research artifact, and a second deployment phase where this artifact was used as a design probe to elicit insights into artists' creative practices.

3.3.1 Phase 1 - Co-Design: We conducted three co-design sessions per participant with P1 and P2, experienced artists whose production had decreased due to their impairments. In this generative phase, our goal was to design with two expert artists to develop a research artifact. By engaging them as co-designers [81], we aimed to ground our artifact in their lived experiences and identify key opportunities for intervention.

We met for 60 minutes three times with each participant (alternating P1/P2). Our exploration began with low-fidelity methods. We employed the Wizard of Oz (WoZ) technique to simulate potential gesture-based interactions without technical constraints. We also provided other tools, such as 3D-printed stylus sleeves [18] and an external macro-pad [26], to gauge interest in physical and functional customization. During WoZ sessions, participants drew and described desired actions for the input device; the researcher interpreted these requests and simulated the functionality (e.g., moving the pointer, triggering shortcuts). These initial explorations revealed that non-integrated solutions like macro pads were cumbersome to configure and that hand movements were a promising design space.

We then introduced a stylus inspired by Guerrero et al. [46], co-creating a 3D-printed sleeve (conductive PLA, flexible TPU) with a capacitive matrix and flexible sensor to understand ergonomic challenges related to grip and pressure. We

[1]https://www.clipstudio.net/en/
[2]https://www.adobe.com/products/illustrator.html
[3]https://www.sketchbook.com/
[4]https://www.figma.com/
[5]https://www.wix.com/
[6]https://www.canva.com/

recorded data from the finger positions using a serial terminal. Iterations led to a textile prototype using conductive thread, reporting data via MQTT over Wifi. These early versions triggered hard-coded shortcuts. Finally, the prototype incorporated a 9-axis Inertial Measurement Unit (IMU) to track the pen’s movements.

We chose that last setup because it allowed us to easily track gestures accurately. The prototype used a microcontroller (nRF52840) to run an algorithm of Digital Signal Processing (DSP) to filter the sensors’ data and a machine-learning model (TensorFlow Lite). The pen was connected wirelessly via Bluetooth Low Energy (BLE) to trigger commands emulating a keyboard on the drawing computer. This last version allowed participants to train customized gestures with hand movements and tell the researchers which drawing actions they wanted to associate them with.

Our co-design strategy offered three customizable layers:

- **Physical layer**: Capturing pen-based gestures such as shaking, flipping, tapping, making a circle in the air, etc.
- **Logic layer**: Assigning gestures to specific hotkeys or macros, activating once, toggling, cycling, etc.
- **Function layer**: Defining which drawing functions get activated, like run undo, colour-picking/change saturation, etc.

Fig. 1 shows three different iterations we co-designed with the participants. We also incorporated their perspectives into the protocol and the evaluation process. Initially, we envisioned focusing on shape and function. However, input from artists shifted our focus towards their creative stage transitions and using pen-based gestures for accessibility. This ultimately allowed us to explore responses to the deployment intervention within their existing tool usage patterns.

Participants personalized the physical layer by training pen-based gestures, repeating a chosen movement 30 times for characterization. They mapped this gesture to a desired drawing function and its activation logic. Once the first session was over, we collected data from a particular participant, and it took us five to ten days to filter and tune a machine-learning model and program the algorithms selected before the second session.

Fig. 1. Progression of the different prototypes, from left to right: v1 with a 3D printed touch capacitive matrix (wired, serial over USB), v2 with a custom moulded shape and a textile touch capacitive matrix (wireless, MQTT over WiFi), and v3 with an IMU unit (wireless, HID over BLE).

3.3.2 Phase 2 - Deployment:

In the second phase, we deployed the customized stylus as a design probe. The purpose of the probe was not to conduct a summative evaluation of the stylus, but to provoke reflection and generate qualitative data on how new, embodied interactions might shape artists’ creative processes [81]. The three customizable layers (physical, logic, function) can be seen as a form of generative toolkit [81] that allowed participants to co-create their own interaction model with the probe. We aimed to identify artistic workflow accessibility challenges, explore pen-based gestures that could be performed while holding a stylus, and test whether these gestures could effectively trigger shortcuts for drawing functions. Additionally, we examined how participants might integrate new interactions into their creative processes.

Fig. 2. Three images captured from a timelapse provided by our participant P3. During *"Initialization"* (left), we see the early stage of the creative process, where ideas are explored, rough compositions are sketched, and the foundation of the artwork is established. In the middle stage, *"Expansion"* (center), details are refined, colours and textures are developed, and the composition becomes more structured. We can see that in the concluding phase *"Finalization"* (right), the final adjustments are made, fully refining colouring, shades, light reflections, and details are polished, having the artwork reach its completed form.

All six participants took part in two sessions. Session 1 (~60 min) focused on understanding their workflows, tools, and needs. After 15 minutes of familiarization with our setup (prototype pen as standard input, choice of ProCreate, ClipStudio, SketchPro, or Krita), they drew for 30 minutes, verbalizing their process and highlighting accessibility challenges, not artistic quality. In Fig. 2, we show different screenshots of the artwork P3 produced, where we can recognize the initialization, expansion, and finalization stages she went through.

