Can Interactive Systems Be Designed for Conviviality? A Case Study.

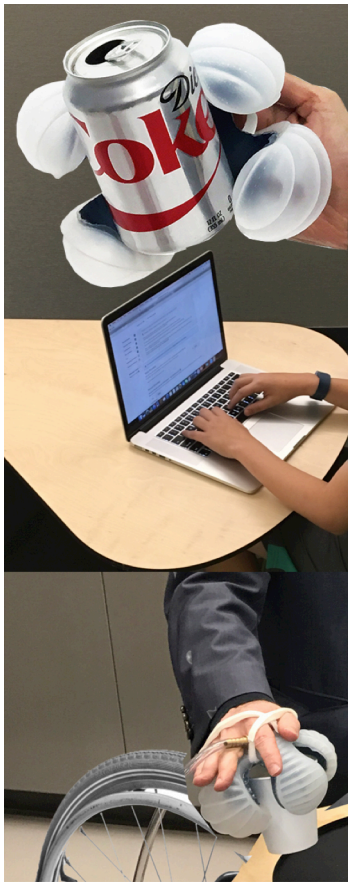

Figure 1: *Helping Hand* (top and bottom) and current prototype of the *Tilting Table* (center).

A video of *Helping Hand* and *Tilting Table* is found at: https://www.youtube.com/watch?v=r93IZ0-JruA

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Abstract
Can interactive systems be designed for conviviality? A response in the affirmative comes in the form of two *convivial* tools, *Helping Hand* and *Tilting Table*, that empower individuals suffering limitations in reaching and dexterity. Our interdisciplinary team developed *Helping Hand* and *Tilting Table* as analogues to a home builder's power tools, but here advanced by mechatronics and transported to home and workplace. This paper presents the two tools in the context of routine, domestic and working tasks, speaks to their design and basic behaviors, and offers an overview of their formative user evaluation involving older adults as part of an iterative, human-centered design process. *Helping Hand* and *Tilting Table* serve as design exemplars of enabling technologies targeting people with limitations in performing everyday tasks. But more broadly, *striving for conviviality* is what this paper hopes to encourage in designers.

Author Keywords
Enabling Technology; Human-Centered Design Research.

ACM Classification Keywords
H.5.2 User interfaces: User-centered design, K.4.2 Social Issues: Assistive technologies for persons with disabilities.

Figure 2: "Michael," the persona we created representing the population for which we designed.

Figure 3: Bad (far-left) and good posture as afforded by angle and height of a work surface [4][5].

Figure 4: Adjusting is difficult [4].

Introduction

How can our existing homes be outfitted with interactive systems characterized as supportive and also empowering and liberating? In our early pondering of this question, we drew inspiration, particularly, from polymath Ivan Illich's book *Tools for Conviviality* [8] that offers two trajectories for new technologies: tools aiming "to extend human capability," that "enable the layman to shape his immediate environment" (i.e., "convivial tools"); and tools, conversely, used "to contract, eliminate, or replace human function" ("manipulatory tools") (also [6]). *Tools for Conviviality* is Illich's plea to designers that they "give people tools that guarantee their right to work with high, independent efficiency, thus simultaneously eliminating the need for either slaves or masters and enhancing each person's range of freedom." *Striving for conviviality* is, more broadly, what this paper hopes to encourage in designers.

Within the conceptual framework of the convivial tool, we identified a problem (mobility challenges in reaching and dexterity [1][3][9][13][28]) and sought to design an interactive, enabling system in response, comprised of two components: an assistive gripper we call *Helping Hand*, and a mobile and adaptive *Tilting Table* (Figure 1).

Previous interactive systems research for healthcare and eldercare applications has tended to focus either on specialized devices aimed at rehabilitation robotics (e.g., [8]), or robot-assisted surgery [13], or prosthetics (e.g., [8]), or as replacements for humans engaged in healthcare-related activity (e.g., [7]), or as "humanoid" companions and/or low-functioning servants [12][27]. Surprisingly, efforts in interactive systems have neglected the domain of enabling tools and furnishings at home and workplace. A notable exception is KAIST's Intelligent Sweet Home [20][21][25] which shares our vision of embedding a suite of interactive devices in the home; however, the only component receiving significant attention, to our knowledge, is a robotic hoist for transferring a user to and from a bed. Diverging from efforts by KAIST, we envision a home environment embedded with mechatronic and robotic furnsihingss that unassertively "ages in place" with those living in it, and that could perform, with human cohabitants "in the loop," domestic tasks enabling independence. But how to envision and design such convivial things?

Introducing "Michael"

To inform the design and evaluation of *Helping Hand* and *Tilting Table*, we generated a persona, "Michael," an older male who suffered a stroke (Figure 2). We viewed "Michael" as both wheelchair-bound and not. As many post-stroke patients are suffering too many deficits and recovery challenges to interact with novel interactive tools in relatively early stages of development, the research team conducted usability evaluations with role-playing participants ("Michaels") to determine the *how and why* of these novel artifacts.

