Hybrid Practice in the Kalahari: Design Collaboration through Digital Tools and Hunter-Gatherer Craft

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ABSTRACT
People have been making things for a long time, yet digital making has developed mostly within an industrial context. We question how non-digital craft cultures can inform the design of digital tools. Furthermore, what methods can help us understand these cultures in ways that are relevant to digital practice? As makers ourselves, we see potential for collaborative making to mitigate barriers in communication and provide insight into non-digital practices and values. To evaluate this approach, we visited a hunter-gatherer community that preserves an ancient craft, bringing with us digital design and fabrication tools. Working together, we merged digital tools with ostrich eggshell jewelry craft. We use this experience to draw conclusions about making as a form of communication, the importance of supporting appropriation and immediacy in collaborations, the challenge of combining abstract design tools with concrete approaches, and the value of incorporating design and making into communal life.

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Design; Collaboration; Hunter-Gatherers; Craft; Digital Fabrication; Hybrid; Computer-Aided Design (CAD).

ACM Classification Keywords
H.5.2. User Interfaces: User-centered design.

INTRODUCTION
Digital technology continues to open new pathways for creation, but people have been making things long before computers existed. We wonder what elements of traditional making are absent in the use of emerging technology and what is required to blend technologically supported making practices with traditional ones. We believe that the dialog on technologically supported making can be enhanced through a better understanding of making practices in traditional indigenous cultures. Anthropology offers one approach to studying indigenous societies; however we are human computer interaction (HCI) researchers, not anthropologists. Therefore we approach these questions through our role as digital makers. Our hypothesis is that by engaging with non-digital crafting societies *through the mechanism of collaborative making,* we can bridge differences in communication, resulting in an enhanced understanding of the making practices of these cultures. Further, we posit that by incorporating digital tools in collaboration with a non-digital, non-industrial culture, we can gain new insight into the affordances and limitations of this technology. To examine this hypothesis, we apply digital design and fabrication technology to the craft of a people with a unique worldview: hunter-gatherer societies.

Figure 1: (a-b) Ju/'hoansi workshop participants, (c-d) traditional ostrich eggshell bead jewelry, and hybrid designs made with traditional materials and (e) CNC or (f) 3D printing.

Because they maintain elements of a lifestyle that dates back thousands of years in the past [12], sub-Saharan hunter-gatherers provide a connection to early forms of human craft. The Ju/'hoansi[1] are a small group of (former) hunter-gatherers in southern Africa who practice a form of

[1] The Ju/'hoansi speak a click based language. Symbols (!, /, and ≠) are used to denote different click sounds of their language.

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Figure 2: The workshop - (a) our car and the working environment; (b) Roland Modela MDX 15; (c) demonstrating the Modela's operation to Ju/'hoan men; (d) Ju/'hoan woman working on a piece of jewelry; (e) collaborative practice and design discussion.

decorative jewelry craft using ostrich eggshell (OES) beads (Figure 1). In this research, we juxtaposed digital making with Ju/'hoan craft practices in two forms. First, as digital designers, we applied our tools to the design and machining of traditional Ju/'hoan craft materials into finished artifacts. Second, we conducted a collaborative design workshop with a Ju/'hoan community in Namibia, where together we created artifacts through a combination of digital and traditional techniques. Our contribution was also twofold: We outline our approach in applying modern technology to ancient practice, and used the analysis of this process to advocate for new approaches to technological design and development. Further, we detailed the challenges and successes of this collaboration, and used this experience to motivate general strategies for engaging greater diversity and participation in making in our own society.

The paper is structured around a presentation of the workshop we conducted in Namibia in May 2014 (Figure 2). In the next section, we introduce the Ju/'hoan culture, reinforcing our motivation for working with this specific group. In *Related Work* we summarize the current trends in digital design and fabrication studies, before presenting the *Technology and Techniques* (both traditional and digital) that were used in this collaboration. The *Workshop* section describes the collaborative experience, followed by the conceptual discussion and conclusions.

THE JU/'HOANSI CULTURE AND CRAFT

The Ju/'hoansi are a small foraging society living in Namibia and Botswana. They maintained their traditional nomadic way of life until the second half of the twentieth century, hunting and gathering in the central Kalahari Desert. Modernization has forced the Ju/'hoansi to permanently settle and adapt a new way of life [3]. The Ju/'hoansi have minimal notions of ownership, hierarchy, and division of labor when compared with agricultural societies. All adult members participate in making activities, with specific activities for each gender.