In the final part of Session 1, each participant selected gestures that felt natural for them (e.g., shaking to adjust brush size, tilting for undo) and repeated each 30 times with pauses. To mitigate potential fatigue, we explicitly offered and encouraged participants to take breaks during this repetitive training process. We collected sensor data during these repetitions. We included further details of chosen gestures and functions in Appendix A.2.

Between sessions, we processed the sensor data, filtering noise and isolating gestures. Using an 80/20 train/test split, we applied spectral analysis and classification techniques to train a neural network model, achieving over 90% accuracy in recognizing the participant-specific gestures. Detailed performance metrics for the models, including precision, recall, and F1-scores for each participant's gestures, are provided in Appendix C. The trained model was deployed onto the stylus's microcontroller, enabling gesture-triggered actions via BLE using a finite-state machine to handle the selected drawing functions.

Session 2 (~90 min) occurred five to ten days later. Participants again familiarized themselves (15 min) and drew for 30 minutes, similar to Session 1. The key difference was using the customized stylus, which was now capable of recognizing their trained gestures to trigger functions. We prompted them to create a similar drawing from session 1, but using their gestures. We reminded them to use the pen-based gestures if they were not using them naturally.

After drawing, a guided discussion explored their experience training the stylus, the impact of gesture-based features on their creative workflow, and the potential of such adaptive tools. This feedback provided insights into the challenges and opportunities of adaptive stylus inputs.

3.4 Data Analysis

We analyzed qualitative data using thematic analysis (TA) [16] to understand artists' experiences living with ULMI when creating digital works. Our interpretive TA approach emphasized researcher insights [21], and we used data from

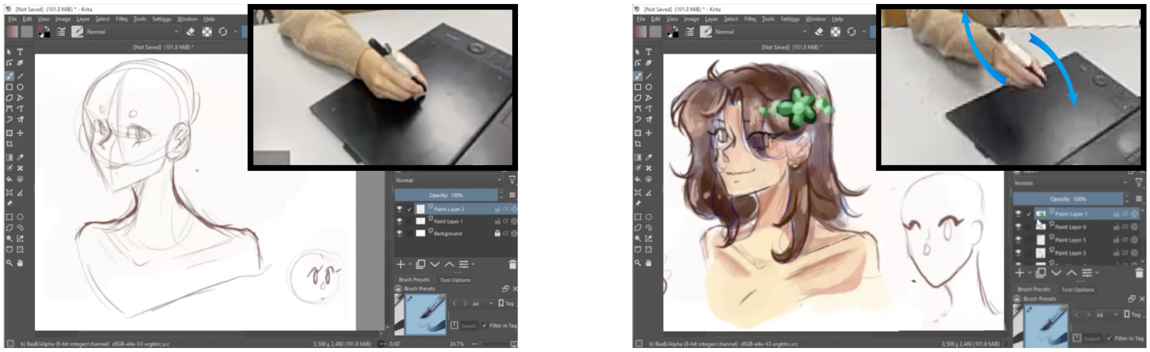

Fig. 3. Two screen captures with their corresponding picture of the hand of P3. On the left, she is sketching freely and explaining that her hand is relaxed and feels no need to erase or use layers. On the right, she is doing a gesture with our prototype, interacting with layers to manage a greater level of detail in her drawings.

semi-structured interviews, behavioural observations, video recordings of the screen activity and the hand movements, and prototype sensor data.

We transcribed, corrected, and imported interviews into NVivo [33]. The primary author inductively coded the transcripts (15 hours, 252 initial quotes) generating preliminary codes. To enrich this, we analyzed 40 key video clips using open coding [23], focusing on moments like learning gestures, facing barriers, or using workarounds. Insights from video analysis refined and contextualized the transcript codes.

All authors organized the codes into themes, iterating and proposing changes according to the quotes and video clips [16]. We collaboratively reviewed and refined codes and themes through discussion, ensuring robustness and consistency in the final thematic structure. We resolved conflicts by negotiating interpretations and refining code definitions, with the primary author synthesizing the coded data into the final themes. We include the final version of our codebook in the Appendix A.4.

In the following section, we present the results of our TA, detailing how participants engaged with the adaptive stylus and how their experiences relate to our research questions. We examine the effectiveness of gesture-based interactions in supporting artistic workflows, the role of customization in addressing individual needs, and the broader implications of these findings for the relationship between artists and their tools. Through this analysis, we offer insights into how future design interventions can further enhance accessibility in digital art-making.

4 Results

By putting the probe in our participants' hands, we had introduced a new art-making tool into their practice. Thus, we were able to observe how their artistic practices shifted in response. This kind of shift is not a linear transition from one state to another. The artist's **extant practice** is still in play as a new **emergent practice** enters the field. Our thematic analysis distinguished these states—*what has been* and *what is becoming*—revealing a complex relationship between artists, their input devices, and their creative practices. To present these findings and clearly demonstrate the insights from our RtD approach, we organize them into two main sections.