Design and Behaviors of the *Tilting Table*

Designing the *Tilting Table* required the research team to understand the biomechanics of reaching and dexterity as well as the ergonomics associated with these. We know from biomechanics [15], for instance, that reaching becomes more difficult as our arm moves farther away from its resting position close to our bodies. Furthermore, when using a table or work surface (e.g. a workbench, a lab bench), there is a

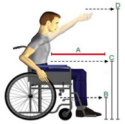

Figure 11. Guidelines for wheelchair users sitting at a worksurface. Use Table 5 for values.

Measurement	Letter	Value
Desk Depth	A	20" – 25"
Lower Reach Height (minimum)	B	9"
Desk Height	C	27" – 34"
Shelf Height (maximum)	D	48"

Table 5. Measurements for wheelchair use. Use Figure 11 for visualization. Data from Dreyfuss, 2000. All measurements are in inches.

Figure 5: Reach limitations for wheelchair users, highlighting (in red) horizontal reach. Image: Allsteel [2].

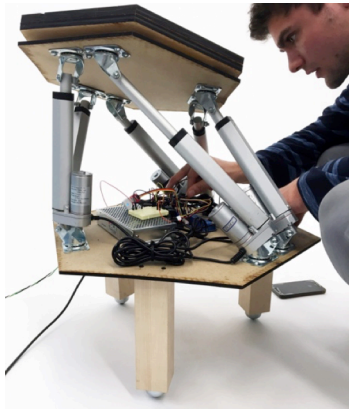

Figure 6: *Tilting Table*—the first fully-functioning prototype shown here without its black, stretchable fabric cover. The linear actuators used in the table are ECO-WORTHY ones operating at 24 volts with a stoke length of 6". Each actuator is capable of supporting a load of 330 pounds. The dimensions from one face of the plywood surface to its opposite face is 15 inches.

tendency for the user to bend over (see figure 3), placing undue strain on the back and causing other bodily discomforts and possibly harm. Raising, lowering and tilting the work surface is a solution. A study by the U. S. Occupational Safety and Health Administration (OSHA) found that tables tilted toward workers "enabled them to see the work more easily and reduced awkward wrist postures" [24]. Furthermore, studies [16][22] have shown that computer workers that had access to adjustable work surfaces reported significantly less musculoskeletal upper-body discomfort, lower afternoon discomfort scores, and significantly more productivity. However, the difficulty with many tables adjustable for height and angle is that those users that may benefit most from adjustable tables—individuals with reaching and dexterity limitations—are themselves not physically capable of manually adjusting such tables to suit a given task. This incapacity is rather obvious when viewing examples of manually adjustable tables (figure 4) where adjustments require the user to kneel, bend, and/or, exercise considerable strength. The difficulty of manual adjustment becomes more an obstacle to those in a wheelchair, as made evident in figure 5.

Our *Titling Table* (figures 6-9) is a mechatronic EHAW that, consequently, serves a broader spectrum of the population (including those individuals with extreme reaching and dexterity limitations) by not requiring manual adjustments for height and tilt, and by being controllable either by wireless, nunchuck game controller, or by voice activation, or by gesture recognition (as we had developed in a robotic table – see [14]. For the prototype reported on here, the research team explored mobile navigation of the table, simulated (as per "WoZ" design methods described by, e.g., [10]). The initial prototype of the table was controlled by a *Wii Kama* wireless nunchuck controller.

Design and Behaviors of Helping Hand

Anatomically, the five digits of the hand comprise a total of fifteen joints, which afford a movement of approximately twenty degrees of freedom (DOFs) [31]. Given the biotechnical complexity of the hand, it is not difficult to envision the potential for limitations to dexterity as a result of injury and disease [28]. But while many of us are familiar with dexterity challenges in older adults (as attributed to arthritis and/or decrease in strength), surprisingly, even millennials (age 20-34), given the prevalence of tech-related work patterns, suffer from weaker grips than their same-age counterparts living in 1985 [11][19].

Practically, the *Helping Hand* (figure 10) is a pneumatically actuated, silicone gripper that attaches to the hand of a user who suffers challenges with gripping small objects. In the design and fabrication of the silicone gripper, we drew from previous efforts in soft robotics (e.g. [29]), translated to a novel application. The *Helping Hand* gripper has three basic behaviors: the hand is capable of *picking-up from the side* (e.g. a wallet, as in figure 10-left, or a drinking cup or bottle); the hand is capable of *cradling* (e.g. a cellphone, as in figure 10-center); and the hand is capable of *picking up from the top or above* (e.g. a beverage can, as in figure 10-right).

Scenario

It's early morning, and Michael, a 75-year-old male, is just beginning his morning routine. Michael relies on a wheelchair, and has difficulty grasping objects. To grab a bottle of his favorite fruit juice, Michael uses a novel

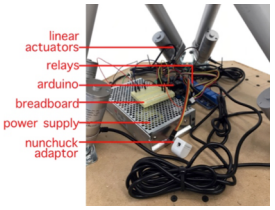

Figure 7: The table's electronic system is comprised of an Arduino Mega microcontroller and 12 relays.