The Ju/'hoan symbolic system is difficult to document [13]. Because the Ju/'hoansi come from a foraging tradition, their material culture emphasizes immediate applications. They invest in social ties rather than material storage, and their symbolic culture does not embody long-term principles [2, 12]. Their aesthetic preferences are driven by personal desire and rarely described in abstract terms. Creativity and individualism are welcomed, but communities favor modesty and equality. Individual pride or exceptional differences in style are disapproved. The prototypical example Ju/'Hoansi symbolic design is their OES craft.

Historically as well as today, OES jewelry craft is relegated to women, with a few exceptions. Traditionally, Ju/'hoansi used OES beads as a raw material for jewelry making, for personal uses or as part of *hxaro*, a gift exchange ritual. Through hxaro networks, artifacts swapped hands, serving as a channel of symbolic communication between communities. Wiessner [20] proposed that individual style preference serves to express identity within the community.

With permanent settlements, the Ju/'hoansi can no longer depend exclusively on foraging, and have sought alternative ways to make a living. A number of Ju/'hoan villages welcome visitors and demonstrate traditional practices for a fee. Ju/'hoan OES craft also provides a source of income in the African curios market. Although commoditized, Ju/'hoan craft remains an important community practice and form of creative expression. Moreover, many Ju/'hoan communities attempt to preserve other elements of their traditional way of life. Although no longer the primary food-source, some Ju/'hoansi still forage, and many still speak their traditional language with click consonants. The villages we visited only had one or two English speakers to translate. Even communicating through a translator proves challenging because of the linguistic divide between western and Ju/'hoan languages.

The Ju/'hoansi are professional makers and create products for contemporary markets, but possess a fundamentally different attitude than that of any industrial or digital society. Their OES craft is a product of their distinct culture. Because they are craft professionals that strongly differ from professionals in post-industrial cultures, the Ju/'hoansi are ideal collaborators in a comparison of traditional and digital practices.

RELATED WORK

Recently, digital design and fabrication has evolved into a mainstream topic within HCI and computer-graphics communities. Current research trends focus on improving interactions with digital fabrication tools [7] or seeking real-time integration of design and fabrication [23]. New technologies affect the design process, directly changing the aesthetics of the resultant artifacts. Tools and techniques including parametric design [16], modular design and assembly [8], digitally made connectors and flexible manifolds [18], or digitally fabricated moving parts [17] are enriching the digital making culture with new capabilities and aesthetics.

Lately, researchers have proposed hybridizing design and fabrication processes for efficiency [14]. We seek a fusion that goes beyond optimization. Zoran et al. outlined the limitations of 3D printing compared to manual craft by describing how digitally designed artifacts are intrinsically reproducible. They combined digital fabrication and craft in a work involving broken ceramics restored with 3D-printed elements, to create objects that function as memorials [22]. *Hybrid Basketry* [21] presented 3D-printed structures that allow the growth and development of hand-woven organic fibers. Others have sought to support new audiences in technological making. Buechley et al. conducted workshops [4] where electronic components were integrated with traditional practice, demonstrating how re-contextualizing existing technology empowers new communities and emphasizes different values. Jacobs et al. conducted several workshops with North American novices using a custom procedural design software, called *DressCode*, and other tools to produce fashion accessories through procedural design, digital fabrication, and manual craft activities [10, 11]. In our work, we applied a similar approach (including a use of DressCode), but worked with makers from an indigenous culture who, although new to digital technology, were professional rather than amateur designers.

Efforts to introduce advanced technologies to traditional societies are not new. Non-profit initiatives like the FabLab program [6] introduce digital tools in developing countries to address local problems. HCI for development focuses on empowering users in underserved populations and applying technological innovations to address challenges in these communities [5]. We are distinguished from these approaches by evaluating practices and tools from our own culture rather than building solutions for developing countries. HCI participatory research strategies seek to involve the user in the process of designing tools and generating solutions for their problems [9]. We seek to work with traditional communities as peers rather than users. Bardzell et al. observed western and non-western craft traditions to provide insight into alternate design objectives for technology [1]. We also wished to evaluate our technology from a culturally distinct perspective, but desired to go beyond observation into collaboration.

In recent years, the industrialized world has experienced a resurgence in DIY (do-it-yourself), popularly termed the Maker Movement. Tanenbaum et. al. describe how making offers the opportunity to democratize design and manufacturing. While pleasure and expressivity are important values in hobbyist making, they coexist with utilitarian objectives [19]. We recognize that our perspectives on making are influenced by maker culture and seek to interrogate this perspective in our collaboration with the Ju/'hoansi.