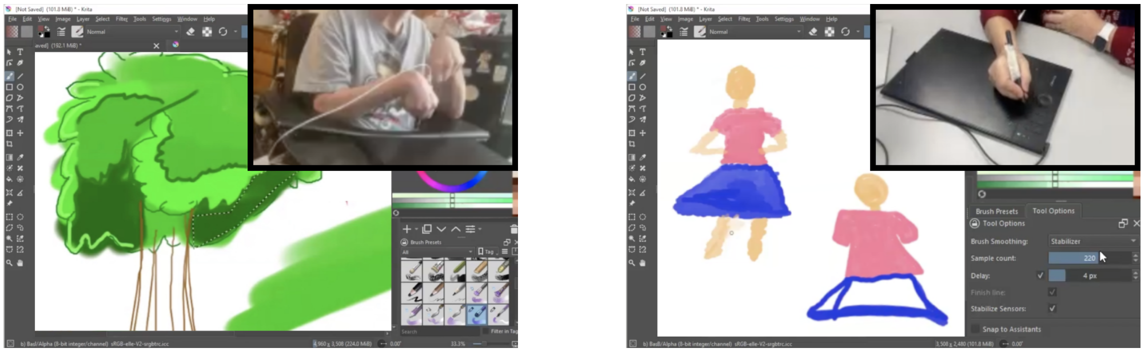

Fig. 4. On the left P2 shows how he can use the up-down gesture to switch tools, even with the lasso tool. He is in the process of adding shadows to a tree he drew, and using the gesture to undo his last action. On the right, P6 showed us how the average filter to smooth curves changes her style. She drew twice the same girl, without and with filters, to what she later added *“That’s nice, but it doesn’t feel mine’!’*

4.1 Extant Practice: The artists and their input devices

Participants’ creative lives were defined by a constant negotiation between their artistic vision, their physical limitations, and the tools available to them. This resulted in a world characterized by resilient, hard-won workflows where limitations often defined their artistic style.

Resilient workflows, with limitations defining style: Participants developed deeply ingrained personal strategies to navigate accessibility barriers. Years of adaptation made them rightly skeptical of disruptions; as P1 doubted, it was even possible for her to *“unlearn”* her methods. This skepticism was fueled by past negative experiences, as P3 noted of unused features on her current hardware: *“I’ve had these buttons for years, and I still don’t use them...”* For some, the primary strategy was simply accepting a slower pace. P2 stated his technique was taking extra time: *“when you’re doing fine details, you’re not doing it this quickly... It lets you take your time.”*

These workarounds often became inseparable from the artists’ stylistic signatures. For instance, P1 managed her carpal tunnel pain by adopting a style of long brush strokes over short, precise ones. P6, who dealt with imprecise lines from tremors, embraced the result: *“my style is like that now. I feel like making mistakes helps your image.”* Similarly, to avoid difficult menu navigation, P3 and P6 created on-canvas colour palettes, using the eyedropper tool instead of software swatches. This directly shaped P3’s colouring process, which she described as often pre-planned. These examples show how artists’ styles are not merely aesthetic choices, but negotiated solutions to accessibility barriers.

Beyond broad style, current devices imposed significant friction on daily tasks. Achieving precision for fine details required strenuous workarounds, which P1 described as *“silly”* and *“strenuous.”* Participants with more significant motor impairments, like P2 and P6, abandoned complex techniques like layer management entirely because they could not precisely click and drag. Correcting mistakes was another major point of friction. P3 found it easier to paint over errors than to use the eraser tool. The cost was amplified for P4, for whom a single ’undo’ command could wipe out significant progress, making the correction process itself a source of frustration.

Physically tense concentration: We found that participants developed a strong link between deep focus, sometimes calling it *flow* or *zone* and physical tension. While losing track of time helped them immerse in their work, it also led to muscle strain, discomfort, and even pain. Some developed personal workarounds, such as adjusting their colouring techniques or taking strategic breaks. However, others found physical discomfort overwhelming to the point that they left their work unfinished.

The tension between creative immersion and physical cost often escalated as an artwork progressed. Finer details introduced significant physical strain, with artists describing an unconscious tension as necessary for control in their work. P3 vividly contrasted this with loose, early sketching, explaining that as she finalized her work, *"everything hurts."*

This physical cost determined whether a piece could be finished. P3 noted how repetitive actions led to fatigue that stopped her process: "If I have to do this… I'm fatigued. I can't do this anymore." While some managed with planned breaks, others, like P1, resisted them, as stopping would end her creative session entirely. Ultimately, for four participants, unplanned interruptions from pain were creatively catastrophic, forcing them to abandon their work. P1 captured this breaking point: "When my hand gets fatigued... Now you're in pain—why would you persist through the pain?"

Retaining Authorship: P6, living with tremors, skeptically questioned the ease of automation by sharing her cognitive load when using accessibility features like smoothing filters, since she finds that precise linework is frustratingly incompatible with smooth curves. We can see in Fig. 4 how the results of this inflexible automation alter artistic style. She shared with us, looking at the drawing: *"That's nice, but it doesn't feel like mine."*

Other participants (P1, P2, and P4) also expressed concern about generative drawing functions taking away their agency as artists, sharing their concerns about Generative AI (GenAI). P1 told us she used often for productivity tasks like composing an email, but not for her art because *"GenAI fans are killing the artistic communities online, now you don't know who spent hours drawing and who just did a copy/paste [of a prompt]..."* P2 told us he tried tools that used AI, but only for fun and that he would not consider it for his art. P3 said she was steering away from any generative functions due to ethical concerns about the training data: *"But how did you train them to make art like that?"* We see the importance artists place on maintaining control and authorship within their resilient, hard-won processes.

