Yo–Yo Machines

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Self-Build Devices that Support Social Connections During the Pandemic

William Gaver
Interaction Research Studio, Northumbria University, w.gaver@northumbria.ac.uk

Andy Boucher
Interaction Research Studio, Northumbria University, andy.boucher@northumbria.ac.uk

Dean Brown
Interaction Research Studio, Northumbria University, d.brown@northumbria.ac.uk

David Chatting
Department of Design, Goldsmiths, University of London, david.chatting@gold.ac.uk

Naho Matsuda
Interaction Research Studio, Northumbria University, naho.matsuda@northumbria.ac.uk

Liliana Ovalle
Interaction Research Studio, Northumbria University, liliana.ovalle@northumbria.ac.uk

Andy Sheen
Interaction Research Studio, Northumbria University, andrew.sheen@northumbria.ac.uk

Michail Vanis
Interaction Research Studio, Northumbria University, mike.vanis@northumbria.ac.uk

Yo–Yo Machines are playful communication devices designed to help people feel socially connected while physically separated. We designed them to reach as many people as possible, both to make a positive impact during the COVID-19 pandemic and to assess a self-build approach to circulating research products and the appeal of peripheral and expressive communication devices. A portfolio of four distinct designs, based on over 30 years of research, were made available for people to make by following simple online instructions (yoyomachines.io). Each involves connecting a pair of identical devices over the internet to allow simple communication at a distance. This paper describes our motivation for the project, previous work in the area, the design of the devices, supporting website and publicity, and how users have made and used Yo-Yo Machines. Finally, we reflect on what we learned about peripheral and expressive communication devices and implications for the self-build approach.

CCS CONCEPTS • Human-centered computing~Interaction design

Additional Keywords and Phrases: design research, research through design, peripheral and expressive communication, self-build, open source, IoT

ACM Reference Format:

1 Introduction

Yo–Yo Machines are simple communication devices designed to help people feel socially connected while physically separated (see Figure 1). When pairs are connected via the internet, they can be used to send simple signals (lights, sounds, or movements) to each other, affording a variety of simple expressive gestures at a distance. Designed as self-

build products that people can make at home by following online instructions (yoyomachines.io), Yo–Yo Machines build on research into systems that support peripheral and expressive awareness to make this style of communication accessible to the general public.

In this paper, we discuss the project as design-led research into two topics: peripheral and expressive communication devices, and self-build products as a methodology. The paper has four sections. First, in the rest of this section we discuss our motivations for the project and relevant previous research. Second, we describe what we designed for the project, including the devices' technical infrastructure, ten variations of four basic Yo–Yo Machines, web-based making instructions, and the publicity used to attract makers to the project. Third, we describe what happened when we went public, including the numbers of people involved, accounts of making the devices, and experiences with using them. Finally, in the fourth section we discuss the insights we gained about peripheral and expressive devices, and about the self-build approach to design research [18].

Figure 1: A selection of the self-build Yo-Yo Machines ©Interaction Research Studio

1.1 Designing for the Pandemic

The Yo–Yo Machines project was motivated by the COVID 19 pandemic. After concerns about the rapidly spreading virus grew during January and February 2020, the UK government finally imposed a 'lockdown' in late March. In response, UK Research and Innovation (UKRI), the national funding agency investing in science and research in the United Kingdom, announced the "UKRI Agile Research and Innovation Response to COVID-19" call for proposals. This was an extraordinary initiative with an emphasis on "clear impact to deliver a significant contribution to the understanding of, and response to, the COVID-19 pandemic and its impacts" [39]. The call emphasised that research into the social effects was just as crucial as proposals investigating medical and economic aspects of the pandemic.

It was self-evident that isolation and loneliness would be significant problems with the advent of the initial lockdown in the UK, which mandated that all people stay at home except for 'essential purposes' [3]. This was particularly hard for the clinically vulnerable, including many older people, who were told to 'shield at home' with no social contacts whatsoever, not even with delivery people, who were instructed to leave groceries etc. outside for them to collect. From the outset of the lockdown, the scale of this problem was emphasised in a variety of contemporaneous reports [17,28,32,42].

We knew from our own experiences and accounts of friends and colleagues that many people were turning to online tools to maintain social contacts. Previous research on remote collaboration (e.g. [19]), however, made us aware that most commercially available systems assume focused attention and that tools supporting more peripheral and expressive forms of awareness could also be valuable. This was a key element of the proposal we submitted to the UKRI's programme.

1.2 Peripheral and expressive awareness

In proposing the Yo-Yo Machines project, we sought to build on a long history of research into technological support of peripheral and expressive awareness. Foundational research was situated in Computer-Supported Collaborative Work (CSCW), and particularly research on "media space" [32, 16, 15, 9, 10, 17] reflecting ethnographic work which showed that even physically co-located collaboration depends as much on 'peripheral awareness' of colleagues' activities as it does on focused, verbal communication [22]. At around the same time, artists and designers (e.g. [2, 34, 11]) were independently exploring how telecommunications technologies could support more ambiguous and expressive forms of connection among people over distances.

These strands of work came together in 1996 at the RCA's Computer Related Design (CRD) department when Rob Strong developed three prototypes, Feather, Scent, and Shaker (Figure 2, left), designed to support nonverbal, emotional communication between separated lovers [37]. This work was foundational in repositioning peripheral and expressive awareness devices from professional and public spaces to the domestic and personal arena.

Other designers followed suit, designing a variety of devices including connected rollers [6], breath-controlled lights [7], and Boucher's teleconference tea kettles (Figure 2, right). For instance, Alexander Grünsteidl and Crispin Jones designed a mobile phone to exchange knocking sounds [27]. Gaver and Boucher developed Lamp Share, connecting two ordinary lamps by the internet so that turning up one dimmed the other [25]. Zhang and Armstrong designed Tok Tok, which transmitted knocking sounds between stand-alone devices, and Tug Tug, which allowed a string to be virtually pulled back and forth between phones [24]. Many of these designs explored combinations of interaction and product design to produce devices that were aesthetically evocative as well as minimally communicative. To this point, moreover, most were interactive prototypes that were not deployed for people to live with over time. In 2005, however, Jofish Kaye and his colleagues reported the 'one-bit communicator' at CHI, software that, when activated locally, turns a single bit red on a remote computer desktop before slowly fading away [29]. This was significant both because the team studied its use by couples in long-distance relationships over several weeks, and because it demonstrated that even this minimal interaction helped support emotional connections.

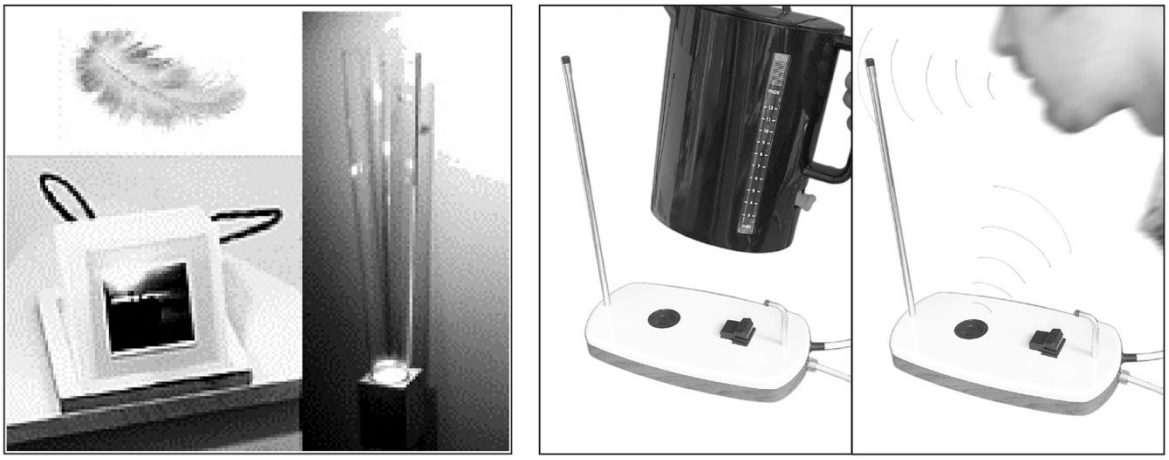

Figure 2. Left: Feather, Scent, and Shaker by Rob Strong; Right: Network Kettle Communicator by Andy Boucher, 1999. ©Interaction Research Studio

By this time, a number of commercial products had started to appear which shared the 'calm computing' [40] aesthetics common to most designs for peripheral and expressive communication (e.g. [1, 30, 27]). For instance, Deschamps-Sonsino launched the Good Night Lamp as a commercial product in 2012 [10]. It received positive critical attention, is part of the permanent collection at the London Design Museum and was on sale for a number of years, but is no longer available.

