Exploring the Use of Electronics to Customize Pervasive Health Technologies with Older Adult Crafters

Ben Jelen
bcjelen@indiana.edu
Indiana University
Bloomington, Indiana

Olivia K. Richards
oliviakr@umich.edu
University of Michigan
Ann Arbor, Michigan

Samantha A. Whitman
samantha.whitman@asu.edu
Arizona State University
Tempe, Arizona

Tom Ongwere
tongwere1@udayton.edu
University of Dayton
Dayton, Ohio

K. Cassie Kresnye
ckresnye@iu.edu
Indiana University
Bloomington, Indiana

Katie A. Siek
ksiek@indiana.edu
Indiana University
Bloomington, Indiana

ABSTRACT

As the worldwide population ages, HCI researchers are designing technologies to better support older adults. We investigated how older adult crafters would customize technologies using electronics by building on their crafting skills. This supported them to explore customizing devices for themselves and advance the design of pervasive health technologies for older adults. We first conducted a survey of 42 older adult crafters to learn more about their crafting habits and gauge interest in technology and health tracking. We then conducted a participatory design workshop with 10 older adult crafters, focused on mutual learning to support them in prototyping how they would customize technology with maker electronics. They brainstormed customized devices around health, games, and safety, as well as aesthetically enhanced artifacts integrating electronics. We discuss how promoting older adult crafters to design and build customized pervasive health technologies impacts future research, and we provide guidelines on how to do so.

CCS CONCEPTS

• **Social and professional topics** → **Seniors**; • **Applied computing** → *Health informatics*; • **Human-centered computing** → HCI design and evaluation methods.

KEYWORDS

Older adults; aging; elderly; customization; craft; crafting; health; pervasive technology; aging in place; maker electronics; maker technology; survey; participatory design.

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Figure 1: Participant 3's quilt with LEDs turned on during a participatory design workshop. The inset is the same quilt with the LEDs turned on.

1 INTRODUCTION

With an aging worldwide population [15], researchers have been designing technologies for older adults to both support them as they age and design technologies they find valuable. These include pervasive health projects from wearables for measurements [10, 16] to rehabilitation [59, 67] to aging in place technologies for the home [13, 17, 49, 55, 69]. Researchers established that older adults find technology more meaningful and appealing if they find value in using it [11, 47, 60]. Older adults value technology that builds on their existing practices, allowing them to personalize and contextualize digital devices [42].

Customization is a way to provide a tailored approach to supporting older adults through technology. This is especially true for pervasive technologies in the home, which require a personalized approach [41]. For example, McGee-Lennon et al. [42] emphasized the importance of personalizing home-based reminder systems for older adults since one size does not fit all. Researchers have also seen challenges with older adults abandoning or not using systems designed for them [4, 18]. Pervasive health researchers often design systems *for* older adults (e.g., [10, 68]). We see an opportunity to support older adults to customize technology *for*

themselves with the advances in maker electronics (e.g., Arduino). Carucci and Toyama [9] showed how engaging older adults in a makerspace could improve their agency as they solved problems they had. Building an artifact for oneself also increases the value they place on it [50], so supporting older adults to customize technology themselves could improve their engagement as they value it more when it is contextualized to their needs. However, few have explored how to support older adults in leveraging these recent advances in maker technology [29, 56].

Older adult crafters already create and customize artifacts themselves, thus, they are an ideal group to evaluate *how* to introduce to customizing pervasive technologies. Older adult crafters customize their artifacts by carefully choosing features, such as the format, colors, and themes of their projects. Our work with these crafters builds on researchers' use of crafting as an avenue to support these technologically underrepresented groups to engage with maker electronics and allow for customization [21]. E-textiles projects in particular have utilized the connection between crafting and electronics, such as LilyPad Arduino [6] and Adafruit's Flora [28]. Both shaped a diverse community creating electronically enhanced crafts and built a bridge between computing and crafting [21]. Buechley and Hill [7], for example, found that LilyPad helped to develop a women-dominated community of electronic makers. Thus, older adult crafters intrigued us as a group of people engaged in customizing artifacts, that could also translate their skills into incorporating electronics into pervasive health technology for older adults.

We explored how older adult crafters wanted to customize technology, including pervasive health devices, through a survey and participatory design workshop. We began with a survey of 42 older adult crafters to understand their practices, and investigated their interest in technology and health. Building on our survey results, we conducted participatory design workshops with a total of 10 older adult crafters to further explore how to introduce electronics for customization and identify what they would customize with technology. We found that participants developed a wide range of ideas, including customized devices, such as health tracking earrings, and aesthetically focused artifacts (e.g., Figure 1). We make the following contributions:

(1) Provide a deeper understanding of older adult crafters' practices.
(2) Explore how to support their practices to engage older adult crafters in customizing technologies with maker electronics.
(3) Discuss how supporting older adult crafters to customize technology with maker electronics can advance the design of future pervasive health technology.

2 RELATED WORK

To support older adult crafters to customize technology, we drew from prior work on older adult crafters, the intersection of creative practices and electronics, and designing with older adults.

2.1 Customizing Already: Older Adult Crafters

We studied older adult crafters since they are already building customized artifacts, but they have not been a common group of study [31]. Not all older adults craft, but for those that do, they gain well-being benefits from crafting. In the United States, a 2009 Pew poll found that 43% of older adult (≥65 years old) respondents had worked on a hobby [65]. Older adults who participated in arts and crafts senior center activities reported several improvements to their well-being, including interactions with friends, self-growth, mental enrichment, and a sense of purpose [20]. Fisher and Specht's work [20] indicated that creativity contributed to active aging by fostering a sense of expertise, purpose, skill, and growth. Crafting, an activity many are already doing, is a pathway for older adults to improve their well-being through creativity and a sense of purpose.