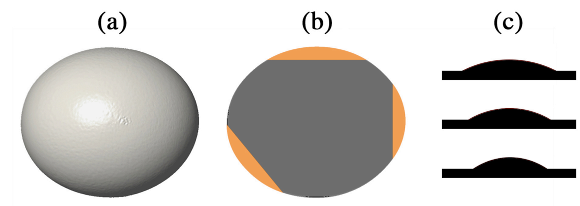

Figure 4: (a) 3D scanned ostrich egg. (b) Cross-sections (in orange) of curvatures from the egg used to prepare three 3D-printed jigs (c) for milling the eggshells.

TECHNOLOGY AND TECHNIQUES

We initiated the research by applying digital tools to Ju/'hoan craft. We based our approach on observations from two prior visits to Ju/'hoan communities. Here we outline the Ju/'hoan OES technique in detail, and describe our methodology in applying digital fabrication to their practice.

Traditional and Manual Technologies

Traditionally, Ju/'hoan makers break whole OES, which have an average thickness of 2.5 mm, into small fragments. Then they manually drill holes in the center of each piece using a long wooden stick with a metal nail. Once drilled, the beads are strung together and sanded. Frequently, beads are dyed or baked to give them a darker color. The beads are manually assembled into necklaces and bracelets, ranging from single strands to complex matrixes and interwoven patterns (Figure 1, c and d). When assembling jewelry, some makers intersperse OES beads with beads made of wood, seeds or nuts, or with purchased glass beads.

Computational Technologies

We explored the hybridization of Ju/'hoan craft with computer-aided design and digital fabrication by creating our own jewelry. This exploration produced a set of sample artifacts (see Figure 1, e and g), as well as a set of digital techniques, which we theorized could be applied to real-time collaboration with the Ju/'hoansi. Our objective was to contribute techniques that brought new forms and aesthetics to traditional OES creation, rather than to render traditional skills obsolete with digital means.

CNC Milling

Computer numerical control (CNC) milling enabled unskilled carvers such as us to create complex forms from OES. We developed a technique to mill OES using a Roland Modela MDX 15, a small and portable 3-axis CNC milling machine with a working area of 152 x 101 mm. We used 1/64" ball-nose and 1/32" square carbide endmills for all the OES milling. The curvature, fragility and irregularity of OES material required a custom technique to effectively mill. We used curved, custom 3D-printed Nylon12 jigs (each 100x75x40 mm) to affix eggshell fragments to the surface of the Modela. We produced the jigs by scanning an intact ostrich egg and extracting several manifolds from the data (Figure 4).

Figure 5: Hybrid designs with traditional elements and 3D printed pendants from //Xaoba (a-e) and from Grashoek (f-j).

Small eggshell fragments (beads and modular parts, below 10x10 mm) could be cut without changing the height of the milling bit (with an average milling time of 5 min). However, larger fragments (up to 50x50 mm) with a significant height difference between their center and edges required a 3D tool path to match the curvature. A custom procedural script in Grasshopper automated the conversion between 2D vector drawings to 3D toolpaths. This workflow required 30-60 min of machining per piece, depending on the complexity of the design.

Additive Fabrication

We explored 3D printing as a way to introduce new materials and mechanical affordances into Ju/'hoan craft. Using computer-aided design (CAD), we created and 3D-printed a series of components to be used in the workshop, referencing traditional Ju/'hoan designs in the process. We sought to amplify the relative advantages of 3D printing (such as enabling the creation of overhanging structures and holes that are infeasible to create through 3-axis milling). We developed three different types of Selective-Laser Sintering (SLS) objects: protective *frames*, 3D-printed *connectors*, and stand-alone *pendants*.

Frames Large milled eggshell pieces were extremely fragile and required reinforcement to make them wearable. In addition to a few milled wooden enclosures, most of the milled pendant designs presented later (Figures 6, 7, and 8) use 3D-printed frames for protection. This series of round, lightweight frames had three flexible struts protruding into the center, which affixed to the back of an eggshell with epoxy, supporting pendants at a range of shapes and sizes. The frames were designed with holes for connecting twine to facilitate their incorporation into jewelry.

Connectors As modularity and assembly are fundamental to digital design practice, we attempted to design modular components that were compatible with OES fragments. We created 3D-printed press-fit connectors that could join 2, 3 or 4 OES fragments, all on the same spatial plain (Figure 9, c). The connectors included small arms with pins, requiring 1mm holes to be milled in the OES, 1.8mm from its edge.

Pendants Additive fabrication enabled the creation of intricate interconnected forms and moving parts not possible through any other form of fabrication. We produced SLS Nylon12 and DMLS (Direct Metal Laser Sintering) steel standalone components, carefully considering the Ju/'hoan traditional jewelry designs, while using a digital design language and 3D printing affordances (synthetic materials and interconnected parts) to highlight the difference in practices (Figure 5).