Despite extensive research, and some commercial activity, however, relatively few people have had access to this style of communication and there is little data about how such devices are used over time in real-world settings. We saw the possibility of addressing these issues in this project by making peripheral and expressive communication devices available as self-build designs, as described in the next section.

1.3 Self-build designs

Another key element to the project proposal was our objective to design devices that people could easily make at home. This was motivated by our interest in extending and assessing the *self-build* approach to circulating research products [35]. This approach is appealing for several reasons. First, it allows large-scale field trials of research products without the costs of making and disseminating them in-house. Second, well designed self-build projects can increase the accessibility of digital making by supporting people of all abilities to construct sophisticated computational products. Third, self-build projects democratise technology by allowing products to be disseminated outside commercial routes and opening them to appropriation and modification by makers. Finally, for this project, self-building offered a route to make an impact during the pandemic with designs meant to support people's social and emotional well-being.

Our self-build methodology builds upon the ProbeTools [5] and My Naturewatch Camera [18] projects, in which designs were disseminated via online instructions that guided people to assemble devices from hardware components that were mostly off-the-shelf or on occasion distributed at cost by the studio, dedicated software downloaded from online repositories, and housings that could be constructed from household materials. For instance, the My Naturewatch Camera, a wildlife camera that captures images when its computer vision algorithm detects motion [18,34], was made by about 3,500 people in the UK and internationally after it was featured on a popular 'magazine' style television programme about wildlife. The project provided a good demonstration of the potential for self-build products to engage people with digital making and topical issues (i.e. local wildlife), and to serve as an effective way to disseminate research products widely and without commercialization.

There are DIY prototyping projects that also make designs available for people to make themselves. Commonly these tend to target audiences with specialised domain expertise. For instance, Desjardins' van project explored how tutorials

can form the basis of disseminating design research [13] in the context of Instructables tutorials that were intended for a particular DIY community [12] In contrast, self-build research products stress accessibility for a wide variety of non-experienced digital makers who are not domain experts. For HCI research, the self-build approach is intended to offer the opportunity to access thousands of participants as well as making practice research open access.

Several key features characterise the self-build methodology:

- A replicable design that carefully considers the making facilities of the target audience. For instance, a design that can be reproduced by a basic 3D printer may be suitable for design researchers (e.g. [5]), while for a general audience it is more appropriate to circulate designs that can be made on a kitchen table with basic tools and household materials (e.g. [18]).
- Software that is packaged for simple installation and that is easy to use without specialised knowledge, including detailed installation instructions and troubleshooting.
- A website containing very detailed visual step-by-step building instructions. There should be no barrier for entry in terms of technical jargon or knowledge; all guides need to be enabling and empowering for participants. Ideally this should include online support to track issues and continuously improve all of the features above, and also for building a community of participants that can support each other.
- Various vehicles for publicity to attract participants to self-build research products. Social media is an obvious example for snowball outreach, but legacy media such as broadcast television (as in [18]) can provide a huge audience very quickly.

Yo–Yo Machines can also be seen as examples of networked IoT self-build designs. Others include Google Creative Lab's Paper Signals [4], which is a papercraft project that contains an Arduino (ESP8266 module) and integrates with the Google Home voice assistant to display simple pieces of data derived from the Internet, such as the weather. Verweij later offered reinterpreted Paper Signals tutorials for the Domestic Widgets study [30]. Google's popular AIY Projects [20] explored a DIY approach to AI, with voice and vision kits for the Raspberry Pi. These make use of relatively complex industrially stamped cardboard nets, in much the same way as Google Cardboard [8] did. In contrast, the reaDIYmates [31] emphasises home production, using printed paper and simple hand cut designs. Like our YoYo Machines, reaDIYmates are simple communication totems used across the Internet, but they used pre-built modules with pre-defined software behaviours and so are relatively inflexible. As Roeck and colleagues imply in their manifesto for DIY IoT [9], Internet connectivity in and of itself changes the dynamics of power of these connected objects and DIY approaches to IoT might go some way to redress the lack of control associated with many networked products. Yo–Yo Machines can thus be seen as offering users greater autonomy by supporting them to build and modify their own IoT products.

1.4 Bringing playful communication to the (locked down) people

Bringing together experience with lightweight communication devices and self-build products seemed to us to offer a real possibility to ameliorate some of the loneliness and social isolation caused by the pandemic. As we wrote in our proposal to the UKRI, the Yo–Yo Machines:

> "…will neither save lives nor replace video conferencing as a primary means of communication, but we believe they will reduce isolation and add a bit of joy to peoples' lives, and we are fully committed to reaching as many people as possible with our designs." (unpublished project proposal)

The project was funded from the start of August 2020 until the end of January 2021[1]. In the next sections, we describe the Yo–Yo Machines self-build designs, how we made them available to the public, and the feedback we gathered about people's experiences with making and using them.

[1] It is important to be specific about these dates because they overlapped with the UK's evolving restrictions at the time. These were constantly changing and difficult to comprehend (for instance, in October 2020 only about half the population understood them [17]), but in general, rules had been substantially relaxed in July 2020, only to be increasingly reintroduced as cases surged, with a second nation-wide lockdown imposed on 5 November 2020, relaxed over Christmas, and re-introduced from January 2021 until July 2021 (see [23]). Thus, the bulk of the Yo–Yo Machines were released just before or during the second and third lockdowns.

2 The Yo-Yo Machines Design work

Distributing research products as self-build devices requires design work beyond that needed to develop the individual artefacts. In this section, we start by describing the development of a scalable technical infrastructure that could underpin multiple designs of Internet communication devices. We then detail the three main components of the self-build Yo–Yo Machines: the four categories of device designs, the online instructions for making them, and our strategy for publicising them.

2.1 Infrastructure

The infrastructure that underpins the Yo-Yo Machines was designed to be adaptable for a distinctive collection of devices. Paramount to the design process was the creation of a system that would be usable by a non-technical audience and so we prioritised easy assembly of the physical and software elements, as well as straightforward network configuration.

Initial investigations of microprocessor platforms included Arduino Uno, BBC micro:bit, Raspberry Pi Zero and Espressif ESP32. WiFi was appealing for allowing the devices to be moved around the house flexibly and inexpensively, and, though we were wary of digital divide issues, we reasoned that people interested in networked devices would most likely have wireless internet at home. We decided to work with the Espressif ESP32 development board as it featured built-in USB and WiFi and is widely available for around $16 for a pair. We were also attracted by the simplicity of the device in contrast to the Raspberry Pi's Unix ecosystem and felt that its limited processing capabilities would be a good match for the simple machines and message transfer that we envisaged.

Using an ESP32 is not without its challenges though: its electrical connections are made by header pins, unlike for instance the crocodile clips of the BBC micro:bit, and we explicitly wanted to avoid self-builders needing to solder. After some experimentation, we found that using a combination of breadboards, jumper wires and flexible cable connectors gave us the straightforward electronics building experience we wanted (see Figure 3). This strategy also allowed us to use a variety of interesting components in our designs, including LEDs, servo motors, fans, and capacitive sensing.