4.2 Emergent Practice: The Impact of a New Pen-Based Gestures

In this section we first describe details related to how their practice found new possibilities for fluidity after interacting with the probe introduced. We then analyze the deeper tensions and gaps the probe revealed between a new interaction and the artists' complex reality.

Enabling Fluidity: The introduction of our gesture-based design probe demonstrated an immediate potential to alleviate these friction points. By mapping common but tedious commands to simple gestures, the probe enabled a more fluid workflow. For P6, the impact was clear: a single gesture that triggered an eraser macro was less distracting and more comfortable than manual selection. The same was true for her use of a gesture to activate the colour-picker, a task she found difficult with a mouse. As she explained, *"It's easier to do this than to reach for the eraser or the colour option. Especially with the colour picker, choosing an exact colour is very hard with the mouse."*

This new fluidity prompted artists to envision streamlined versions of their own workflows. P1 considered a wrist-flip to alternate between zooming and panning, P3 imagined an impulse gesture to cycle between her most-used tools, and P5 was enthusiastic about the convenience of a gesture-based 'undo.' The probe's impact was in showing how a well-designed interaction could reduce the cognitive and physical overhead of navigating a complex software interface.

Revealing the Gaps: Tensions in a Complex Reality While promising, the probe's true value as a research arteffact was in revealing the gaps between a simple function and an artist's complex reality.

- **The Gap Between an Interaction and a Workflow:** The probe's mixed success with corrections revealed a crucial distinction. For P6, the eraser macro solved a tedious interaction. For P4, however, a shake-to-undo gesture did not solve his core workflow problem. While the gesture was easy, undoing a long, carefully crafted line was still deeply frustrating. This highlights a critical gap: an efficient action does not automatically fix a fundamentally frustrating workflow. A tool must address the workflow, not just the command.

- **The Gap Between Potential and Physical Reality:** Artists, grounded in the physical reality of their bodies, quickly identified the gap between a feature's potential and its physical sustainability. While excited by the possibilities, participants like P1, P3, and P6 immediately worried that frequent gesturing could become fatiguing in its own right. P3's comment, *"I don't think that would be a very smart idea"* about repeating a gesture dozens of times, represents this tension. Any new interaction must be weighed against the real-world physical costs of repetition and strain.
- **The Gap Bridged by Agency:** Finally, the probe helped bridge the gap between the artists' initial resistance to change and their adoption of a new tool. Their willingness to engage was directly tied to the agency the probe afforded them. This was most evident with P4, who struggled with inconsistent gesture recognition because his movements were too similar to his drawing style. Yet, his reaction was not frustration, but an eagerness to re-train the system with a different gesture. His willingness to co-create a solution, despite the technical flaw, demonstrated that when users are given control and treated as partners, they are more willing to bridge a tool's imperfections. This suggests that the key to bridging the adoption gap is not a perfect tool, but a tool that empowers the user.

5 Discussion

In this section, we connect our findings to our research questions and the broader landscape of accessibility research. We explore how new interactions can enhance accessibility in artistic processes, how customized input devices can help reduce cognitive and physical strain, and the crucial role of embodiment in understanding digital art. Finally, we present design recommendations for developing new accessible artistic technologies.

5.1 Pen-based gestures can make artistic processes more accessible

Answering our first research question *"How can pen-based gestures be designed to better support the creative processes of digital artists with ULMI?"*, we found that customized pen-based gestures can potentially improve creative processes by reducing physical and cognitive barriers. Gestures helped with frequent actions like tool-switching for colouring/detailing and corrections using undo or eraser macros. Participants perceived these as a way to reduce fatigue and maintain creative flow by minimizing repetitive hand movements.

From prior literature, we know artists develop sophisticated workarounds to channel inspiration onto the canvas [15, 65]. Our data confirm that artists with ULMI shape these processes significantly based on interactions with their tools [27, 30]. These processes are often hard-won and resistant to change, a crucial consideration for HCI researchers proposing "optimizations." Input devices using new interactions should carefully consider whether artists perceive a need for change in a specific workflow.

Participants reported significant friction points beyond shaping their artistic style, resulting in limited production or abandonment. Key areas included achieving fine details, selecting colours, and correcting errors. Workarounds like zooming/panning or complex layer management added cognitive load and physical strain. For artists with limited motion or fine motor control, these tasks could become insurmountable, restricting creative options.

Similarly, difficulties with erasing or undoing influenced artistic approaches, sometimes making drawing more stressful than playful. While pen-based gestures offered potential relief, concerns about gesture fatigue for highly repetitive tasks remained, highlighting the need for careful design balancing convenience and physical demand. Unexpected tool behaviour or unwanted automation also disrupted flow, emphasizing the need for predictability.

There is a strong link between concentration and physical tension, which is particularly disruptive as the effect of pain leads to abandoning work. While planned breaks can be managed, pain-induced interruptions critically undermine the creative process. We see the potential of new interactions in input devices minimizing physical strain and supporting sustained engagement. For example, P3 expressed her excitement in switching between drawing tools with fewer clicks and movements when colouring. Another example could be a pen-based gesture that turns the smoothing filter on/off for P6, who struggles with her current tools because of the long menu selection workflow.