COLLABORATION METHODOLOGY

Our goal of collaboration with Ju/'hoan makers required us to prepare the techniques we developed in the lab for deployment in Ju/'Hoan communities in Namibia. In practical terms, this necessitated that our techniques were **mobile** (we rented a 4WD pickup truck for the workshop and powered the Modela via the car battery), **robust** (we refined the milling technique to the point that we could repeat it more-or-less without error, and brought 3D printed pendants not dependent on milling), and **open-ended** (we attempted to create a variety of approaches, that could suggest different creative possibilities). We had no means to contact the Ju/'hoan villages in advance, so the only way for us to propose a workshop was to ask in person.

We estimated that our greatest challenge would be in effectively communicating our intent given the cultural and

Figure 6: Digitized Iconography: digitizing a particular symbol (a, b) before engraving it on the dyed OES (c).

Figure 7: (a) Boo's drawings; (b) a digitally duplicated hyena; and (c) a digitally engraved and dyed hyena on an OES.

language barriers. We planned a variety of introductory acts with the hope that one would provide an entry point into the collaboration. We shared the OES sample artifacts we had created in our lab and described the tools we used to create them. We also shared personal artifacts that we had created outside of this project to attempt to give context to our work as makers prior to our interest in OES craft. Because the Ju/'hoansi have a strong culture of gift giving, we brought gifts with us as another form of initial engagement. The gifts ranged from edibles (tea and tobacco), commercially made jewelry components and tools (glass beads, sand paper, twine and connectors), and artifacts we designed in advance (3D-printed pendants and beads). Following these "icebreakers," we explained that we had brought our tools (a CNC mill and computers running CAD software) with us, and if they were interested, we would like to return, share our techniques, learn from them, and make jewelry together.

This work was not without some risk, such as the potential for miscommunication or unintentional exploitation as a result of the economic divide between us and the Ju/'hoansi. We attempted to mitigate this risk through transparency in our intentions. When proposing the collaboration, we explained that we were interested in sharing Ju/'hoan craft with people in our community. We asked permission to take photos of the artifacts that were created to aid in telling the story of how Ju/'hoan craft could connect with our way of making. Because the Ju/'hoansi have a commercial interest in selling jewelry, we offered to buy any artifacts they produced in the workshop *only* if they were interested in selling them. Although we support advocacy and aid efforts on behalf of the Ju/'hoansi, our goal was to broaden perspectives on digital design. Therefore we approached the Ju/'hoansi as creative peers and design professionals Despite our preparations, there was no precedent for which to base this collaboration. This made it difficult to predict how the Ju/'hoansi would react to the idea of a collaborative workshop, and what they might consider the benefits of such an interaction.

WORKSHOP

We ended up working with two communities of Ju/'Hoansi makers in Namibia, in the villages of Grashoek and //Xaoba. Both villages had opened living museums to the public and one or two English speakers. We began with single day visits to both villages. Showing our prior work provided an entry point into the collaboration. The Ju/'hoansi were curious about the materials and techniques we used (CNC'd wood, plastic and leather), which in-turn,

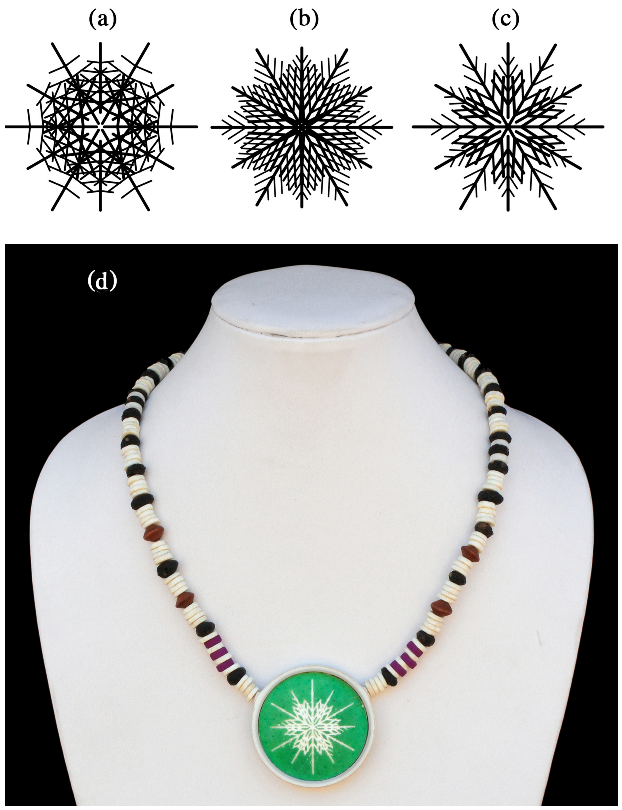

Figure 8: (a-c) Parametrically designed snowflakes and (d) the final design engraved on a dyed ostrich eggshell.

allowed us to describe our interest in their materials and techniques by showing them the OES jewelry we had created. We also gave a collection of 3D-printed beads and pendants to each community.