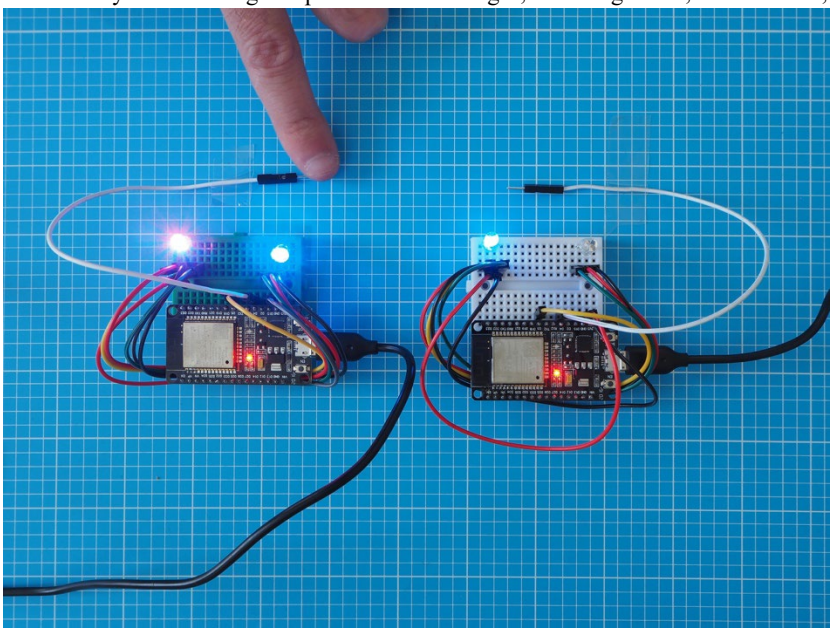

Figure 3. Connected ESP32 breadboard assemblies for Light Touch. ©Interaction Research Studio

However, off-the-shelf ESP32's are not designed with the novice user in mind, each requiring a program to be boot loaded to make them usable. A common way of working with the ESP32 modules is via a USB connection to a computer (requiring a USB driver installation) and the Arduino IDE, into which code is written and uploaded to the board. We did not want users to have to work with code in this way and so we developed a bespoke firmware uploader application in Python that could be distributed for both Mac and Windows. The app was simple to use, allowing users to choose which Yo-Yo Machine they were building from a menu and press an 'upload' button. Although still requiring a one-time USB driver installation, the app was designed to be extremely easy to use.

We also simplified network configuration, specifically for entering the home WiFi credentials and the identity of the paired device. On initial start-up the Yo–Yo Machines create a *captive portal*, a temporary network that the device itself makes, that once joined by a third-party device, pops-up a simple page allowing a network and password to be set. Once completed, the captive portal page disappears, and the configured network will be joined. The software allows for two paired devices to be configured at once: Yo-Yo Machine codes (ten-digit device identity numbers) are automatically exchanged and the WiFi credentials of a remote location can be set locally. This allows both the devices to be made by a single maker, with one of the pair to be mailed to a family member or friend.

Originally, we intended to build a peer-to-peer Yo-Yo Machines network to ensure long-term operation beyond our ability to support a centralised infrastructure. However, while early experiments were fruitful, it became clear that the most reliable user experience would be via the use of a lightweight central server. We built a simple socket-based system, allowing the near-instantaneous exchange of short messages between paired Yo-Yo Machines. We also implemented some simple (anonymous) usage statistics and download reporting on the server. All of the firmware was written in the Arduino IDE and the software is openly available via GitHub [26].

2.2 The Yo-Yo Machines

Based on the infrastructure we developed, we set out to design the devices themselves. Given the wide variety of possibilities for supporting peripheral and expressive awareness that have already been explored, we were less concerned in this project with breaking new ground than we were with designing devices that were simple, appealing, and which could be made by anybody at home for a low cost. At the same time, we had promised in our proposal to release multiple devices – we estimated 6 over the six-month duration of the project. We were aware that this gave us the opportunity to explore various features or dimensions of the design space for such devices. For instance, we listed four at the outset:

- *Intentionality* - do people trigger the devices to send messages, or do they work automatically? How does this affect the interaction quality? E.g., intentional messaging might seem more intimate but also imply a greater obligation to communicate.
- *Information density* - are relatively high bandwidth connections like images or soundscapes necessary to reduce isolation, or can very low bandwidth signals like lights or movement help? What are the trade-offs between density and perceptual effort?
- *Modality* - what qualities of togetherness do visual, auditory or tactile signals afford? How do these interact with context? E.g., haptic communication devices might be more appropriate for families than less intimate friends or colleagues.
- *Semantics* - devices can 'borrow' meaning by adopting familiar forms – e.g., devices might use heart-shaped housings. What are the trade-offs between ease of understanding and popular appeal, and excess sentimentality or constraints on interpretation?

We did not set out to systematically design permutations of these dimensions, and indeed our sense of what dimensions are important evolved through our design work and people's experiences with the devices (see Section 4). Nonetheless, designing multiple devices provided a valuable opportunity to investigate the design space for peripheral and expressive awareness devices beyond a single example.

In the end, we developed ten variations of four basic Yo–Yo Machine designs. Each one is designed to be made as a networked pair, allowing two households to be connected, and are assumed to be symmetrical in the sense that both sides send and receive the same signals. This contrasts with, e.g. the Good Night Lamp [10], in which multiple 'slave' lamps

are controlled by a single 'master', with no ability to respond. We chose symmetrical communication for simplicity and limited the number of devices to two to avoid combinatorial complexity. In this section, we describe each of the Yo–Yo Machines in the order that we developed and released them.

2.2.1 Light Touch.

Light Touch devices allow people to exchange coloured lights with friends and family across the internet (Figure 4). When someone uses their device to choose and send a colour, it pulses on the partner device then fades away slowly, supporting realtime awareness while leaving traces that can be found later.

Figure 4. The three variations of the Light Touch; each has step-by-step building instructions on yoyomachines.io. ©Interaction Research Studio

Each Light Touch has two LED lights: a "send" light controlled from the local device, and a "receive" light that the remote partner controls, as well as a capacitive sensor (a metal piece that senses touch; see [41]) that is used to select and send colours. When the capacitive sensor is touched and held, the 'send' LED cycles through the colour spectrum repeatedly until the sensor is released to select the current colour. Tapping the sensor again sends the colour to the partner device.

In allowing people to send lights to each other, the Light Touch is similar to the Good Night Lamp [10] and also the Lamp Share experiments by the Interaction Research Studio [25]. The most direct inspiration, however, was the One Bit Communicator [29], which allowed users to light a slowly fading pixel on their partner's computer screen. Light Touch elaborates this basic light-sharing strategy in two ways: First, by allowing different colours to be chosen and sent, it opens a new expressive dimension for appropriation. Second, using separate send and receive LEDs allows partners' contributions to be differentiated and affords the creation of different colour mixtures.

We released three different approaches to housing the Light Touches on our instructional website. These vary in the materials used, how they afford being positioned in a space, the degree to which the lights are enclosed, and how they mix or separate the coloured lights. As we will describe later, many other approaches are also possible.

2.2.2 Knock Knock.

Tapping on a local Knock Knock box causes an identical knocking pattern on its remote partner (Figure 5). Each Knock Knock contains a piezo microphone mounted on its inside surface to sense the noise made by tapping on it; this is used to activate a solenoid mounted to tap the inside surface of its partner.

The simplest of the Yo–Yo machines, Knock Knocks are clearly similar to Tok Tok by Zhang and Armstrong [24] and to the knocking version of Jones' Social Mobiles [27]. We didn't embellish the interaction and released only a single design based on mounting the hardware in small boxes with optional decorations. We chose to develop the Knock Knocks to assess the appeal of a realtime audio interaction that leaves no traces.

Figure 5. The Knock Knock in a simple decorated enclosure. ©Interaction Research Studio

2.2.3 Speed Dial.

We describe Speed Dials as like a mood barometer shared with a friend or family member (Figure 6). Devices hold a replaceable 'dial' showing seven graphic or textual messages. Tapping the device's capacitive sensor triggers a servo motor to indicate one of the choices, and this is replicated on both the local and remote partners. Dials – usually arranged to be identical on the two devices – are replaceable, allowing different collections of messages to be chosen.