By potentially reducing strenuous repetitive movements or streamlining complex sequences, personalized gestures could help mitigate fatigue and pain triggers, allowing artists with ULMI to remain engaged longer and finish work.

5.2 Customized input devices can reduce cognitive and physical loads

Answering our second research question, *“How do digital artists with ULMI experience and utilize the customization of pen-based gestures?”*, we found that customization is key to reducing cognitive and physical loads when introducing new interactions like pen-based gestures.

Consistent with findings that disabled artists often use customized mainstream input devices [29] and that customization enhances adoption and empowerment in assistive technology [18, 51, 53, 88], our results align with Ability-Based Design principles [93]. Participants valued the ability to tailor the stylus’s behaviour in different layers such as the physical gestures, drawing function mapping, and the activation logic to their specific needs and preferences.

Drawing involves constant negotiation between precision, fatigue, and skill. Participants already employed cognitive strategies like shortcuts, device choices, and colouring techniques to be able to produce artwork. Introducing a new interaction method initially raised concerns about learning curves and remembering gestures. However, the personalized nature of the gestures in our prototype appeared to minimize this cognitive load; participants recalled and used their self-defined gestures fluently. This suggests that while learning any new interaction imposes some load, customization can make it feel more natural and integrated, ultimately reducing the overall cognitive effort required to operate complex drawing software. Predictable recognition in gestures and user control over function mapping are essential to building trust and avoiding frustrations from unexpected actions.

Physical load, manifesting as pain and fatigue, significantly impacted participants’ workflows and ability to complete work. Customization directly addressed this by allowing participants to choose physically comfortable gestures to perform repeatedly. While concerns about potential strain from frequent gesturing remained, the ability to select which gestures to use and what they triggered mitigated this.

Our physical, drawing, and function customization layers proved effective. Participants particularly valued the physical layer because it allowed pen-based gestures to be tailored to individual movement patterns. Though simpler algorithmically, the logic and function layers provided essential control over how the physical interaction translated into software actions, ensuring the gestures supported, rather than disrupted, their workflow.

With recent advancements in sensing hand posture and finger movements [47, 67, 89], we believe there is immense potential in using this technology to interact in new ways with input devices, and validates further exploration and development.

While results were promising, artists remained mindful of potential strain. Interactions requiring excessive hand movement, like lifting the stylus and twisting the wrist, were considered counterproductive. Finding the optimal balance between reducing existing strains and avoiding new ones through interaction design remains critical. Further research should explore alternative interaction techniques beyond pen gestures. An open question is whether such techniques can be designed to effectively reduce physical load by placing significantly less stress on hand movements compared to current methods.

5.3 Embodiment as a crucial aspect of understanding drawing

Our third research question asked, *"How does interacting with a customized stylus shape artists' relationship with their tools and creative practice?"* And this can be better understood through the quote from P1 we used for our title *"Why would you persist through the pain?"* The interactions with an input device are not only about ergonomics or functional, they tap into the nature of an artist and their perseverance to create work.

Therefore, the input device an artist uses is not a neutral instrument. It becomes an active partners in this deeply personal and often strenuous negotiation. Our probe deployment showed that digital artists who live with ULMI embodied their relationship with their input devices, revealing complexities such as the tension between immersion and physical discomfort, the strategies to maintain focus while minimizing strain, the role of predictability in creative flow, and the importance of authorship and control over artistic tools.

Accessibility challenges often forced workarounds that increased effort or restricted expression. The probe deployment, introducing customizable pen-based gestures, provided a window into how artists negotiate these constraints. Within the intimate connection participants had with their input devices, introducing automation was both a promise of simplifying tedious tasks but triggered resistance when the changes felt imposed or threatened their control and sense of authorship. In this context, investigating responses to learning personalized gestures revealed the critical role of preserving agency.

The contrast between free-flowing sketching and tense, demanding detail work illustrates the constant negotiation between artistic intent and physical capability. Maintaining flow is crucial, but often challenged by tool unpredictability or physical strain. Our findings resonate with accessibility research in gaming, where customizable controls and adaptive features help maintain engagement despite limitations [2, 45, 96]. Similarly, accessible art tools must balance challenge and support to sustain creative immersion without causing undue frustration or pain.

We cannot ignore the strong reactions against unwanted automation, like P6's rejection of the style-altering filter that diminished the effects of her hand tremors. Concerns about GenAI show the importance of intent and control. Artists need tools that anticipate needs and offer support without overriding agency or diminishing ownership, aligning with calls for careful consideration of AI's role in creative workflows [11, 62].

We suggest that realizing the potential of "Accessibility 2.0" [61] in the arts requires an approach that takes into consideration this embodiment. Perhaps we should consider "Accessible Artistic Technologies 2.0," with systems leveraging AI for personalization and prediction, but always prioritizing user control, supporting creative stages, managing flow, and keeping the artist in charge of intent and outcome.

In the next section, we propose design recommendations that take into consideration the focus on artistic processes we should have, the skill/challenge balance tools should maintain, the different needs experienced by novice users, and the benefits of customization of tools for users with evolving motor impairments.