2.2 Enhancing the Creative Process using Electronics

To promote crafters' integration of electronics into artifacts, a balance needs to be struck between creative processes and electronics. Crafters and electronic makers evoke slightly different emotions when creating artifacts [8]. Buechley and Perner-Wilson [8] found that, although crafters characterize feeling peaceful when completing a piece, electronic makers appreciated their work's electronic concepts and took joy from accomplishments. Combining these two approaches, using maker technology's discrete components and craft's embodied traditions can produce a more well-rounded experience [2, 22], but researchers acknowledge needing to balance craft with electronics [71].

Researchers have explored the intersection of crafting and electronic making by studying crafters working alongside maker experts. Their work looked to collaborate with various crafting-focused groups, such as carpenters [39], needle-crafters [58], and urban knitters [43]. Tsakanki et al. [66] explored Hybrid crafting – the integration of physical crafting and digital media [22] – with Silversmiths to integrate small sensors into their crafted artifacts.

Researchers have built on these works by designing tools inspired by crafting or designed to be integrated into crafting [29, 30, 44, 46, 53]. Research projects have included Chibitronics [54], an electronic toolkit for integrating with paper crafts. Toolkits provide opportunities for people to create customized electronic devices that fit into their lives, but projects have often been geared towards engineering or young innovators, while ignoring the contributions of underrepresented groups, such as older adults [57, 64]. There has been a growing interest in promoting children's interactions with maker electronics [32, 62], often for educational goals to increase interest in science, technology, engineering, and math (STEM). Researchers have developed systems to alleviate technological barriers for children to build electronic devices [3, 5, 32]. We aim to build on the design of electronic tools inspired by craft to explore supporting older adult crafters' integration of electronics into their artifacts.

2.3 Designing with Older Adults

Researchers have often engaged older adults in design workshops, from which we drew inspiration for our workshop [14, 25, 37, 40]. Researchers pointed out that participatory design sessions should be catered towards older adults by helping them to understand intangible concepts and promoting designs that do not revolve around the workplace [37]. Massimi et al. [40] found that many older adult participants felt that they were learners rather than designers in their workshop designing mobile phone applications.

Destination	Counts
Family	35 (83.3%)
Self	32 (76.2%)
Friends	29 (69.0%)
Donated	25 (59.5%)
Sale	6 (14.3%)
Competition	5 (11.9%)

Table 1: Destinations for the crafts respondents made.

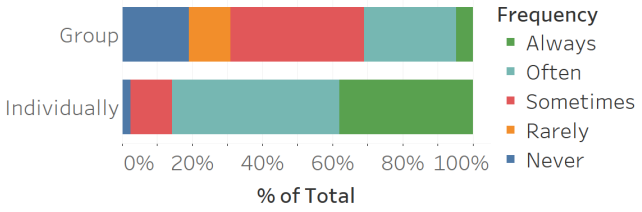


Figure 2: Comparing the percentages crafters' response to how frequently they crafted in a group or individual setting.

Similarly, older adults today likely know little about maker technology, so strengthening their knowledge before designing could be a valuable way to engage them in design.

Rogers et al. [56] facilitated workshops with older adults who interacted with MaKey MaKey toolkits. Their findings noted that older adults surpassed expectations by mastering the technology with intense focus and diverse ideas. They suggested that participants should be given the opportunity to gain knowledge suited to their preexisting skills. Since older adults can learn to think creatively with maker electronics, we sought to investigate how older adult crafters could integrate technology into their artifacts.

3 INVESTIGATING CRAFTING TO ENGAGE IN CUSTOMIZATION

We conducted a survey to better understand how older adult crafters could be engaged in customizing devices for themselves. In the survey, we asked questions about crafters' crafting habits, their interest in technology including customization with electronics, and their interest in health tracking technologies.

3.1 Method

A total of 42 older adult crafters completed the survey – 23 online and 19 on paper. We recruited participants aged 65 years and older who self-identified as a crafter – defined as someone who creates a tangible object. Participants were recruited online via social media for a web-based survey and in-person at local crafting groups and senior centers for an identical paper survey. In total, 39 respondents identified as women (92.9%), 2 men (4.8%), and 1 preferred not to answer (2.4%). They had a variety of crafts they did most frequently, however, most were fiber artists (36/42; 85.7%) which included knitters, people who sew, crocheters, and quilters. Other crafts included pottery, painting, carving, jewelry making, and scrapbooking.

The survey had 36 questions over 4 sections, including demographics, crafting habits, technology interest, and health. Knowing that many crafters practice several crafts, the crafting habits section focused on respondents' most frequent craft. The health section of the survey drew from Davidson et al.'s [14] participatory design investigation of what health topics older adults want to track. Survey participants were entered into a raffle for a 1 in 20 chance to win a $20 gift card. All study activities were approved by Indiana University's ethics board. Where necessary, we report the independence of online and paper responses using a Fisher's exact test in SPSS with a significance level of $\alpha = .05$.

3.1.1 Limitations. The results of this survey are limited by the method respondents used to fill it out. Since half of them took the survey online, a common survey method (e.g., [8, 24]), some results are more likely to reflect those technologies, especially the types of technologies they use in crafting. We also note that we had far more respondents identifying as women than men, which is common for studies with older adults (e.g., [51, 55]) and crafters (e.g., [38, 53]). We attribute some of this difference to the crafting groups we recruited from, which included more fiber-artists.

3.2 Results

We first delve into why and how older adults craft, before exploring their interest in using technology for their health and environment.

3.2.1 Crafting Habits. We explored older adult crafters' habits by focusing on their motivations for crafting, who they crafted for, how they learned new skills, and how they typically participated in their craft. Respondents were motivated to craft by the joy of creating and giving their handiwork away. They were often crafting for fun (32/42; 76.2%), to give crafts as gifts (28/42; 66.7%), and to create artifacts for themselves to enjoy (24/42; 57.1%). Rarely were they selling what they made (3/42; 7.1%). Overwhelmingly, they agreed or strongly agreed that they enjoyed their craft (39/42; 92.9%).