Speed Dials are distinct from most peripheral and expressive awareness devices in using graphic or textual messages. This suggests that phrases or sentences can support peripheral and expressive awareness the way that 'status messages' are used on some social media platforms to give a sense of a user's mood and activity. Speed Dials constrain messages to a set of seven choices at any time, however, differentiating them both from status messages and the continuously varying signals (light, motion or sound) offered by most other peripheral awareness devices.

We released the Speed Dials in two variations. The first rotates a disk with a cut-out window to reveal choices from a dial mounted below; we suggest using an empty cereal box, perhaps with a spoon as the capacitive touch sensor. The second turns a pointer to indicate options on a dial that is mounted on top of a postcard-sized backing (which might indeed be a postcard). We made a set of predesigned dials available for printing, ranging from one based on traditional barometers to others with snacks or the seven deadly sins, and also encouraged makers to invent their own.

Figure 6. The two Speed Dial variations we released. ©Interaction Research Studio

2.2.4 Flutter By.

Flutter By are devices that create ambient movements when someone is present near their remote partner (see figure 7). Each is equipped with a passive infrared sensor (PIR) to detect local motion and signal their remote partner. Partner devices respond by triggering local display elements to move while remote movement is sensed.

We released four versions of Flutter By to explore different motion displays. Each uses one of two different fans to create movement: a small cooling fan that is inaudible but not very powerful; or a larger fan that is more powerful but also noisier. Flutter By Twist, for example, mounts the large fan over a jar filled with bits of sponge, paper, or even popcorn, creating a miniature maelstrom when motion is detected remotely. Flutter By Ribbon uses the small fan, mounted under its top surface, to spin an attached ribbon or string, which takes on a variety of ghostly shapes as it spins – an homage to Jeremijenko's Dangling String [40]. Flutter By Thaumatrope suspends a card with different images on each side from the large motor; when the card spins fast enough perceptual fusion causes a single composite image to be seen. Flutter By Feather, finally, uses the small motor to spin cut-out paper 'feathers' within an enclosure made from a glass jar, creating a subtle and evocative movement with little or no noise.

Flutter By are distinct from the other designs, and most peripheral and expressive awareness devices, in being triggered passively instead of relying on people to, e.g., touch a sensor or knock on a box. They are also distinctive in using movement alone to signal presence, rather than sound or light. This seemed an appropriate medium for signalling remote activity, particularly when the smaller, quieter fan is used. It is unusual, and somewhat uncanny, for electronic devices to create movement without sound. We refer to this as a "mysterious sense of presence".

Figure 7. The four variations of Flutter By. ©Interaction Research Studio

2.3 YoYoMachines.io

As we worked to design and develop the Yo–Yo Machines, we also designed the website that would make them publicly available. Given that our aim was to circulate the devices widely, this was as important as the design of the devices themselves.

The website we created has two sections. The first, yoyomachines.io, hosts a front page with introductory text, links to an 'about' page describing the project, a history page reviewing historical work on peripheral and expressive awareness devices, and a page for each Yo–Yo Machine describing what it does and how it might be used. All the pages use informal language, brightly-coloured backgrounds and many images to convey that the project is not demanding but entertaining and pleasurable. The primary purpose of yoyomachines.io is to entice people to click the 'make' button highlighted on the menu bar, which takes them to make.yoyomachines.io, the second section of the website. Make.yoyomachines.io provides detailed, richly illustrated instructions for making the Yo–Yo Machines, in keeping with other recent self-build projects such as ProbeTools [5] and My Naturewatch [18]. Each set of instructions briefly introduces what is to be made and includes a parts list with links to suppliers, followed by a step by step, illustrated instructions for assembling the designs (see Figure 8) built on the same Dozuki.com platform that powers sites like ifixit.com.

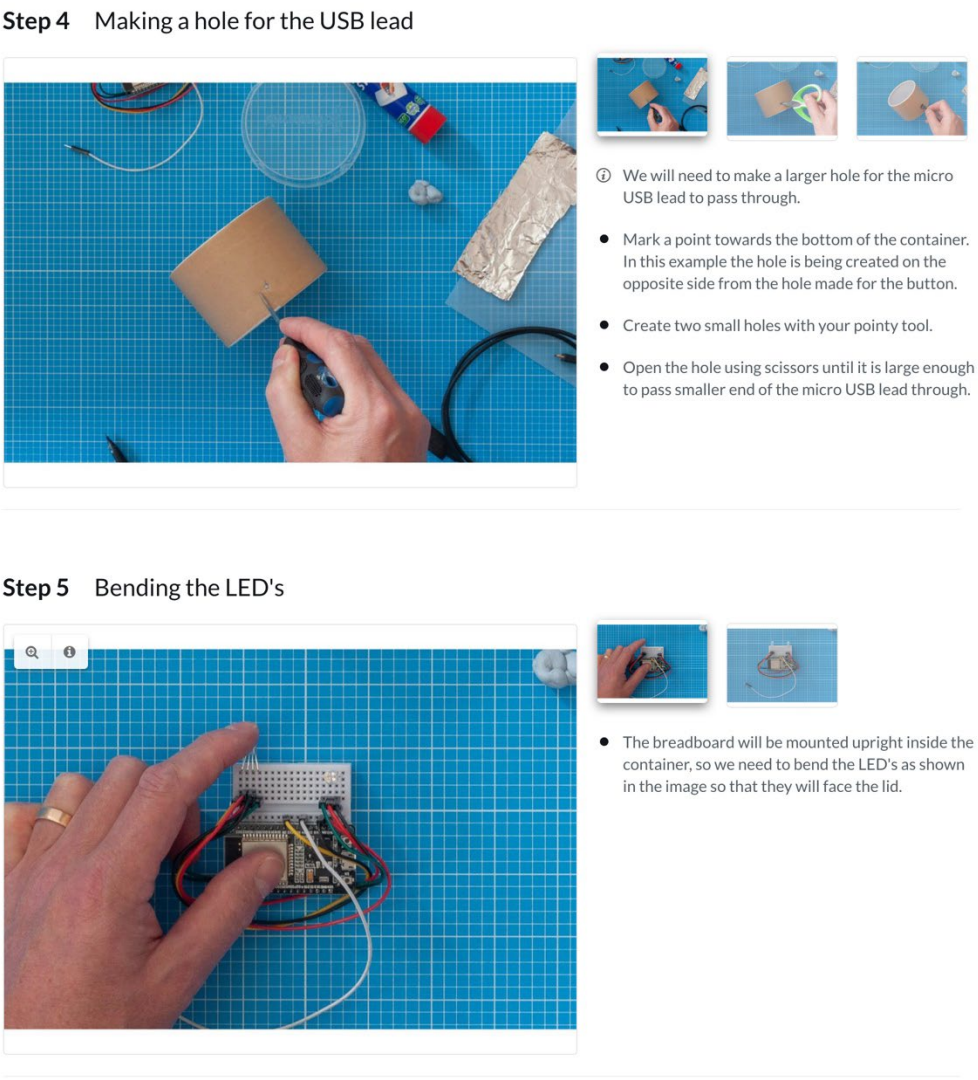

Figure 8. Example steps for building a Light Touch from cotton bud packaging. ©Interaction Research Studio

2.4 Publicity

Finally, because our objective was to encourage as many people as possible to make Yo–Yo Machines, the design of our publicity strategy was also integral to the project. As we prepared to release Light Touch, the first device, we started to announce the project on social media, using our personal and group Twitter and Instagram accounts. Our posts included images and stop-frame animations of the devices, as well as brief 'teaser' texts, to attract attention and convey the kinds of experiences the devices offer. We continued posting regularly throughout the rest of the project, and also sent press releases to a variety of print and online publications, as well as to several television programme teams that we thought might be interested in the project.