5.4 Design Recommendations

Designing accessible digital art tools requires moving beyond technical fixes to understand the lived experiences and creative strategies of artists with motor impairments. Product designers looking to integrate accessibility into digital art tools must consider not only technical solutions but also the lived experiences of artists with motor impairments.

Our findings highlight challenges with current tools and the potential of adaptable interfaces. We offer the following design recommendations:

5.4.1 Support existing artistic workflows

Focus on adapting tools to artists' natural, often highly individualized, processes rather than forcing accommodation to predefined interactions. Enable seamless transitions between creative stages (sketching, refining, etc.) by minimizing friction points identified by users. Support, do not dictate, the workflow.

5.4.2 Design for uninterrupted creative flow

Minimize interface friction (e.g., cumbersome menus, unpredictable actions) that breaks immersion. Offer customizable shortcuts, intuitive gesture controls, and optional automation for repetitive tasks to maintain artistic rhythm. Balance challenge and support, allowing flexible interactions adapting to different motor abilities and styles.

5.4.3 Layered customization for accessibility

Offer customization in gradual layers to avoid overwhelming users. Provide sensible defaults but allow progressive fine-tuning of physical interaction (gesture sensitivity, type), logical mapping (adapting to the artists' workflow, like toggling or switching), and function (according to the drawing needs).

5.4.4 Make interactions intuitive, not trivial

Aim for ease of use without oversimplifying interactions to the point where they feel detached or remove meaningful engagement. Reduce effort for tedious tasks but preserve the cognitive and physical connection that makes creation satisfying. Balance accessibility with artist agency and control.

5.4.5 Adapt to both novice and expert artists

Recognize that experience level and history with impairment shape needs. Offer structured guidance or simpler options for novices, while providing deep customization for experts with established workflows. Consider adaptable interactions that support embodied engagement for artists who rely on physical feedback.

6 Limitations and future work

Our study has several limitations, including noting that the small sample size of six participants limits the generalizability of our findings to the broader population of digital artists with ULMI. We should also note that, while the two-session deployment provided valuable initial insights, the relatively short duration could not fully capture the long-term development of creative flow or the sustained use of the adaptive stylus in participants' daily practice. Our final prototype focused on customizing relatively simple pen-based gestures (e.g., shake, tilt) linked to existing shortcuts or macros, which did not allow us to explore more complex automated drawing functions or finer-grained gesture differentiation (e.g., based on isolated finger movements).

A key insight was that existing accessibility barriers often turn drawing into a stressful task rather than a playful, flexible activity. Overcoming these requires tools that actively foster creativity. Future work should focus on refining the customization algorithms, particularly for the logic and function layers, to offer more sophisticated and adaptive workflow support. Exploring alternative interaction modalities beyond whole-pen gestures (e.g., pressure modulation, subtle finger movements on the barrel if feasible, integration with voice or gaze) could offer ways to further reduce physical strain and expand expressive possibilities for artists with diverse motor abilities. Longitudinal studies observing artists integrating such tools into their regular practice over extended periods would also yield a deeper understanding of their impact on creative flow and productivity.

7 Conclusion

This research explored the potential of adaptive technologies, specifically a co-designed stylus with personalized pen-based gestures, to enhance the digital art-making experience for artists with ULMI. Focusing on the artists' creative processes, we identified key accessibility barriers related to fine detail work, error correction, and managing physical strain, which often disrupts the flow and limits creative output.

Our findings demonstrate that customizable pen-based gestures can offer intuitive and effective ways to streamline workflows, reduce cognitive load, and mitigate physical discomfort, provided they are designed to support, rather than supplant, the artist's established practices and sense of agency. This study highlights the critical importance of personalization, predictability, and user control in the design of accessible artistic technologies.

We propose design recommendations centred on supporting existing workflows, enabling flow, offering layered customization, balancing ease of use with engagement, and catering to diverse expertise levels. Ultimately, by developing tools that adapt to the artist, we can foster greater inclusion and expression in the digital arts for individuals with diverse abilities, potentially contributing to a new generation of Accessible Artistic Technologies 2.0 that prioritizes the creator's process and intent.

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A Appendices

A.1 Participant Demographics

P#	Gnd.	Age	hs./wk.	Education	Occupation	Impairment
1	F	24	18+	Bachelor	Administrative	Joint pain - Carpal tunnel syndrome
2	M	56	30+	High school	Graphic Designer	Limited range and motion - cerebral palsy
3	F	18	12+	High school	Student	Fatigue and stiffness - undiagnosed
4	M	53	12+	Bachelor	Graphic Designer	Limited fine motor skills - spina bifida
5	M	44	6+	Bachelor	Product Designer	Joint chronic pain - undiagnosed
6	F	75	6+	PhD	Retired	Tremors - multiple sclerosis

Table 1. Participant Data, showing gender, age, range of hours per week of computer use, education, current occupation, and their self-declared motor impairment.