Figure 8: Maximum rise and tilt.

Figure 9: Three use cases.

Figure 10: Helping Hand gripping three objects.

domestic tool, the *Helping Hand*. The *Helping Hand* inflates as soon as it comes into contact with the bottle (via its touch sensor, that operates effectively through the thickness of the silicone). Michael takes a sip from the bottle, and places the bottle down on the table surface. Michael then remembers to water his plant beside the kitchen table. For this, Michael uses another new domestic tool he has acquired, the *Tilting Table*. He tilts this robotic table with a wireless controller (or, alternatively, by voice command) until the table tilts a watering can (held to the table by an embedded mechanical gripper) to water the plant. Next, Michael slightly levels the tabletop with his controller to prepare for working on his laptop. He places his laptop on the table's surface that provides him the ideal height to work comfortably. While making progress on updating his spreadsheet, Michael remembers that he needs to purchase a birthday gift for his niece from an online specialty store. Having identified the perfect gift, Michael uses the *Helping Hand* to lift his wallet to a height that allows him easy access to the credit card inside his wallet. With the credit card's numbers visible, Michael makes the online payment. Returning to and (finally) completing the spreadsheet, Michael shuts down his laptop and uses the controller to level the *Tilting Table*. Michael's new domestic tools have helped enable his morning routine. Feeling accomplished, Michael uses the *Helping Hand* to lift his coffee cup for a sip as he plans the rest of his day.

Formative User Study with Older Adults

A formative usability evaluation of the *Helping Hand* and *Tilting Table* was conducted with five [34] older participants. The five participants were shown a video introducing the *Helping Hand* and *Tilting Table*. Following the video viewing, the team offered a live demo of the hardware, and allowed the participants to control the table. Following the video and live demo, the participants responded to seventeen Likert-scale and open questions. Key results are shown in Table 1.

Results in Brief and Conclusions

The defining criterion for a convivial tool is that it ensures, in Illich's words, "the protection of … self-image and dignity" [18]. It is important to recognize that Ivan Illich did not categorically reject technology. As Illich explains in *Tools for Conviviality*, "in principle, the distinction between convivial and manipulatory tools is independent of the level of technology of the tool." Furthermore, "it is a mistake to believe that all large tools and all centralized production would have to be excluded from a convivial society." Instead, Illich fully recognized that "individuals need tools to move, to dwell," and "to communicate with one another."

In this paper, we introduced a pair of tools of our own design that, following from our formative study, suggest a capacity for helping older adults *move and dwell*, at home, *with dignity*. Participants overall embraced the tools: they understood how the novel tools operated, and they recognized that the tools would make domestic tasks easier to perform. The pair of tools are part of a larger ambition we call *home+*. Currently, we are user-testing *home+* artifacts (Figures 12-13) with wide-ranging stakeholders performing routine domestic tasks to ensure conviviality. This paper hopes to inspire other designers to strive for conviviality in designing their own interactive systems.

Acknowledgements

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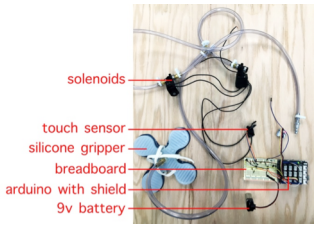

Figure 11: *Helping Hand*—its electronic components.

-- Helping Hand --		
The "Helping Hand" assists in making daily activities easier to perform	I could envision the "Helping Hand" in my home	I understand how the "Helping Hand" works on a basic level
Mean 4.2	3.6	4.6
SD 0.8367	0.8944	0.5477

--Tilting Table --		
The "Tilting Table" assists in making daily activities easier to perform	I could envision the "Tilting Table" in my home	I understand how the "Tilting Table" works on a basic level
Mean 4.4	3.2	4.6
SD 0.5477	0.4472	0.5477

Table 1: Key survey results of the formative user study (5-point Likert scale, where "1" = strongly disagree and "5" = strongly agree).

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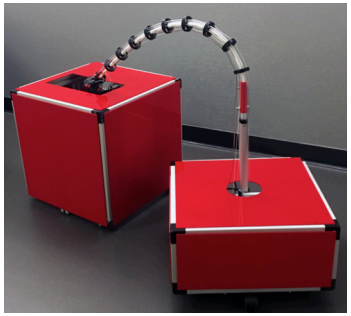

Figure 12: Convivial *home+* furnishings (prototype-2): *h+cube* (left) and *h+lamo* (right).

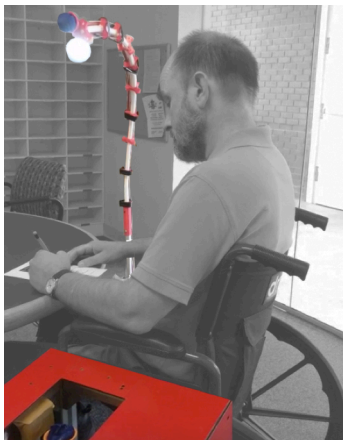

Figure 13: *home+* and a human "co-habitant" working convivially together, at home.

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