Respondents typically made items for themselves, family members, and friends (Table 1) and were most concerned that the recipient liked what they made. Some donated their crafts, sold them, or entered them into competitions. Older adults had some interest to continue making artifacts for themselves after mastering their respective crafts, despite a majority crafting for over 10 years (33/42; 78.6%). When giving or selling projects, respondents were primarily concerned with whether someone liked it (30/42; 71.4%) rather than how often (9/42; 21.4%) or long (2/42; 4.8%) they used it.

When learning new crafting techniques, older adult crafters often turned to online resources and people. Respondents most frequently consulted at least one online resource (33/42; 78.6%) or another person or group (28/42; 66.7%), but only half looked to print sources (22/42; 52.4%). We found that the sampling mechanisms were reflected in the role of online resources. A Fisher's exact test for independence between the online and paper respondents resulted in $p < .001$, signifying that there were differences between the populations of the two sampling mechanisms.

The older adults surveyed more frequently worked on their craft individually than in a group atmosphere (Figure 2). Most participants "always" or "often" worked individually (36/42; 85.7%), but still "sometimes" or "often" worked in a group atmosphere (27/42; 64.3%). Sampling differences were reflected in these results,

Technology	Counts
Computer	39 (92.9%)
Phone	30 (71.4%)
Electronic medical device	9 (21.4%)
Medical emergency alert	8 (19.0%)
Medication reminder	7 (16.7%)
Smart home tech	6 (14.3%)
Fall detectors	5 (11.9%)
Medication dispensers	3 (7.1%)

Table 2: Pervasive healthcare technologies respondents owned and used.

too, given that most paper respondents – recruited from groups – responded as "sometimes", "often", or "always" working in a group (16/19; 84.2%), compared to half of online respondents (13/23; 56.5%).

3.2.2 Technology Interest. The older adults surveyed owned and used phones and computers the most, and had not used many pervasive or healthcare technologies (Table 2). Most respondents had a computer (39/42; 92.9%) and were comfortable or very comfortable with using it (28/42; 66.7%). Far more online respondents reported that they were comfortable (21/23; 91.3%) compared to the paper respondents (8/16; 50.0%). Many respondents also regularly used a phone, but few had used more specialized medical and home technologies, such as electronic medical devices (e.g., blood glucose monitor), medical emergency alerts, medication dispensing systems, and smart home technology (e.g., internet enabled thermostats).

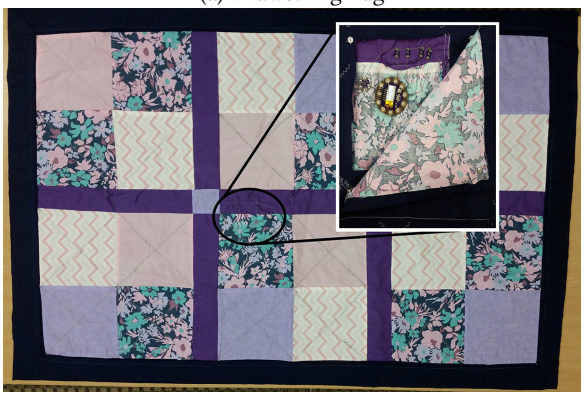
Few older adult crafters in our survey were already using technologies besides computers and the internet with their craft, and they were not interested in maker electronics. None were using electronics or circuits with their craft. Computers (23/42; 54.5%) and the internet (23/42; 54.5%) were most commonly used by older adult crafters. Both of these were impacted by the sampling method given online and paper respondents were not independent (Both: $p = .002$). Some used social media with their craft (e.g., for resources) (11/42; 26.2%), but a quarter of them did not use any technology with their crafting (10/42; 23.8%). After a brief written explanation with pictures of two maker electronics artifacts (Figure 3), older adults in the survey were not interested in including maker electronics in their projects. Two-thirds of respondents had little or no interest in maker electronics (29/42; 69.0%).

3.2.3 Health. Since digitally enhanced crafts can be used on-body or in home environments, we asked the respondents about their interest in health trackers and found that the older adult crafters surveyed were interested in them broadly. Nearly three-quarters of respondents (31/42; 73.8%) were interested in at least one health topic – activity, medications, mood, steps, stress, or another health-oriented task. The most popular topics were step counting (13/42; 31.0%) and medication adherence tracking (11/42; 26.2%).

4 EXPLORING THE CUSTOMIZATION OF TECHNOLOGY

We were undeterred by the low interest in maker technology due to separate discussions with older adults outside the scope of this paper. We suspected hands-on learning would be of greater interest

(a) Drawstring Bag



(b) Quilt Examples

Figure 3: (a) Example light-up draw string bag using 3 LEDs and a LilyPad Arduino. (b) Sample quilt we created as an example of integrating electronics into a craft. We used a LilyPad Arduino with 4 LEDs to respond to the accelerometer.

to crafters more than a written explanation. We chose participatory design to engage in mutual learning between the research team and participants, in homage to traditional Scandinavian participatory design practices [61]. Introducing researchers to participants' crafting practices and culture provided both groups with the ability to become more comfortable with each other before prototyping. Additionally, since the surveyed older adults had limited experience with circuits, we wanted to reduce knowledge and power discrepancies in the group to ensure participants were knowledgeable and comfortable with circuitry before brainstorming ideas.