The purpose of the publicity was to entice people to visit the project website, and ultimately to buy the hardware and follow instructions to make their own devices. Given that the publicity was the typical entry point to the rest of the Yo–Yo Machines designs, the deployment effectively started with our first announcement, and we started collecting results from that point on.

3 Results

Over 5,000 unique visitors viewed yoyomachines.io over the 14 months since the site opened (Figure 9), with most appearing in January - March 2021 as the designs were released and publicity was at its peak.

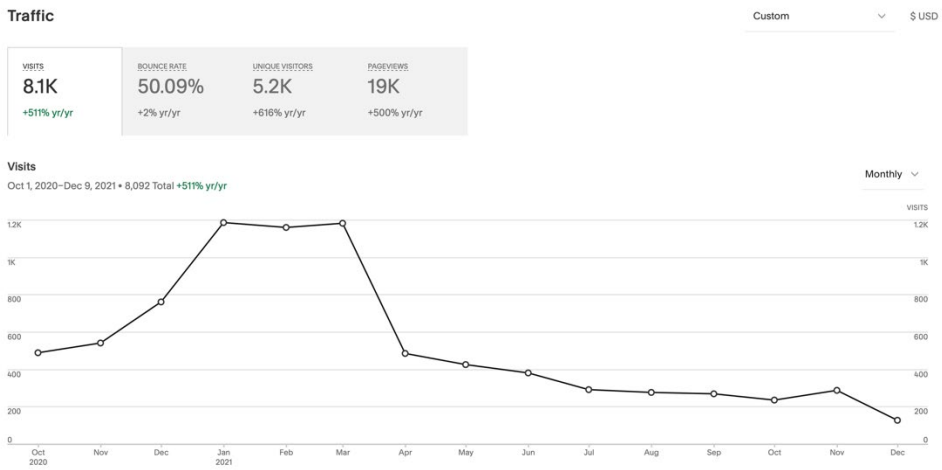

Figure 9. Visits to yoyomachine.io between October 2020 and December 2021

Our best estimate of the number of makers comes from the statistics gathered by our server that provides ESP32S firmware for each of the devices (see Table 1). These figures are useful in giving an overall sense of the numbers of people who engaged with any of the devices, as well as each device separately (e.g. *Light Touch*, released first, was downloaded about 8.5 times as often as *Flutter By*, our last release). These numbers are indicative but not definitive, however. Some downloaded software may have been used for multiple devices, while others may reflect repeated downloads for the same building attempt.

The statistics also give a sense of ongoing engagement with the devices. Most importantly, *Users Online* indicates that 274 devices are actively registered and communicating with each other at the time of writing, which we believe compares favourably with other examples of self-build projects.

Table 1. Download / usage statistics from the Yo–Yo Machines server (19 December 2021)

ITEM	# DOWNLOADS
Firmware Uploader – Mac	257
Firmware Uploader – Windows	160
Total	*417*
Light Touch	861
Speed Dial	361
Knock Knock	137
Flutter By	101
Total	*1460*

Users	283
Users Online	274

3.1 Experiences with Yo–Yos

We have relied on three main sources of information about people's experiences: feedback on social media, both spontaneous and in response to requests that we posted; responses to more direct requests for feedback from people to whom we gave kits; and our own autobiographical accounts of using the devices with our friends and family. Here we describe overall appreciation for the project, reports of making, and accounts of using the Yo-Yos.

3.1.1 Appreciation and anticipation.

Many comments, both online and sent to us directly, have expressed appreciation for the concept of the project in general, e.g.: *"Presence besides communication, something important in these weird times of isolation."* (Angelo, Milan), sometimes acknowledging the background of the research: *"I like the history of projects around peripheral and expressive awareness research–hopefully by knowing what has gone on before, it can spur further thinking and imagination to explore other interaction spaces."* (Chris, Broughty Ferry). Others focus on the project as an opportunity for digital making, and perceive it as aimed at inter-generational communication: *"I think this is a good opportunity to get our children into a bit of digital making and connecting to their grandparents without having to actually talk to them."* (Sean, Tayport), or *"I think Grandma and grandchildren will enjoy negotiating how to label Speed Dial."* (Graham, Fife). We were also told that people had recommended the project to friends, e.g.:

> *"I love your yo-yo. I've been sending it around to all kinds of people, esp with kids who like to make things. Fantastic activity and great way to connect to classmates, cousins, grandparents, etc. Really nice public service project!"* (Ken, Portland)

3.1.2 Reports of making.

Feedback from makers indicates that assembling the Yo–Yo Machines was usually successful, though minor problems were sometimes encountered. For instance, customers who have bought kits to build Yo–Yo Machines from the online electronic hobby store Pimoroni (shop.pimoroni.com) have commented:

> *"A really easy to use kit- we were up and running in minutes. The online instructions were helpful, also." - Anonymous, 6th September 2021*
>
> *"These made a great birthday present for my mom. The only issue was that I accidentally burnt an LED, and couldn't find another of this type to replace it anywhere in my country. I ended up fashioning my own replacement out of an addressable light strip. It worked, but it was still annoying."- Eli, 2nd September 2021*

In addition to acknowledging the useability of the kits and devices, the second also indicates issues with working with fiddly bare components, a difficulty that we return to later.

We also offered Yo-Yo Machines kits to interested parties in exchange for more detailed accounts of making or use. Most of these reports come either as people made the devices or shortly thereafter, e.g. "I've finally had a Sunday making day and assembled the Yo-Yo Machines! It was a lot of fun!" (Leo, Munich). Sometimes these include detailed comments about the difficulties or confusions they had following the instructions to make the devices (e.g. "installing the USB driver can appear scary, so reassuring text here would be good") that were extremely helpful as we continued to improve the site.

Some included descriptions of building the devices and the experiments they tried. For instance, Kristina and her 15-year-old daughter Rosa wrote from the Netherlands, and included detailed documentation of their build, in which they reconfigured the components onto different boards to permit different possibilities for housings and experimented with different treatments for the lights (Figure 10).

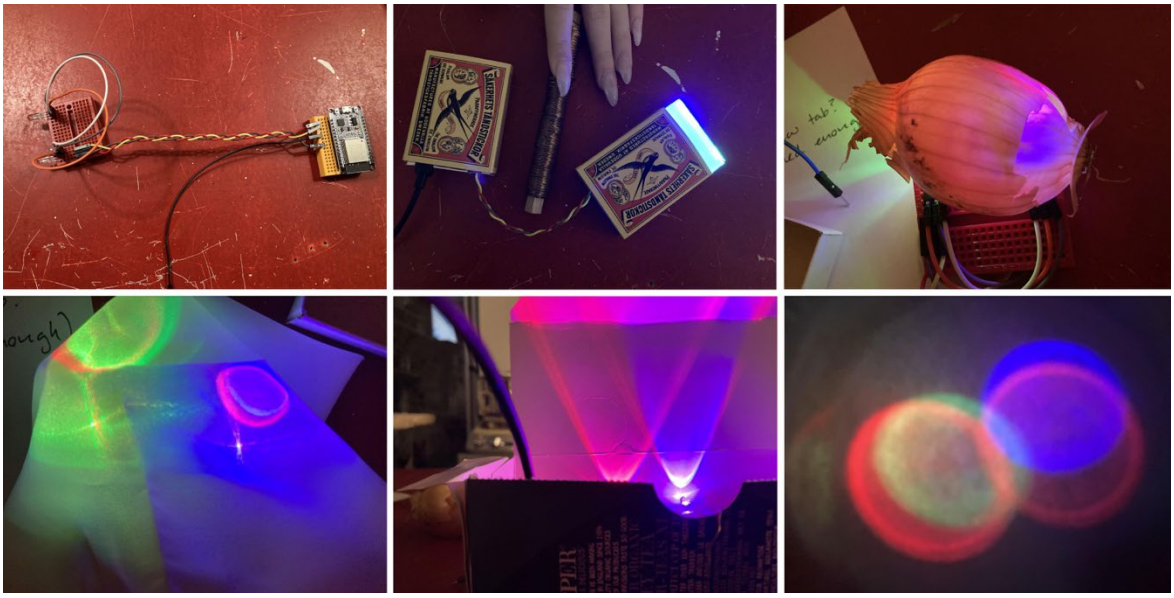

Figure 10. Rosa and Kristina's experiments, from right to left, top to bottom: separating the sensors from the main board; mounting the lights and sensors in matchboxes; onion skin as a diffuser, fabric diffuser; in situ in a tea box; other effects.