A.2 Gestures and Drawing Functions

Participant	Gesture	Logic	Function
1	tap	activate once	picker
1	double tap	toggle	eraser
1	wrist flip	rotation	switch tool
1	impact	rotation	switch tool
1	other hand	rotation	switch between brush/lasso/picker
2	up-down	rotate	switch between brush/eraser/picker
3	impulse	activate once	undo
4	up-down	activate once	undo
5	short tap	activate once	copy
5	two taps	activate once	cut
5	long tap	activate once	undo
6	up/left	toggle	picker/brush
6	up/right	toggle	eraser/brush

Table 2. Mapping of gestures to functions for each participant

A.3 Machine Learning Implementation Details

Parameter	Value / Specification
Target Microcontroller	nRF52840
Input Sensor	LSM6DS3TR IMU
Sampling Frequency	50 Hz
Input Window Size	500 ms
Min. Samples per Gesture	30 repetitions
Training/Testing Split	80% / 20%
ML Pipeline	Spectral Analysis (DSP) + Neural Network (Classifier)
Deployment Platform	Edge Impulse
Output Model Format	TensorFlow Lite

Table 3. Machine Learning Model Training and Deployment Parameters.

Metric	Value
Latency Breakdown	
Spectral Features (DSP Block)	3 ms
Classifier (NN Block)	1 ms
Total Inference Latency	**4 ms**
Memory Usage	
Peak RAM Usage (Classifier Only)	1.6 KB
Peak RAM Usage (Total Model)	**2.9 KB**[*]
Flash Memory Usage	**19.3 KB**
Model Performance	
Overall Accuracy	**93.83%**

[*]Total peak RAM here is likely dominated by the Spectral Features of the DSP block to implement a low pass filter of order 6, contributing to the 2.9 KB total. Depending on the participant, we used different filtering resulting in lower RAM requirements.

Table 4. On-device performance metrics for the gesture recognition model deployed.

A.4 Final Version of our Codebook

Table 5. Codebook detailing themes, sub-themes, codes, definitions, and examples derived from thematic analysis.

Code	Definition	Example Quote(s)
Theme 1: Affordances and Limitations of Input Devices		
Focuses on how the artistic practice are affected by the tools, and the ways they limit it.		
1.1 Shaping Stylistic Choices		
Style Adaptation	Adjusting artistic style (e.g., line quality, color use, level of detail) due to tool capabilities/limitations.	*"my style is like that now. I feel like making mistakes helps your image."* *"...that’s just like a stylistic choice because some people do really like these messy, messy lines for their art. A lot of people don’t like when you do that but it’s an easy shortcut."*
Tool Selection Strategy	Deliberately choosing specific tools or techniques to bypass difficult interactions (e.g., using eyedropper instead of color wheel).	*"Usually I would just like use the eyedropper tool and just grab that. And then I can just get straight into it."* *"I typically don’t change brushes in my painting stage either."*
1.2 Elusive Details		
Precision Difficulty	Experiencing challenges in achieving fine motor control required for detailed work.	*"it’s just harder to get the lines where I want them to go."* *"Reaching the exact spot I want is difficult."* *"Sometimes, I struggle with drawing straight lines..."*
Detail Workaround	Employing specific strategies to manage detailed work (e.g., zooming/panning, using layers, lasso tool).	*"Um zooming very important for me. Panning. Very important for me."* *"this is probably one of the most valuable tools for early on in my pieces is these uh, lasso tools."*
Technique Simplification	Avoiding or abandoning complex techniques (like extensive layering) due to difficulty or impairment progression.	*"...layers don’t matter for me personally. Um, because I won’t use more than 2 or 3 layers."* *"using layers, making layers, deleting layers, um, aren’t something I use"*
1.3 Expensive Mistakes		

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Table 5 – continued from previous page

Code	Definition	Example Quote(s)
Correction Difficulties & Frustrations	Finding the process of correcting errors (erasing, undoing) effortful, slow, or frustrating due to tool interaction issues.	*"it's a lot more effort to, like, go, click the eraser tool and then erase the mistakes that you make in your drawing."* *"Yes, the pencil size... I have to go back and select the pencil size every time I want to change it... it gets tedious."*
Correction Workarounds	Developing alternative methods to deal with mistakes instead of direct correction (e.g., painting over, drawing slower).	*"So it's just easier to, like, go slower."* *"...if you have this thick of a line going away from where you want it to be, then it's best to just erase that."*
Correction Impact on Workflow	How the difficulty or ease of making corrections influences the overall artistic process and time investment.	*(Finding Summary) "Impairments can amplify the cost of mistakes, impacting not just the correction itself but the entire workflow."*
Theme 2: Sophisticated Artistic Workflows		
Focuses on the established routines, physical experiences, and adaptation patterns related to creating art with ULMI.		
2.1 Resilient Processes		
Workflow Habituation/Resistance	Deeply ingrained work habits making users resistant to changing tools or processes, even if potentially beneficial.	*"Like the way I hold my stylus... I'm so used to it that it's like, you know, when you learn how to hold the pencil. That's just how it is."* *"...because I've been doing this for over ten years, my brain is so used to a single tap to find a color."* *"I almost want to call it resistance to change things."*
Negative Past Experiences with Accessibility	Previous negative experiences with assistive technology or accessibility features leading to skepticism or non-use.	*"I've had these buttons for years, and I still don't use them, even though they're technically easier than not."* *"...holding the Shift key too long activates sticky keys, which can be frustrating."*
Skepticism Towards Automation	Wariness about automated features altering artistic style, reducing control, or not being genuinely easier.	*"But why? Is this going to be easier?"* *"With this stabilizer setting, the lines feel better, but the delay might need adjustment."*