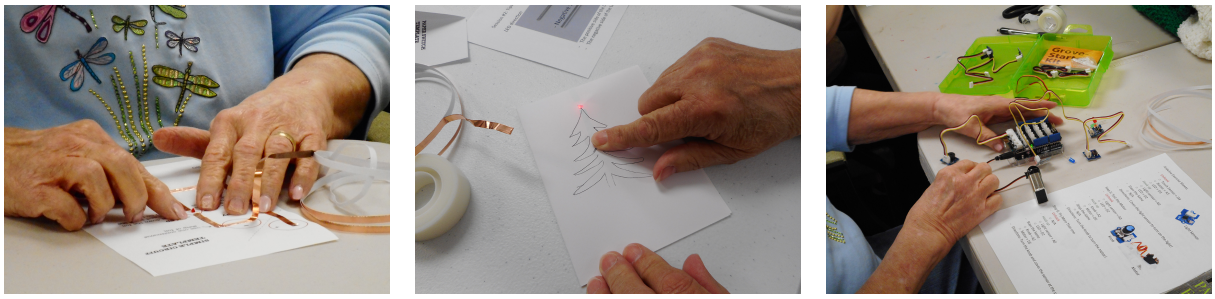
4.1 Method

We recruited from Bloomington, Indiana, USA and surrounding communities by contacting crafting groups directly or reaching out to older adult organizations. In total, we recruited 11 older adult crafters (10 who identified as women, 1 as a man). Ten participants (9 who identified as women, 1 as a man; avg. age 76.7 years old) completed all three workshop sessions in 2 groups of 5 participants (Table 3). P1-P5[1] were recruited from a quilting group that was a part of a community recreation center, and P6-P10 were from either a fiber-arts-focused senior center group or a retirement community.

[1]We indicate participants with P#.

ID	Age	Gender	Race	Education Level	Prev. Occupation	Craft(s)
P1	65	Woman	White	Completed College	Chemist	Quilting, Crochet, Embroidery, Sewing
P2	80	Woman	White	Technical/Trade/Vocational	Nurse	Sewing, Quilting, Knitting
P3	75	Woman	White	Technical/Trade/Vocational	Factory Assembler	Quilting, Knitting, Crochet
P4	79	Woman	White	Completed High School/GED	Factory Assembler	Quilting, Crochet, Pottery, Embroidery
P5	67	Woman	White	Completed High School/GED	Factory Assembler	Sewing, Quilting
P6	77	Woman	White	Some College	Medical Billing	Sewing, Knitting, Crochet
P7	90	Woman	White	Completed Post-Graduate	Psychiatric Social Work	Art
P8	83	Woman	White	Completed Post-Graduate	Medical Lab Supervisor	Sewing, Knitting, Crochet, Embroidery, Quilting
P9	75	Woman	White	Completed Post-Graduate	Special Education	Sewing, Crochet, Knitting, Crafts, Jewelry
P10	76	Man	White	Technical/Trade/Vocational	Machine Technician	Woodworking, Machining, Jewelry, Blacksmithing

Table 3: Participant demographics for the participatory design workshop. Note that P1-P5 (above the line) were a part of one workshop, and P6-P10 (below the line) were another.



(a) Folding Copper Tape (b) P5's Light-Up Card (c) Grove Kit Exploration

Figure 4: During Session 2, participants created paper circuits (a, b) from Qi et al.'s Circuit Sticker Notebook [54] and completed activities with a preprogrammed Grove Arduino Kit to learn more about maker technology.

All participants were compensated for their time with a $25 gift card per session ($75 in total). The workshops were approved by Indiana University's ethics board.

The workshops consisted of a set of three interactive two-hour sessions focused on (1) understanding their crafting habits and practices; (2) providing hands-on knowledge about customizing technology with electronics; and (3) prototyping ideas of how they would electronically enhance artifacts. We prioritized filling in participants' knowledge about electronics while learning from participants, putting the brainstorming power in the hands of participants.

4.1.1 Session 1. Participants taught us about their crafts through a show-and-tell of crafting projects, similar to a typical crafting session, followed by a focus group discussion about their crafting habits to expand on our survey results. Although some discussion questions overlapped with the survey, we felt it was important to confirm our survey findings, follow up in more detail, and build rapport. We discussed what they crafted, what they did in a typical session, their motivations, and how they learned new techniques. We administered a survey to collect demographics, crafting habits, and their familiarity with digital technologies. We also facilitated a discussion with participants about the minimum skills and tools needed to participate in their crafts, which helped inform the tools and skills needed for learning about electronics in Session 2.

4.1.2 Session 2. In Session 2, we carefully scaffolded activities for working with basic electronics and interactive electronic toolkits for customization. Participants individually learned about electronic circuitry basics with a paper circuit activity [54] (Figure 4) where they made their own light-up cards, as time permitted (e.g., Figure 4.b). Afterwards, participant pairs explored basic Arduino components through hands-on tinkering with 6 configurations of LEDs, capacitive touch buttons, physical buttons, buzzers, potentiometers, and servo motors via a pre-programmed Arduino Grove Kit from Seeed Studios [63] (Figure 4.c). For example, a later step in the activity was to connect the potentiometer and servo motor to the Arduino to allow participants to control the motor[2]. The complete activity took participants 15-20 minutes. We noted how participants evolved from connecting one output or input to configuring multiple components simultaneously.

We chose the Grove Kit toolkit [63], a commercially available prototyping toolkit with several inputs and outputs connected via 4-prong cables. Using the toolkit allowed participants to get a feel for working with electronics without needing extensive training. The components and connections were larger than most available toolkits (e.g., [5, 12, 23, 32]), thus making circuit creation more accessible for those with less dexterity.

We concluded the workshop by discussing electronics in general – highlighting the capabilities (e.g., sensors for recording data) and limitations (e.g., components are stiff; batteries needed) as they relate to crafting customized technologies. We administered a pre-

[2]Please refer to the Supplemental Material for our instruction guide at the following: https://osf.io/rsn7g/?view_only=47370f733adc43deafc9a7a8af0e7200

and post-survey to evaluate their comfort and confidence in working with electronics. Participants were encouraged to bring pictures or artifacts they wanted to electronically enhance to Session 3.