Other builders have shared their final creations. While many have followed our instructions to build one of the versions we released, others have explored a wide variety of other options. For instance, Figure 11 shows examples of variations on the Light Touch. These vary in materials and configurations, the degree to which they reveal or obscure the use of household materials, and the aesthetic sensibilities taken to the designs. For instance, while some work to achieve a minimalist appearance, others are more playful or even humorous. These reveal new possibilities for relating to the Yo–Yo Machines, and perhaps something about the relationships they are anticipated to support.

Figure 11. Variations on the Light Touch by at-home makers. From top to bottom, left to right: Jasmine Cox, Michael Shorter, Leonardo Amico, Andrew Cook, Angelo Semeraro, Rosa & Kristina Andersen

Finally, a few makers reported using the Yo–Yo Machines within their own homes, rather than to support communications with distant friends and family as we had anticipated. For instance, Peter from the Netherlands described making a set of Knock Knocks to call his son to dinner (see www.pjtr.be/knock-knock). The version he made for his kitchen was "*pretty standard*", but he "*thought it would be fun to have a little butler to tell our son that his dinner is served*" (Figure 12). Examples like this emphasise the degree to which the designs are open to appropriation by makers.

Figure 12. Peter's 'butler' Knock Knock, made to tell his son dinner is ready, is an example of Yo–Yo Machines made for use in a single household.

3.1.3 Experiences of Use.

Despite numerous reports of the devices people made, few included details about their lived experiences with the devices. One exception is a relatively detailed account from Mathilde, who made Light Touches to connect her family in Sweden with her parents in the UK (see Figure 13). Mathilde and her parents assembled their Light Touches separately and managed to connect them while coordinating on Zoom. She writes:

> *"The moment when we first got it to work - it took my Dad a few attempts to get the electronics right - was really lovely. I remember we were all in the kitchen table around the computer, my Dad talking away with Jean (anon.) on zoom, trying to troubleshoot things, and then finally, his board flashed to show it was alive and connected."*

Over "*the next few weeks*" the whole family used the Light Touch to communicate once or twice a day. Mathilde points out the particular benefits to Jon, her 7-year-old son: "*he clearly felt connected in the moment to my parents - which is something that has been harder and harder for him to feel since it has been so long since he saw them*." After a few weeks, however, Mathilde moved the Light Touch to a less accessible position to keep it away from her 2-year-old, and from this point she became the primary user of the device. She reports:

> *"When I was cooking, normally I would see it and change the lights. Sometimes if my parents responded quickly then we would send each other different lights for a bit. It was nice, I felt they were thinking about me, and I was thinking about them. In my head I could imagine where they had the Light Touch in their dining room, and so it sort of made me feel like I was there, in their home with them for a few moments."*

About 3 months after they first deployed the devices, however, Mathilde's parents knocked their Light Touch to the floor and it stopped working. She reports that "*I am not sure if they have tried to fix it, but occasionally I still send them lights to see if I will get one in return. I'm still waiting.*"

Figure 13. Mathilde's tweet about the Light Touch she made with her parents.

We have also collected autoethnographic [11] accounts from two team members who have used Yo–Yo Machines over months with their friends and family, as these sorts of reflections offer more nuanced and considered detail than we received from casual users.

For instance, Bob [anon.] made a pair of Light Touch devices to share with his 92-year-old mother Fay [anon.] who lives in California. He paired the devices and pre-configured his mother's light with her WiFi credentials before mailing one to her. This meant that the two started communicating almost immediately after she unpacked and powered her device and continued sending one another lights regularly from that time. About three weeks after installing the devices,

however, Fay's Light Touch stopped working when the weight of the power cable dragged it off the cupboard she had kept it on. From Bob's contemporaneous notes:

> *"We spend days trading emails and texts, her sending pictures, one or two Zoom meetings… turns out the captouch lead has come loose from the inside of the box. She manages to reinsert and tape it down — also the button. Then she discovers capsense wire has come out of the breadboard! I tell her where it has to go, and using a strong magnifying glass, reading glasses and a powerful light she manages to find the correct hole and reinsert it. It works again!"*

The persistence which Bob's mother showed in repairing her Light Touch seems powerful evidence of the value she found in the connectivity afforded by the devices. After this episode, the two continued to use the devices regularly. Because of the time difference between them, the slow decay of the lights was important in allowing them to send colours that would be found later. Bob developed a routine in which he would send a light upon awakening in the morning as well as just before going to bed, as well as numerous times during the day as circumstances allowed, and his mother followed suit. The two agreed that it was important to maintain the lights together, like collaborating to care of a houseplant, as finding one's Light Touch unlit made it seem 'dead'. Bob and his mother are still using the devices regularly at the time of writing, a year after they were first deployed (see Figure 14). As Bob wrote about a month after the first deployment:

> *"They're surprisingly compelling — when she sends me a light from California it feels like she's right next to my desk in London. It's also really nice when I wake up or return home and find a light she's sent earlier, and she says she looks for a light from me particularly when she gets up at night."*

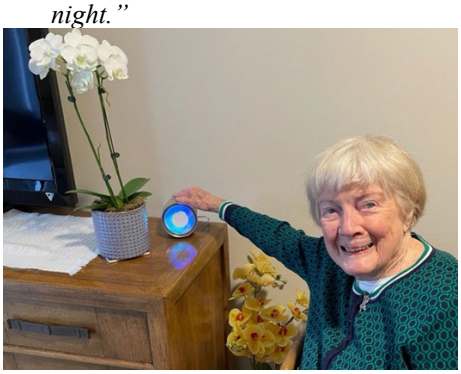

Figure 14. Bob's mother, Fay, with her Light Touch. ©Interaction Research Studio

Meanwhile, Alan (anon.) was keen to share Flutter By with his own distant parents, but the lack of reliable wireless internet and a general phobia of technology in the remote location meant this was impossible to arrange. Instead, Alan installed both devices in his own home. This had become a site containing a satellite office of a human resources department, remote primary & secondary schools, and a design research studio. The home was frantic with activity, but the whole family was tethered to screens and headphones in their individual corners of the house, together in one sense, isolated in another. So, the Flutter By Feather on Alan's desk became an important tool for awareness within this confined but fragmented space. The other Flutter By was located on top of a staircase that led up from a space directly behind Alan's makeshift desk in the living room. In the noise-cancelling headphone environment of the desk (a pandemic necessity), Alan's family's frequent stomping up and down the stairs to collect sustenance from the kitchen or receive yet another delivery was transformed into the balletic visual spectacle of the Flutter By Feather spinning elegantly, a reminder of human closeness that the other work focussed-technologies were working so hard to block out. Over time, the frequency and length of the movement became quite meaningful. Starting work early would always come to end with the first spin of the day, indicating the kids were up and wanting their breakfast. Continuous spinning meant someone was loitering on the staircase, usually to ask for something or to announce hunger as mealtime approached. Overall, the frequent intermittent spinning in the periphery throughout the day became a comfort. It was an indicator that stuff was

happening, people were fine and getting on with the day. This finding was a surprise considering that the project was conceived for remote locations, but serves as a reminder that being continuously plugged into the far and away can leave a yearning for the nearby.

4 Discussion

Hundreds of people have made and used the Yo–Yo Machines since they were first released. With ten variations of the four basic designs, and many others devised by participants, this is one of the largest deployments of a range of fully functional devices designed to support peripheral and expressive awareness of which we are aware. We have amassed considerable experience with making and using the Yo–Yo Machines both from users' accounts and our own enagements. Here we discuss the insights we have gained about peripheral and expressive communication devices, and more generally about self-build research products as a research methodology and approach to disseminating designs.