We received positive reactions from both communities about the possibility of a multiple-day workshop. //Xaoba was more remote than Grashoek and received less tourist traffic, so we began our long-term collaboration there, setting up camp next to the village a day after our initial visit. On the first day of camping, we demonstrated the process of CNC milling with a supply of OES we had purchased beforehand. Immediately the makers of //Xaoba gathered their tools (blankets, drills sanding stones and twine), put forth ideas for designs to create on the mill, and began crafting beads nearby. In total, we spent five days in //Xaoba, working six to eight hours a day with ten women. This time was interspersed with a three-day hiatus to restock our food and materials, and iterate on our collaborative strategies. Following time in //Xaoba, we returned to Grashoek for a single-day visit, enabling us to compare different approaches with the 3D-printed components between the two communities. All the makers in our collaboration were women. The men participated by contributing ideas and company, and often worked on other crafts simultaneously, such as crafting arrows and axes.

Overall, we collaboratively created roughly 60 artifacts (30 hybrid 3D-printed pieces, 8 milled pendants, and some small milled pieces). We detailed the process of creating these pieces by categorizing them by style and approach: *3D-printed hybrids*, *digitized iconography*, and *modular assembly*. We developed a set of criteria to aid in reflection with regards to the artifacts: Do the artifacts appeal to our personal stylistic sensibilities? Do our collaborators consider the artifacts successful? Do the artifacts show evidence of meaningful application of digital design and fabrication? Are the artifacts stylistically distinct from prior examples of Ju/'hoan craft? Do the artifacts demonstrate successful combinations of our techniques and Ju/'hoan techniques?

Style Diversity with 3D-Printed Hybrids

The ease of sharing 3D-printed components with the Ju/'hoansi enabled us to compare styles between two communities. Both Ju/'hoansi communities in Grashoek and //Xaoba readily accepted these pre-made components as gifts and incorporated them into the production of a large number of hybrid jewelry pieces that blended 3D-printed elements with OES and glass beads. In each village the 3D-printed components were distributed equally among all the makers, with each woman receiving at least one bead of each style and color. In both communities, the English-speaking member of the community performed the distribution with remarkable efficiency and fairness. As a result, the hybrid jewelry generally contained one central 3D-printed element, surrounded by handmade or glass beads or both. This approach differed from our intuition in using the beads ourselves (i.e. using multiple 3D-printed beads that matched in color and style in a single piece of jewelry).

Although we observed similar communal practices between Grashoek and //Xaoba, the styles of the artifacts were markedly different (Figure 5). Whereas the makers in Grashoek used a single 3D-printed component per necklace, they balanced the design by OES, wooden beads, or seed that directly complimented the color or shape of the 3D-printed component. Alternatively, they created a coherent composition by augmenting the 3D-printed part with handmade beads. The //Xaoba makers took a different, free-form approach in integrating the 3D-printed components, by breaking some of them apart into smaller beads and situating them with similarly colored pendants.

Whereas we observed evidence of different styles between individuals, these differences were subtle, and deferred to the overall style of the community. The existence of personal style encompassed by community style lended credence to our objective of a collaborative design process with the Ju/'hoansi makers. It demonstrated that despite differences in our symbolic worldview and use of technology, we were engaging in design practices with comparable levels of sophistication, with an awareness of individual style and community norms.

Figure 9: Modular Assembly. (a) Digital designs of modular beads, and (b) a pattern demonstrating design possibilities, using two modules. (c-e) Examples of different design configurations.

Digitized Iconography

One primary affordance of digital practice is the systematic reproduction of a motif with variations in scale and physical medium. The makers of //Xaoba readily took advantage of this, resulting in a series of graphic pendants in the form of large, dyed eggshell pendants inscribed with a motif. Both men and women in the village dictated the designs for the pendants by either drawing on the sand or sketching on paper. We digitally duplicated the drawings, and following the pendant's completion, one of the women (either the woman who designed it, or a female relative of the male designer) assembled the pendant into a complete necklace.

Very few of these designs corresponded with traditional Ju/'hoansi motifs. In the most extreme example of this, several people requested designs by referencing of images on their clothing. The village healer requested a lion, using his Chelsea Football Club hat as a source (Figure 6), and another man requested a snowflake, by referencing the design on his knitted cap. In these cases, the people selecting the designs were unfamiliar with their original meanings; the man who selected the snowflake was unaware that the graphic referenced actual snow.