4.1.3 Session 3. Session 3 started with participants brainstorming what they might electronically enhance based on their experiences in Sessions 1, 2, and their everyday lives. We encouraged health and aging in place ideas through our probing questions, but welcomed any idea for customizing with electronics. This activity was also used for inspiration – participants shared what they wanted to enhance with electronics and how they would add in electronics. Then, participants created low-fidelity prototypes based on their brainstorming using craft supplies (e.g., paper, markers, pipe cleaners) and sample components (e.g., LEDs). Based on our survey results, older adult crafters were interested in monitoring their health, so we concluded with a questionnaire asking what health topics they wanted to track, based on Davidson et al.'s work [14]. We also asked for workshop feedback.

4.1.4 Analysis. Two authors analyzed the workshop's themes using affinity diagramming [27] to iteratively draw themes from the participants' ideas, discussions, artifact sharing, and prototypes. Session 1 was fully transcribed for analysis since it was most like a focus group and the ideas were wide-ranging. Sessions 2 and 3 were spot transcribed, focusing primarily on comments about the activities and any customizations they brainstormed. The pre-post survey in Session 2 was analyzed quantitatively using paired t-tests ($\alpha = .05$) in SPSS to gauge if participants felt they improved their electronics comfort and confidence. One participant arrived late for the pre-test, so they were not included in analysis.

4.1.5 Limitations. One limitation of the workshop was our use of crafting supplies (e.g., pipecleaners, buttons, colored paper) in the participatory design sessions, which can carry connotations and give participants an impression that their ideas may not be taken seriously [33]. However, by working with crafters, we hoped craft supplies would encourage them to incorporate their creative skills into their prototypes. Similar to the survey, we had more participants who identified as women than men, which is due to crafting groups we recruited from that included more fiber-artists.

4.2 Results

Our results first detail older adult participants' motivations to craft artifacts in their everyday lives and how they go about creating these artifacts. We then delve into how we could support older adult crafters to customize artifacts with electronics. Eight *takeaways* are emphasized that can help the pervasive computing community understand how they could help older adults customize future smart sensing systems.

4.2.1 Why do older adult crafters learn their customizing skills? Overall, participants discussed their motivations for developing their customizing skills that come with crafting. The clearest motivation for them was the social good that comes from giving their artifacts. They gave artifacts to everyone from friends and family to donations at local hospitals for decorating pre-term infants' cribs. Giving was such a powerful motivator, that P7, who rarely gave them away, frequently explained how selfish she felt about not sharing, *"I don't see where I'm helping others. I think it is a very selfish thing. On the other hand, I keep thinking to myself '[P7], you are over 90 years old. You should be selfish (S1)*[3]*.'"*

> Takeaway #1: Support participants to build on their desire to improve social good.

Participants openly discussed the health benefits in continuing to create artifacts echoed in the literature, *"[Quilting]'s calming (P1)"*, and *"And [quilting] keeps my mind going... (P5; S1)"*. For P4, it gave a purpose, *"Because when you retire you don't want to lay down and die (P4; S1). [Laughing from P1-P5.]"* Another motivation, especially evident from P1-P5 who knew each other well, was the social motivators of participating in a group, *"I was beginning to lose a little bit of interest [in quilting], so I realized I needed to get involved with the group, and they've renewed it (P2; S1)."*

4.2.2 How do older adult crafters learn their current customization skills? For many participants, the first introduction to acquiring a customization skill came from a trusted role-model. Several participants spoke about their mothers or grandmothers who got them started, *"...I started very, very young because my mother taught me and I think that's true for a lot of women. You reach a certain age and it's a mother-daughter sort of thing. I was taught to embroider when I was 5 or 6 years old (P1; S1)."* Similarly, P9 spoke about it as a tradition, *"It's a hereditary thing, my mother was a seamstress, my grandmother was a tailor, and we all learned to sew (S1)."*

Participants relied on formal and informal groups to continue their craft and acquire new skills. Formal family structures provided the scaffolding to learn and practice skills as part of a tradition, *"Well it was just what you did in my family (P9; S1)."* Whereas, many mentioned how informal, crafting-oriented groups supported them to continue, especially whenever they encountered challenges. P5 explained, *"We came together and –"*, and P1 finished her sentence, *"– Figured it out as a group, really (S1)."* Fellow crafters were one of the more commonly suggested sources for new crafting knowledge, especially for the P1-P5 who exchanged help frequently. Even when participants worked independently, they periodically sought assistance from trusted, knowledgeable people. P1 explained, *"...we are [quilting] by ourselves and we use the group to get ideas and to get help."* Family sometimes helped, too, as P8 shared, *"So I finally have a new quilting frame that my daughter and I are setting up."*

Many described acquiring new crafting skills by taking group-based, crafting classes and learning from organized lectures. P1 and P5 spoke about opportunities through a local quilt guild, *"...[The guild]'s good because they have speakers that teach us stuff (P5; S1)." "You can take classes, and you can also just get ideas and see other people's quilts... (P1; S1)"* In addition, they named their favorite books, magazines, and TV shows – *"I like to watch TV programs to get ideas there. There is different programs on some knitting and crocheting, some sewing (P6; S1)."* Some spoke about searching for online videos, *"I found some of those [That Perfect Stitch videos] online which lead to tutorials... (P8; S1)"*. These results mirrored the survey on using people and online resources for new ideas.

> Takeaway #2: Introduce new electronic customizing skills through formal or informal groups where a

[3] Study sessions are noted as S#

Figure 5: In Session 1, participants shared artifacts they crafted in a show and tell format, e.g., jewelry and clothes.

trusted familiar person can teach new skills by example (e.g., a teach the teacher model).

When asked how they would introduce their crafting skill to a new person, participants emphasized aesthetics to ensure the final piece would match the intended context, and mentioned specific skills, such as hand stitching. Interestingly, they also emphasized one's mindset by encouraging novices to have an *open, positive outlook*. A key to this outlook was to tinker and experiment, *"...try everything and then find what [you] like to do (P9; S1)."*

Takeaway #3: Emphasize the final artifact, including aesthetics, and how it is okay to experiment (e.g., fail).