4.1 Peripheral and expressive awareness

Reflecting on our own and participants' experiences with making and using the Yo–Yo Machines has led to several insights about peripheral and expressive awareness devices that we discuss in this section. Overall, our findings support historical claims that devices create connection and a sense of presence over a distance. We identify several features of the design space appear important in determining the experiences afforded by the devices. However, more idiosyncratic design features can also strongly affect engagement with the devices. Moreover, the context of use for the devices – both locally and in terms of global communication trends – also influences how the devices are perceived and used. Taken together, these insights lead to suggestions about new directions that might be explored in designing devices that support peripheral and expressive awareness.

A recurring theme in remarks made about Yo-Yo Machines is that *peripheral and expressive awareness devices can create a palpable sense of presence and connection between remote spaces.* While this claim is implicit in virtually all work on peripheral and expressive devices, our study supports this with the real-world experiences of multiple users over weeks and months. It is clear from people's comments and our own experiences that even this simple sort of presence can be emotionally satisfying to people, helping them feel connected to one another. For instance, for Mathilde using the Light Touch with her parents *"made me feel like I was there, in their home with them for a few moments".*

At heart, the sense of connection with remote people and spaces seems to depend on an understanding that changes in a local device – a flash of colour, knocking sound, moving pointer or fluttering ribbon – cause, and are caused immediately and only by, changes in a remote one. This is an understanding that cannot initially be created by the devices themselves, but once it is established via a parallel communications channel it persists until there is evidence of a breakdown. From this perspective, it seems that any device that creates this kind of real-time connectivity can support this basic sense of presence (see [29]).

Beyond this simple sense of presence, however, participants and our experiences suggest that *several features of the design space are important for peripheral and awareness devices.* Many of these are the same as the ones that we thought would be important at the outset (section 2.2). However, our designs did not vary significantly in their *information density*, while a new dimension, *persistence*, emerged as particularly salient:

- *Modality* – as expected, the devices were clearly differentiated by their use of light, sound, movement, or images and words. This had implications for all the features we discuss here, and also for the *noticeability* of signals sent from remote locations – for instance, Knock Knock doesn't require visual attention and can be heard throughout a living space, whereas Flutter By Ribbon can be easy to overlook because the fan is silent and the ribbon becomes translucent when spinning rapidly.
- *Persistence* – Light Touch signals fade over several hours, allowing them both to create a sense of realtime presence and to act as asynchronous 'messages'. Knock Knock's signals, in contrast, are completely ephemeral, making them exclusively realtime devices. Speed Dial and Flutter By signals persist, but rely on memory for changes to be noticed, which is easier for the former than the latter. These variations have significant effects on the situations for which the devices are suitable. For instance, Knock Knock and Flutter

By convey a sense of virtual co-presence, while Light Touch and (to a lesser extent Speed Dial) also allow signals to be found later, which is valuable across time zones or for households with different activity rhythms.

- *Intentionality* – Light Touch, Speed Dial and Knock Knock all rely on signals being triggered intentionally; this means that seeing a new signal usually indicates that the remote user intends to make contact. Flutter By, in contrast, is the only device we made that did not rely on intentional triggering. This tended to convey a sense of physical, but not emotional presence, as it was possible to tell when someone was active in a remote space, but not whether they were thinking of the local recipients.
- *Semantics* – Beyond a sense of presence, the devices vary in the 'depth' of messaging supported. Flutter By simply signals a period of presence and movement at the remote location; the look and feel of the signal (e.g. whirlwind v. ribbon) is pre-determined and does not depend on remote circumstances. Colours sent on Light Touch can convey a more purposeful semantic message, but though a few users reported agreeing 'codes' for colours, usually they were chosen for aesthetic effects or to convey a sense of energy (bright colours during the day, darker ones for night). Knock Knock allows patterns of sounds to be created, and, although we also have no reports of agreed 'codes' being developed for this device, this still permits a degree of expressivity. Finally, Speed Dial allows a choice among messages that can be semantically explicit (e.g. "We're not in Kansas anymore") but, because choices are constrained, they are highly unlikely to be exactly what is intended. Overall, the 'messages' sent by all the devices are ambiguous and indicative, a feature that was greeted as positive by the makers we heard from.

Comparing the Yo–Yo Machines along dimensions such as these is useful for considering the experiences they support and how new ones might be designed. However, *idiosyncrasies of designs seem at least as important in influencing the feeling tone of devices and thus how they might be used and by whom*. This can be appreciated by considering the range of Light Touch devices shown in Figure 11, which vary in whether lights are separated or allowed to mix, and also in terms of their presentation as serious or lighthearted, organic or high tech. This space of possibilities is multiplied enormously when considering the possible variations within and between the other basic designs. Thus, while some basic dimensions such as modality and temporality are useful in thinking about these sorts of devices, there is a great deal of scope for design explorations of new possibilities.

Moreover, *the local context of use is crucial for whether and how the devices are engaged*. For instance, Mathilde reports that she moved her Light Touch after it stopped working reliably and she fixed it: "*Then it sort of seemed delicate, and I moved where we were keeping it — from the table to on top of a speaker…. From then on, I think it was only me who used it.*" Beyond their intrinsic characteristics, Yo–Yo Machines are liable to be used or neglected depending on whether they are sited in locations where they are convenient to interact with and which are visited regularly. The devices are also vulnerable to abandonment if they break down, as this is a natural time to stop using them rather than initiating repairs and restarting interactions.

In addition, *Yo–Yo Machines implicitly prefigure the nature of relationships that they support*. All are designed to be always-on devices, and appear inert when unused, with nothing to distinguish a Yo–Yo Machine that is idle from one that is broken. This suggests that they should be used frequently and regularly, e.g. at least once a day, and failing to do so can be perceived as a snub to one's partner. While this is appropriate and useful for some relationships – e.g. Bob and his mother – it is too intense for some others. Many friends, colleagues, and family members are accustomed to slower and more intermittent interaction rhythms, and Yo–Yo Machines may implicitly suggest or demand an uncomfortable degree of intimacy.

Taken together, these observations suggest that new designs could be focused on supporting irregular and infrequent interactions while continuing to provide a compelling experience when idle. For instance, the Light Touch might be redesigned to display a continually shifting light show, with purposeful interactions indicated, by pulsing the appropriate light for a period of time. This would prevent unused devices from appearing 'dead', and encourage people to place them in visible locations, perhaps allowing them to better support a greater range of relationships.

It is important to note, however, that *the historical context of use also affects engagement* with the devices. Since Feather, Scent and Shaker [37] were first proposed in 1996, the technical ecosystem for these kinds of communication

devices has changed radically, with the advent of smart phones and social media in the 2000s. Possibilities for casual online communication have exploded enormously, rendering the value of stand-alone, peripheral and expressive awareness devices questionable to many. For instance, when one of the authors suggested that his daughter might want to use one of the Yo–Yo Machines to stay in touch with her best friend when they went to different universities, she replied "*Why would I want to? I have a thing called a 'phone'*".

Though choices for communications technologies have proliferated, Yo–Yo Machines and other peripheral and expressive communication devices occupy a unique niche amongst them. As stand-alone devices that share ambiguous and impressionistic signals, they offer an always-on, undemanding presence, in contrast to the relatively focused, intermittent contacts afforded by screen-based applications jostling for attention amongst a myriad of others. While Yo–Yo Machines might not be for everyone, then, for some they provide a valuable sense of social connection despite physical distance (including, sometimes, within a single household). Moreover, the portfolio of four Yo–Yo Machines illustrates different styles of dedicated support for peripheral and expressive awareness, from the immediacy of the Knock Knock to the slow pace of Light Touch, the ephemerality of Flutter By and the playful ambiguity of Speed Dial, and their variations suggest how they can be given different expressive tones. We believe all are successful in their way and for their settings, and that, given our experiences, there is still a large, untapped potential for peripheral and expressive awareness devices in the future.