During the last days of our stay, we collaborated with a skilled illustrator named Boo to produce an additional series of graphic pendants. Boo's subject matter corresponded with traditional conceptions of Ju/'hoansi culture. From his illustrations, members of the village selected specific drawings to be translated to pendants (Figure 7). In several cases (such as the snowflake), the style of the designs provided by the Ju/'hoansi makers was highly procedural in nature. In these cases, we employed parametric modeling to provide another means of collaboration: we used DressCode to create a parametric model of their original design, presenting variations to the local maker (Figure 8). Although the Ju/'hoansi were impressed with parametric tools and appreciated the motifs they produced, they did not show interest in using them to explore new designs.

The graphic pendants represent a successful collaboration. Together with the Ju/'hoansi we were able to systematically apply iconography defined in a variety of formats and translate it at a smaller scale to a different material with high fidelity. Although we provided the tools for this process, both the iconography, and the approach (take a specific image from a different context and apply it to the eggshell) were dictated by the Ju/'hoan makers. Although they had a novel aesthetic, the pendants preserved qualities of the style and character of the //Xaoba makers. The primary limitation of the pendants was that they were restricted to one application of digital fabrication (translating a digital design to a new physical context). We therefore attempted to explore other affordances of digital fabrication that could be integrated with Ju/'hoan practices.

Modularity and Precision

Beaded jewelry making can be described as a form of modular design wherein a variety of modules can be assembled into varying configurations. Well-crafted modules are highly reconfigurable, enabling an exploratory design process. We observed modular design among the Ju/hoansi; designers would distribute all of their beads on a blanket in front of them, select groupings of 2-5 beads, and thread them in sequence onto a necklace. After several iterations, the Ju/'hoan designers evaluated their progress, removed beads and begin again with an altered sequence, while consulting others for suggestions. Frequently, necklaces were re-assembled 4- times before completion.

Digital fabrication supports the rapid and precise production of small volumes of compatible parts, making it an excellent tool for prototyping modular systems. We attempted to exploit this these affordances in several different ways with respect to Ju/'hoansi practice:

Multi-part standalone configurations dependent on precision: This included a press-fit working gear pendant (Figure 12), a press-fit wood and eggshell pendant (Figure 9, d) and a gradient consisting a series of beads, which when strung in order of size produced a transition between a circle and star pattern (Figure 10).

Modular bead systems: These consisted of OES sets with multiple connection points that could be combined in multiple configurations by hand with handmade and glass beads by the Ju/'hoansi to produce different patterns (Figure 9, a and b). Several of these reconfigurable designs were compatible with 3D-printed press-fit connectors, that could be snapped together to create different arrangements (Figure 9, c).

Modular systems comprised of press-fit components: Combining the two approaches above, we created a series of press-fit cube "beads" out of OES (figure 11). In this case, the press-fit components that comprised the beads themselves were modular, and the assembled beads were also re-configurable and could be assembled with other types of beads.

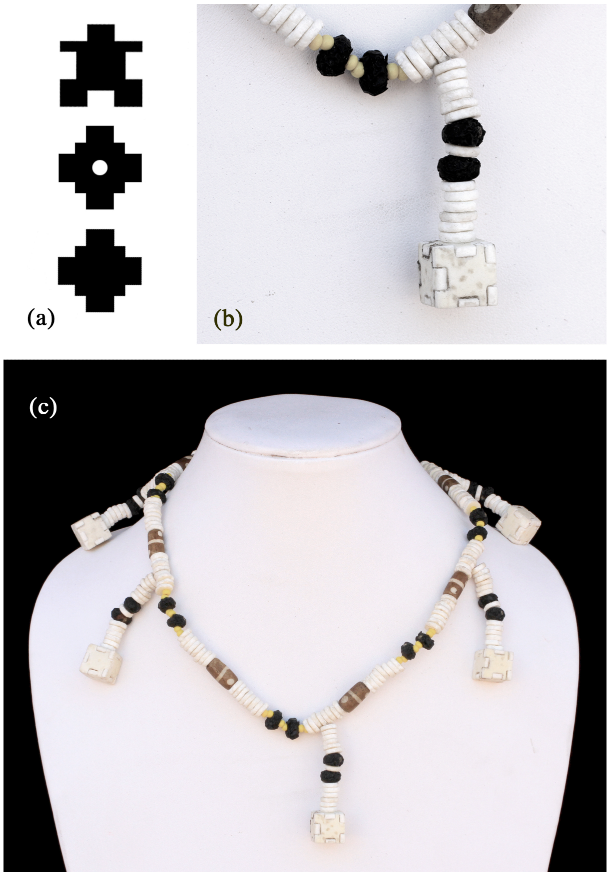

Figure 11: Press-fit cubes, a common technique in digital fabrication. (a) The cube components; (b) an assembled cube; and (c) the final jewelry designed and assembled by a Ju/'hoansi maker.