4.2.3 What are older adult crafters' current customizing and creation practices? Participants brought a variety of artifacts they created to sessions 1 and 3 (Figure 5). P1-P5 shared baby hats, potholders, pillowcases, table runners, and gift boxes. P6-P10 showed Christmas quilts, jewelry made from polished rocks, and stuffed animals.

Crafters also talked about the tools needed to do their craft. Most talked about having a space dedicated to their craft, where they could store all of their tools and materials. One participant discussed computer programs needed to control embroidery machines, however, the consensus on minimum tools required for quilting (P1-P5) included measuring implements, cutting tools, plans (e.g., templates, patterns), and key instruments (e.g., sewing machines).

Takeaway #4: Identify creative practices and map participants' practices and tools to electronic equivalents.

Participants also discussed how they modified their current practices to adapt to their changing capabilities. P5 described her physical limitations, *"And the fingers get tired, don't they?"* to which many participants agreed. Whereas, P1 added how she changed her quilting projects over time to accommodate physical and cognitive changes, *"I just don't make bed-sized quilts anymore. It takes so long... I don't really want to be doing the same one forever."*

Takeaway #5: Consider the physical and cognitive burden of new skill attainment and scaffold appropriately based on the user group.

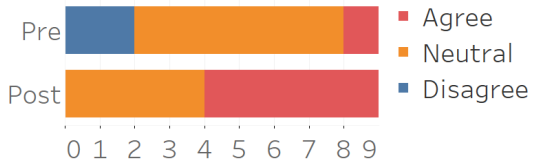
4.2.4 How can we support them to customize with electronics? After we developed a sense of participants' crafting practices, we began activities to teach them about the minimum skills and resources needed to digitally enhance crafted artifacts – akin to the minimum tools needed for crafting. Participants built up their knowledge of electronics as we led them through basic paper circuit activities (Figures 4.a and b), and then let them experiment with Grove Kit activities (Figure 4.c). Not only did most (8/10) participants' confidence in working with electronics improve or stay the same, but they all (10/10) rated this session as their favorite saying, *"I knew nothing about electronics before [Session 2] (P7; S2)."*

Most participants were not familiar with electronics, but a few had experience working with electronics, soldering, or programming. Half had no experience with computer programming or hardware. P10 had experience with electronics from his time making toys at a major toy manufacturer and P1 programmed in her previous job. P3-P5 knew how to solder from their previous job in a television factory and were familiar with component names, but they described how they never learned how circuitry worked.

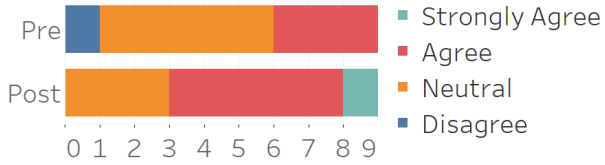
After seeing an initial demonstration of how to create a paper circuit, participants completed their circuits – sometimes working with the group – while some brainstormed ideas. Some participants took advantage of the group setting by consulting each other for help. For example, P7 asked, *"What did you do when you get to the edge?"* and P6 promptly explained, *"You take it that way, and then this way"* mimicking the actions with copper tape (S2). P1-P5 noticed that some techniques, such as folding the tape, were directly translatable to quilting. When researchers demonstrated folding copper tape, P1 exclaimed, *"Ben's quilting! That's what you do when you put the binding on (S2)!"* Participants stayed engaged throughout the session and were already considering ideas for how to use what they just learned, *"You could sew this, couldn't you? What if you put needle holes in the tape (P8; S2)?"*

Takeaway #6: Encourage peer support through group activities to promote experimentation.

Participants continued to actively participate as they interacted with the Grove Kit activity, asking questions such as *"Oh. What we plug in does something. Do all of these [ports] do the same thing? (P5; S2))"*. There was a noticeable amount of excitement as people succeeded in completing the six activities, especially for the buzzer and servo motor. Another example of Takeaway 6 was how participant pairs enjoyed collaborating on each activity, but for the first couple of toolkit activities, some looked to nearby pairs for help. Most did not need help from the research team by the last activity. Participants' main difficulty was in identifying components and occasionally identifying which ports to use. They also continued brainstorming how electronics could be integrated into crafts, *"So there are projects you could hide it in, like a teddy bear (P10; S2))"*. P3 was so excited about integrating electronics into her craft that she went to the local RadioShack (an electronic hardware store) between Sessions 2 and 3 and bought out their entire stock of LEDs,



(a) Comfort with Electronics



(b) Confidence with Electronics

Figure 6: In Session 2, we administered a 5-point Likert pre- and post-test to evaluate participants' comfort (p = .004) and confidence (p = .095) with electronics.

spools of conductive thread, and a sound-to-light kit. Later, P3 asked for help from us outside of the study to try them out.

The pre- and post-surveys showed improved comfort with electronics and a trend towards improved confidence with electronics (Figure 6). Their *comfort* with electronics before and after was statistically significant (p = .004). Participants' *confidence* with electronics did not significantly change (p = .095).

4.2.5 What did participants brainstorm and prototype with their customization skills? Once participants had built up their knowledge about electronics, they spent Session 3 brainstorming and prototyping ideas – mostly around aesthetically-focused and customized objects. Although Session 3 was designed as the sole brainstorming session, participants were so audibly excited about sharing their craft and physically tinkering with electronics that brainstorming happened throughout the workshop series.