4.2 Self-build devices

In addition to investigating the potential for peripheral and expressive computing to benefit people during the pandemic, the Yo-Yo Machine project contributes to a research programme investigating self-building as a means for circulating research products [5][18]. The primary contribution of this research is a novel case study demonstrating the components of the self-build approach in a novel domain, including an ambitious IoT design that was nonetheless approachable by nonspecialist makers, networking software crafted to be easy to install and configure, a website that supported novices to undertake relatively complex technical assemblages, and an approach to publicity that emphasised social media. Taken together with previous examples of self-build projects, the success of this project suggests that the self-build methodology is potentially applicable to the circulation of computational products to very diverse populations and across a wide range of HCI domains.

In the rest of this section, we discuss several more nuanced lessons from this project. First, publicity is integral to the success of self-build projects if this is measured by the number of makers they attract. Engagement depends on other factors as well, however. For instance, the hands-on access to technologies required for some products may be in tension with ease of making. Moreover, networked devices such as the Yo–Yo Machines introduce new barriers to making and maintenance. Finally, there is often a trade-off between promoting circulation of self-build products and access to their makers for study, and this implies a tension at the core of the self-build approach. Below we discuss each of these points in turn.

Attracting potential makers is an implicit aim for any self-build project, and thus a *publicity strategy is integral to the design efforts of self-build projects*. In general, it seems clear that many people need to encounter a project for each one that will go on to make a device, though the proportions can vary. For instance, the My Naturewatch Camera [18] was developed in collaboration with a national broadcaster and featured on a primetime television programme seen by over 2,000,000 viewers; this led to 80,000 visitors to the project website, of whom about 1 in 25 made a camera [18]. The Yo-Yo Machines project, in contrast, did not have a development partner to help promote the project, so we have pursued a strategy of rolling promotion on social media and in print and online publications, as well as making kits available on the popular online electronic hobby store Pimoroni (shop.pimoroni.com). This has succeeded in attracting about 5000 visitors to the project website, with about 1 in 10 or fewer making a device. This suggests that successful publicity depends not just on the number of encounters but also on how well they are targeted.

Take-up of self-build projects also depends on factors other than publicity, however. For instance, the Yo–Yo Machine's *hands-on approach to making may dissuade some potential makers*. Building the devices required using breadboards, hook-up wires and bare components such as resistors, capacitors and transducers. This method brings clear benefits through lower cost and reusability of parts, while also allowing for users to switch between Yo-Yo Machine type

with little extra investment. Working directly with passive components also provides an opportunity for learning about electronics, as evidenced by feedback from users who built devices with children. There are some drawbacks, however. First, a breadboard is more ideally suited to prototyping rather than permanent installations so reliability issues can occur. These are often due to a loose hook-up wire (as described in section 3.1.3) which can occur when devices are dropped or mailed from one location to another. Second, the fiddliness of working with bare components might dissuade potential users from trying to make the devices. We only have sparse anecdotal evidence for this so far, but it seems nonetheless that self-build designers will need to be mindful of the tension between hands-on access to technologies and ease of making in developing future designs.

Moreover, the particular character of the Yo–Yo Machines as *linked devices may also have dissuaded some makers*. At the heart of the Yo-Yo Machines project is the notion of two connected peripheral awareness devices in different locations. While the romance in this idea is clearly a recurring theme in HCI it does produce some practical constraints with respect to the self-build methodology. For instance, while there are clearly many people interested in engaging with self-build devices, the requirements of the Yo–Yo Machines for two people, in separate locations, each to be willing to build a device and connect it to a partner, may well have limited the potential audience. Many users instead elected to build a pair of devices, connect them locally and send the already paired unit to a friend or loved one. We anticipated this possibility and optimised the build process accordingly, for instance by allowing remote WiFi credentials to be entered while setting up locally. Nonetheless, unexpected bugs could easily derail the system, from loose hook-up wires to WiFi range issues at the remote location. Repairing a device required the non-making user to engage in a debugging process that often involved dismantling electronics made by someone else, a daunting challenge that may well have deterred further engagement from some users (e.g. Mathilde's parents).

Finally, there seems to be an *inherent trade-off between ease of participation and access to makers for research*. Similarly to the My Naturewatch Camera project [18], we minimised technical barriers to making Yo-Yo Machines, did not require people to register to download software, and chose not to monitor activity between any of the online devices. Since anybody making the devices can remain anonymous, we have little or no access to the majority of people who built them. Realising this was likely to be an issue, we ran several Instagram & Twitter competitions to give away Yo-Yo Machine kits to people willing to share stories of building and using devices. However, despite giving away scores of kits, only a small percentage honoured the competition brief by sending accounts of their experiences (see 3.1). The result is that the self-build methodology continues to pose a dilemma: lowering technical barriers to attract many users to build and use devices restricts access to those users for the research team. In future studies, we could avoid this by requiring people to register their details before gaining access to plans for building or by logging network activity, but we remain wary of creating new access barriers or creating privacy issues that would be transformative of our open relationship with the makers. We will continue to explore solutions to this dilemma, but for now plan to continue using a sample-based research to gather material for research insights.

The trade-off between accessibility and access is not just a pragmatic issue, but also reveals a tension at the core of the self-build programme. Arguments for releasing self-build projects typically stress both the potential for large-scale field trials, and the inherent appeal of distributing research products more widely than usual. While these two endeavours might seem to go together – it makes sense that larger circulations should permit larger field trials – our experience is that they will often work at cross purposes, at least until a way of gaining access to makers without discouraging participation can be found. Thus, designers interested in pursuing self-build projects would be well advised to consider the degree to which they want to emphasise circulation versus research access in their projects.

Lessons such as the ones we have discussed here are useful for sensitising designers to considerations important for developing successful self-build projects. More generally, however, Yo–Yo Machines, along with the previous self-build projects we cite here ([5], [18], [34]) provide strong evidence to suggest there is a large audience willing to engage in building devices once the technical barriers to entry are broken down.

4.3 Conclusion

Yo–Yo Machines make low-cost, fully functioning peripheral and awareness communication devices far more accessible than they have been previously. From our perspective, it is quite remarkable that they are so cheap, and yet so functional

and accessible in comparison to similar commercial products (eg. the Good Night Lamp [10]). By taking a self-build approach, the project has succeeded in disseminating hundreds of the devices with relatively little cost to the research team, and at low cost to the people who made and used them. This is one of the disruptive strengths of a self-build strategy as the user can have a sophisticated electrical product at effectively wholesale prices. Moreover, enabling people to construct the electronics and make the housings themselves opened opportunities for them to appropriate the designs in a number of ways, further elaborating the space of possibilities for these devices. In sum, the breadth of circulation afforded by this approach shows the potential of well-designed self-build products to bring low-cost, appropriable IoT research products to far wider audiences than usual.

As research methodology, the difficulty of collecting data about peoples' experiences is a continuing issue for the self-build methodology. We believe this is mitigated, however, by the insights available both from a small sample of users and our own experiences. Moreover, as a collection of ten variations of four basic designs, Yo–Yo Machines has allowed comparisons amongst a range of approaches for supporting peripheral and expressive awareness within a single study. Based on the experiences of makers, including ourselves, we have identified four dimensions – modality, persistence, intentionality and semantics – as particularly salient to the differences among them, although there are many other distinctions and comparisons that could be made. In addition, we have pointed out the importance of details in their deployment for people's engagement with them. Perhaps most importantly, the fact that peripheral and expressive awareness devices like Yo–Yo Machines presuppose (at least) two people who are equally willing to use (and possibly make and maintain) them relatively frequently may limit their appeal, especially in a technical landscape that offers many alternative possibilities for remote communication. Nonetheless, it seems clear from our evidence that some people have found the Yo–Yo Machines to be of real value in creating a palpable feeling of connection to friends and loved ones when circumstances keep them separated.

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