Figure 12: Design of a working gear mechanism (a), and the final assembly of the jewelry (b). We designed the gear-pendent and Ju/'hoansi integrated our work inside the necklace.

Our objective in developing these examples was to communicate the modular affordances of the digital tools to the //Xaoba makers, thereby enabling them to offer suggestions for effective modular beads. In this case, our intentions for Ju/'hoansi-prompted iterations did not come to pass. For the press-fit cubes and gear mechanism, the //Xaoba makers treated the beads in a similar fashion to the 3D-printed beads; they incorporated them into necklaces, and complemented them with hand-made beads of similar colors. Despite our explanation that, unlike the 3D-printed beads, we possessed the means to make additional variants of this style, the //Xaoba makers never pursued this. We saw similar results with the reconfigurable beads. The //Xaoba makers experimented with different configurations, and produced completed necklaces with the beads; however, they never requested variations or alterations. This was despite the fact that design flaws in the structure of the beads quickly became apparent. For example, when creating intricate woven patterns of beads, the Ju/'hoansi pass multiple strands of twine through the center of the beads; however, the holes on the milled beads were too narrow to accommodate this technique.

DISCUSSION

We began this work with the goal of understanding how digital practices could be reconciled with traditional making, and how making could enable symbolic communication. We discovered that immediacy and appropriation in digital design can support the ideation and iteration, even in a society that is new to digital affordances. We also identified limitations of digital technology in non-digital cultures: the abstractions of digital tools conflict with the concrete design practices of the Ju/'hoansi, and the design of the digital tools themselves conflict with the social aspects of Ju/'hoansi making. We succeeded in using making as a method of communication, insofar as it provided a method to overcome significant differences in language and culture, resulting in a prolific collaboration. Through making, we gained an understanding of how the social craft activities of the Ju/'hoansi strengthen community ties and reflect on how this compares to the role of making in our own culture.

Making as a Form of Cross-Cultural Communication

Language and cultural differences can pose severe barriers in collaborative settings. We found that engaging in collaborative making indeed enabled us to bridge many of these barriers, as evidenced both by the significant number of artifacts we produced together, the fact that the Ju/'hoansi's valued the artifacts, and that they expressed great interest in pursuing similar collaborations.. When attempting to collaborate with people of different cultures, sharing prior artifacts that communicate one's personal approaches and aesthetics can assist in communicating values and ideas. Preparing a diversity of avenues for creation allows for people to explore alternatives, when some efforts prove infeasible. Finally, the process of making itself offers a form of practical communication (for example showing an example sequence of beads, or drawing a pattern), when verbal language is not an option.

Joint Affordances in Digital and Traditional Tools

Chiefly, we saw compatibility between digital and traditional tools in mechanisms for appropriation. Ju/'hoansi makers are extremely skilled in working with

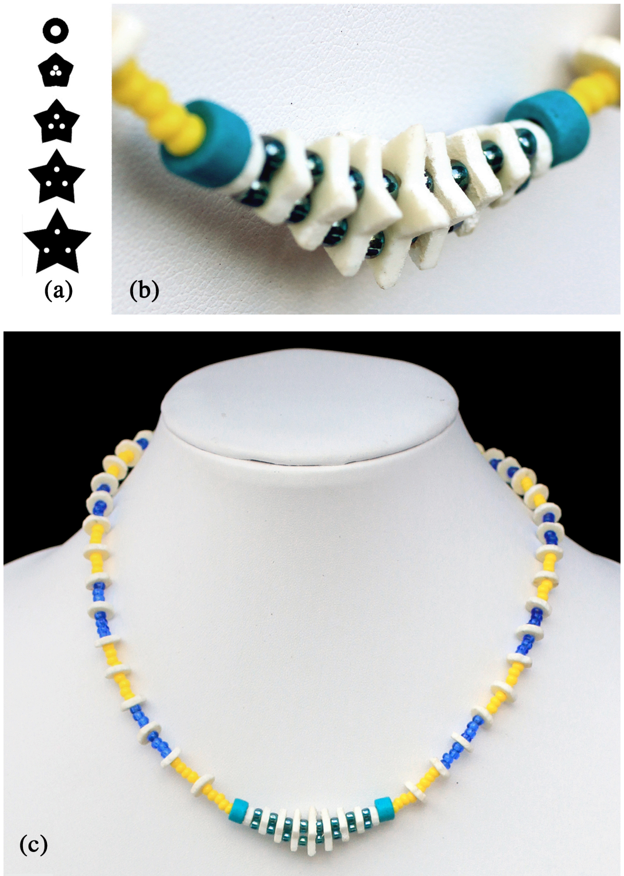

Figure 10: Configuration through transformation, morphing two geometries together (a) to achieve an OES design that is digital by nature (b-c).