Ideas in the **customized object** theme had a functional purpose in the areas of health, games, and safety. Participants brainstormed **health** devices to support and monitor their health and the healh of older adults in their care around the home – such as P1 and P2's paper prototype of a heating pad, which included an extra sensor to detect when someone was getting too warm to alert a caregiver (Figure 7.a). P2 suggested, *"... the best place for the electronics would be on the edge away from the center of the heating pad (S3)."* A popular suggestion among P6-P10 was P8's idea of helping older adults with medications, *"Both my [daughter-in-law] and sister-in-law have trouble making sure their parents take their medications. That would be a good place for a sensor to say 'I've taken my lunchtime medications (S3).'"* Participants built on the idea by suggesting to add motion sensors for detection of specific pillbox cells. P10 brainstormed ways to promote weight loss, by putting *"... a picture of yourself on the front door of the refrigerator, and it's a motivation. Do you want to lose the weight or eat (S3)?"*

Participants were also interested in monitoring their physical health with in-home and on-body sensing. P10 discussed a smart toilet to detect blood in your stool and track restroom use for people with health conditions in which that is a challenge. P9 described earrings to detect oxygen levels or blood pressure. Participants acknowledged the earrings were more aesthetically focused, *"I was thinking [the earrings] would be decorative. That's the scientists' problem [to figure out how it would work] (S3)."* Other health ideas included a device to warn someone if their blood sugar dropped.

Several participants thought of **games**, such as P10's puzzle box that would only unlock if buttons were pressed in a particular sequence. P10 previously discussed how he made puzzle boxes for all of his grandchildren, *"I made the grandchildren a puzzle box... It's to the point now where I've gone through the whole family (S1)."* Adding in electronics to the boxes was an easy next step. Another example was P5's modified checkerboard to help players identify moves by LEDs lighting up, which P3 noted, *"That would be good for an Alzheimer's patient (S3)."*

Lastly, participants talked about personal **safety** devices to protect themselves and communicate how they are doing in their homes. P7 prototyped a smart home suite of sensors in the carpet, bed, and mirrors of her house, so she could *"... let people know that you're up and at 'em. You're not dead in bed (S3)."* The system would detect when she got up and communicate to her daughter that she was doing well (Figure 7.d). Participants described various versions of night lights to turn on when it got dark or with motion, suggesting they be integrated into quilts (P2) or a painting (P6). They also shared their visions of lights that turn on if there was an intruder (P1) and sensors to let the assisted living community's staff know that you were up, so there was no need to call (P9).

> Takeaway #7: Engage participates in hands-on experimentation with electronics to foster customization ideas by increasing their comfort with electronics.

The **aesthetics** theme pertained to how participants wanted to alter the visual appearance of artifacts without a specific functional purpose. Participants sought to improve aesthetics by adding **lights**, such as the candles in P8's Christmas quilt, shown in Figure 8.a. Additional ideas utilized LEDs to add a motion effect (e.g., a spinning effect on a pinwheel quilt (P5; S3)), improve visibility (e.g., a table decoration (P4; S3)), or highlight artistic details (e.g., projecting silhouette carvings onto a wall (P8; S3)). Building on their Grove Kit experiences, they suggested **interactive, aesthetically pleasing light** systems that went beyond only LEDs to utilizing inputs and outputs. For example, P9 suggested having a stuffed dog where the eyes light up and a speaker barks (Figure 8.b).

The post-survey offered more insights about health technologies that interested them and their overall health. Similar to the survey's older adult crafters (31/42; 73.8%), workshop participants wanted to track at least one health topic (9/10; 90%). The most common ones were medications (6/10; 60%) and weight (6/10; 60%). When asked about what was important to their health, participants responded with specific conditions impacting them (e.g., diabetes), staying active, medications, and supporting them to age in place.

> Takeaway #8: Define activities with some flexibility so that participants feel comfortable bringing in their own ideas (e.g., crafters being interested in aesthetics).

(a) Heating pad with sensor (b) Night light painting (c) Christmas shirt with LEDs (d) Smart home system

Figure 7: Low-fidelity paper prototypes from Session 3.

(a) P8's Christmas quilt (b) P9's stuffed dog

Figure 8: Objects participants brought for the brainstorming during Session 3.

5 DISCUSSION

Through our survey and participatory design, we investigated what older adult crafters would customize with electronics, and how we might support them to do so. In the survey, we first learned more broadly about older adult crafters' habits, finding they were motivated to create for fun and to give artifacts as gifts. They often learned new techniques from people and online resources. Additionally, older adult crafters were less interested in maker technology, based on the written descriptions we provided in the survey. Respondents showed broad interest in tracking health areas, such as step counting and medication tracking.

Building on the survey results, we conducted a 3-session participatory design workshop with 10 older adult crafters to further investigate what they would customize with electronics and how to introduce electronics for participatory design prototyping. We further explored their motivations for crafting artifacts, finding that they enjoyed the good that comes from giving artifacts to people. Participants learned their skills from trusted sources, such as family members, and transitioned learning to formal and informal groups of peers. In teaching them about electronics, they improved their comfort with maker technology and actively participated in activities. This helped them generate prototypes of artifacts they could customize, including health and aging in place projects.

In the following sections, we first discuss the impact these results have on the design of pervasive health technologies, such as the role customization played in participants' designs. We then outline our suggestions for *how* to support older adult crafters to integrate electronics into designs.

5.1 Advancing the Design of Customized Pervasive Health Devices for Older Adults

Our work highlights the value that comes from supporting older adult crafters to be more hands-on with electronics, which can prepare them for future customization of health and aging in place technologies and add to the growing interest in customized pervasive health devices. Researchers have called for more personalized devices for older adults [1, 42]. In the case of working with crafters, we saw participants combining their crafting skill sets with maker electronics to brainstorm several ideas ranging from smarter pillboxes to blood sugar sensing systems. Projects such as pillboxes have been studied extensively by researchers [35, 36, 51]. The value in their ideas stemmed from the unique ways they customized them, often building on their crafting skill sets. For example, P9's earrings that sensed oxygen levels and blood pressure drew from her experience as a jewelry crafter. We saw she was focused more on aesthetics rather than the function given her comment that the technical details of the technology were "... the scientists' problem" – a key feature of low-fidelity prototyping with older adults [37]. These types of ideas demonstrate how older adult crafters were building on what they learned about electronics in the workshop, while grounding their ideas in their established customization skills, such as creating aesthetically pleasing devices.