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Code	Definition	Example Quote(s)
Agency and Ethics Concerns with AI)	Specific concerns about AI/GenAI regarding artistic agency, control, ownership, art theft, and impact on art communities.	*"I'm not at that stage where I'm comfortable enough to let AI and that kind of thing into my life,"* *"I don't like how it uses other people's art to generate things. Uh, I it feels like art theft"* *"...people accuse the original artist of AI because it was their art that was fed into the AIs."*
2.2 Physically Tense Concentration		
Focus-Tension Link	The connection between deep concentration ('flow', 'zone') and increased physical tension, poor posture, or unawareness of the body.	*"there's always that unconscious feeling of you need to tense up your whole hand."* *"when you're in the zone, you're not thinking about your posture"* *"affects posture too, because when it's like this, I'm reaching over and I'm kind of hunched over..."*
Physical Discomfort or Fatigue	Experiencing specific physical symptoms like pain, fatigue, stiffness, heat, friction, or general strain during/after drawing.	*"usually I tend to draw from like at least 3 hours to 6 hours in one session. My fingers get, like, super stiff"* *"fatigue in my hands after a while."* *"Sometimes my hand feels rigid. The way I hold the pencil can cause pain"*
Discomfort Management Strategies	Deliberate actions taken to prevent or alleviate physical discomfort (e.g., scheduled breaks, stretching, changing tasks).	*"Usually I try and like... put myself in, like, a schedule..."* *"usually I just like, scroll on my phone if my hands are getting stiff"* *"...that's usually one of the times where I need a break is when like my hand starts to get a little hot or so I feel like getting it off of the screen."*

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Table 5 – continued from previous page

Code	Definition	Example Quote(s)
Pain-related Work Abandonment	Stopping a drawing session or leaving artwork unfinished specifically due to overwhelming pain or fatigue.	*"So typically for me, when my hand gets fatigued, my pen goes down, and then I'm totally done for the day."* *"I have a painting that I worked on for like 3 or 4 hours... And then I was like okay I'm fatigued, I can't do this anymore. And I never picked it back up again."* *"The second my pen goes down I'm done with that picture."*
Action-Specific Strain	Identifying particular actions or tool uses that cause specific strain (e.g., short strokes, repetitive gestures, pressure, reaching).	*"if you like, zoom in and do super details, you have to do a lot of those, like small strokes and... those are pretty... strenuous on your hand..."* *"doing this action [eyedropper gesture] on a repeated basis. Yeah. Fatigue my hand because that's a lot."* *"Because... the whole reason why I have hand issues in the first place is my small, repeated actions over so many years."*
2.3 Interaction Learnability/ Adoption		
Initial Doubts Towards Learning	Expressing doubt or concern about the ability to learn, remember, or adapt to new interaction methods (e.g., gestures).	*"I honestly don't think it's even possible for me to unlearn a single tap for that."* *"...it's definitely hard to get out of old times."* *"Maybe it'll be like that for the first ten minutes, and then you're going to get into your old bad habits again."*
Observed Learnability/Recall	Demonstrating unexpected ease in learning, remembering, or incorporating the new interaction method during the study.	*"That's easy to remember,"* *"Um. At the beginning it got confusing. But, uh, then I, I thought ok, I shake it if I want to erase. And tilt if I want to reset..."*
Customization Value	Explicitly valuing the ability to personalize interactions (gestures, timings, mappings) for comfort, preference, or usability.	*"Gestures could also be customized to improve comfort."* *"Because taps can be personalized... The key is flexibility and adaptability in the design."* *"hey could be fully customizable, like setting double-click timing in Windows."*

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Code	Definition	Example Quote(s)
Interaction vs. Workflow Change Preference	Indicating a greater openness to adopting new interaction methods than changing fundamental artistic workflows or habits.	*"gestures are appealing because they're different... It's, it's physically different."* *"this isn't as useful for me... because this isn't... action I'm used to."*
Novel Interaction Ideas	Suggesting new concepts for input devices or interactions (e.g., physical tool mimicry, flute-like actions, dials, placement).	*"...what if there was a set of tools that were technically styluses... but they mimic traditional art."* *"I could also see this being longer... having, like, almost like a flute action."* *"there's like a console that you can like spin, spin a dial like this..."*
Gesture Usability Factors	Discussing specific factors affecting gesture practicality (e.g., frequency, fatigue, comfort of movement, accidental activation).	*"double tap and triple tap I wouldn't recommend for the eyedropper tool because naturally the action is single clicks."* *"The key is small gestures that don't tire my wrist."* *"if I had been often, it would be more difficult."* *"strong movement with the wrist. It's going to be difficult..."*
Ergonomics & Form Factor	Comments related to the physical shape, size, weight, or grip of the stylus and its impact on comfort or usability.	*"shape of the stylus I think is really important too..."* *"anything that's bulky around these front fingers... Not good."* *"For me, pressure is bad... because it puts a lot of strain on my fingers."* *"I don't have a good grip on the pencil. It's hard for me to hold it properly due to bad habits."*

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