available components to suit their design. The breaking of 3D printed components to create unified compositions in //Xaoba is a testament to this appropriation. One of the powerful aspects of digital design tools, is that they enable creators to pull pieces of content from other places, reshape those pieces, and add them to new creations. The iconographic pendants represent a successful hybridization of Ju/'hoansi approach to appropriation (applying foreign symbols from their clothing to a their own contexts), together with our own digital approach. The milling workflow aligned with the immediacy of Ju/'hoansi practice: they dictated an idea; we translated it to a pendant; and within one hour they could begin assembling a piece. This immediacy translated into a rapid set of successive ideas on variations on the process (drawing in the sand; selecting icons on one's clothing; drawing icons by a skilled illustrator). Research into interactive fabrication often has a similar goal in aiding iterative design by reducing the amount of time between ideation and realization. In reconciling digital tools with tradition, we argue that supporting immediacy and appropriation is essential.

Barriers Between Abstract and Concrete Practices

A significant barrier we observed in our collaborative practice involved the incompatibility between digital and non-digital mechanisms for iteration, highlighted by our failed attempts to collaboratively make new modules with new affordances. In digital practice, designers must translate design ideas, including variations to an existing design, to a systematic sequence of software operations. This process requires an abstracted conception of the functionality of the software. Conversely, the Ju/'hoansi identify with immediate concepts and their making practices are dictated by the concrete. Specifically, they explore variations by iterating over available physical components in view in front of them on a blanket. Thus, many of our attempts to encourage conceptual-design discourse through demonstration of new digital solutions were rejected. The Ju/'hoansi makers used the parts we generated with CNC techniques as unalterable beads rather than as templates for iteration. Conversely, when provided with concrete components like the 3D-printed pieces that afforded variation (albeit unexpectedly), the Ju/'hoansi modified them to suit different functional and aesthetic purposes.

In seeking ways to make digital tools that better facilitate exploratory modular practices, one approach is to design domain-specific CAD tools that enable designers to reconfigure virtual and physical modular parts through a small number of operations that are derived from the topology of the parts themselves. This may serve as an alternative to current tools that require designers to work from an expansive set of operations to generate custom forms. Tools like this could be relevant to non-digital cultures; however, they may also assist in broadening participation in digital design and fabrication in our culture.

Reinforcing Community Through Making

Our collaboration with the Ju/'hoansi enabled us to develop an understanding of the communal role of making. Despite the fact that the Ju/'hoansi are professional designers, craft is not merely a professional practice. Within the communities we observed, the act of making is imbedded within the other elements of daily life. The Ju/'hoansi also exhibit a lack of hierarchy in making. While there are different levels of skill and expertise among different craftspeople, *all* Ju/'hoansi participate in making. Collective making is important, not only as a recreational activity or a source of income, but as a mechanism for sustaining community bonds. Conversely, in our culture, craft is often either practiced by experts in a professional setting or a hobby for amateurs in their leisure time. In either case, craft is performed in a specialized setting and frequently among individuals of comparable skill. Papert argued for creating educational environments that are embedded in rich cultural-social experiences as a mechanism for encouraging meaningful participation [15]. Similarly our experience with the Ju/'hoansi suggests that if we wish to broaden meaningful creative participation in our own culture, we should seek to incorporate making more closely with our daily lives. Part of this approach involves continuing to design digital tools that encourage working collectively rather than individually. The greater challenge perhaps, is to create environments where experts and novices, young and old, can make together as colleagues.

CONCLUSION

By conducting a workshop with makers from a non-digital culture and practice, we demonstrate the opportunities and limitations of collaborative making as a mechanism for cross-cultural creative dialog. In the face of severe communication challenges, collaborative making can convey one's objectives and approaches. It offers the opportunity to examine our own tools and practices from a different worldview, resulting in new avenues for technology design.

As a final note, we add a personal, important reflection: *The value of a communal working atmosphere should not be underestimated*. Working with Ju/'hoan makers, we experienced intangible qualities in the environment. Ju/'hoan makers readily share resources and ideas without individual pride. They invest long working hours to learn from foreigners while seamlessly maintaining the flow of daily life. In the interest of creatively empowering entire communities within our own culture, we feel strongly about the need find ways to incorporate these qualities back into to digital practice.

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