The hands-on nature of learning about and brainstorming technologies by themselves is a next step beyond current participatory methods. HCI researchers have been designing with older adults in the design process through participatory design and co-design [26, 34, 37, 40]. Ambe et al. [1], for example, used co-design to support older adults to personalize home Internet of Things (IoT) technologies built by the research team. They abstracted the knowledge needed for their participants by using cards to represent functions and using string to represent Bluetooth connections. Through mutual learning [61], we took their work one step further by supporting older adult crafters as the designers and encouraged them to experiment and build with maker electronics by themselves. This allowed participants to not only describe the function, but also focus on the aesthetic qualities of what they designed. Participants took inspiration from their crafts, such as adding nightlight capabilities into a painting or quilt. Supporting older adults as the designer and builder of technologies provides another method of incorporating them into the design process. We encourage designers of pervasive technologies in the home to consider supporting older adults to engage in a more hands-on way with technology design.

As more researchers focus on teaching older adults to work with electronics, we promote teaching them more about the underlying technology so they can better generate ideas that integrate their personal experience. Researchers have studied how older adults learn computer programming [24] or create with maker electronics through toolkits [29]. Participants in the survey and workshop showed that they are interested in pervasive health devices, but they may need to learn more about the technology first. By teaching them more about maker electronics before prototyping, our participatory design participants developed some unique ideas for health devices. For example, the modified heating pad took an everyday health device and modified it using maker electronics so it was better for the participants – in this case, by making it safer for someone under their care. Toolkit designers have highlighted how maker electronic toolkits that are more open-ended to allow people to create unique devices [1, 44, 46, 53]. We encourage further development of open-ended electronic toolkits that can promote older adults to design personalized pervasive health devices.

5.2 Guidelines to Support Older Adult Crafters to Create with Electronics

Our work highlights the potential of supporting older adults to be more hands-on with electronics that can lead to future customization of health and aging in place technologies. Rogers et al. [56] taught older adults to use the electronic toolkit MaKey MaKey [12] and engaged them in a discussion of how this technology could be used in sharing, experimenting, humor, or other interactions. Similarly, researchers have shown that older adults *can* learn to use new technology [19, 47, 48, 52, 60]. We see an opportunity to support older adults to learn to design with maker electronics, especially crafters, who are already creating and making customized artifacts.

We provide a set of three guidelines to support older adult crafters to create with maker electronics grounded in our survey data and eight takeaways. First, we encourage **hands-on learning** to support older adults in creating *(Takeaway #7)*. Mellis et al. [45] explored supporting amateurs to create their own custom PCB boards through workshop. They suggest hands-on activities to promote skill learning. In our survey, we responded to the negative survey results about making by challenging ourselves to find a hands-on activity for the participatory design workshop. Paper circuits [54] and Grove Kits [63] offered tangible experiences with maker electronics to help participants brainstorm. These activities led to an improvement in their comfort with electronics, allowing them to experiment while focusing on their customized artifact idea *(Takeaway #3)*.

Second, we recommend supporting them to **learn in groups**, so they can receive peer support *(Takeaway #6)*. Survey respondents and workshop participants relied on trusted sources of help, and one of those that was easy to tap into was their peers. Researchers have noted that older adults and amateur electronic makers are often more comfortable learning new technology from their peers and can more easily receive hands-on support in groups [45, 70]. We saw this peer support during the paper circuits activity where participants were asking each other about the next steps rather than the researchers. Models for supporting groups, such as a teach-the-teacher model where researchers train one person to take the new skills to the rest of the group, could support better dissemination through groups *(Takeaway #2)*. Researchers could work with well-respected crafting community members to support them in learning to create. The participatory design participants noted how important the camaraderie of working in a group was to their craft.

Finally, we encourage the development of **maker electronic toolkits** as a way to support older adult crafters to create customized devices. Traditionally, crafting does not include much digital technology, outside of modern embroidery machines. As we mentioned previously, electronic toolkits could be one way to support that integration, especially when mapped to their creative practices *(Takeaway #4)*. Successful toolkits geared towards older adults, such as the IoT Un-Kit [1] and Craftec [29], are an opportunity to support older adult crafters to create the personalized projects we saw in our participatory design workshops. Such toolkits could be geared towards the older adults we saw in both parts of our study to reflect the changes in how they learn *(Takeaway #5)*, or engage them in their desire to improve social good *(Takeaway #1)*. They would also allow for the aesthetics-focused ideas we saw in the workshop to come to life through the imagination of the crafters, matching their preferences *(Takeaway #8)*.

6 CONCLUSION

We explored how older adult crafters would use electronics to customize technologies, such as pervasive health devices, and investigated how to support them to do so. We first conducted a survey of 42 older adult crafters to learn about their crafting habits, their interest in technology, and their interest in health. We identified how they often learned from people, and created items for themselves, friends, and family. We then conducted a participatory design workshop focused on mutual learning with 10 older adult crafters to teach them about customizable electronics, so they could combine their new skills with their existing crafting projects. Participants' comfort with maker electronics improved with the workshop activities, and they brainstormed ideas by incorporating their crafting skill set with maker electronics. Brainstormed and prototyped ideas included customized objects around topics such as health (e.g., a customized heating pad) as well as aesthetics-focused projects (e.g., adding LED lights to an artifact). We discussed the impact of promoting older adult crafters as designers and builders of pervasive health devices, highlighting how supporting crafters to integrate their skills with electronics can lead to ideas that are customized to them. We also present three guidelines grounded in our survey data and eight participatory design takeaways on how to support older adult crafters to create with maker electronics, including hands-on learning done in groups.

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