Rudiments 1, 2 & 3: Design Speculations on Autonomy

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ABSTRACT
This work describes the design process and installation of three speculative, rudimentary machines, or *rudiments*. Through careful iterations in their design, the rudiments are intended to provoke curiosity and discussion around the possibility of autonomy in interactive systems. The design of the rudiments is described in detail, alongside the design decisions that were made to suggest a machine autonomy and to provoke discussion. Some preliminary reflections from installing the rudiments in two separate households are also reported. Widely divergent opinions of the rudiments from the two households are used to discuss a number of themes for thinking about autonomy and interactive systems design. Overall, the presented work adopts a perspective strongly oriented towards guiding future research, but, importantly, aims to do so by opening up and exposing the design possibilities rather than constraining them.

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Autonomy, social robots, speculative design.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design.

INTRODUCTION
In this paper, we describe our recent efforts to explore the role machine autonomy has in interactive systems design. The work we present builds on a small but growing body of research that has been investigating how innovations in areas like robotics and artificial intelligence might introduce new possibilities for designing interactive systems.

A central theme to our work has been to consider what the implications would be for interactive systems if we remained open to the way autonomy is exhibited. That is, our interests have not been limited to the kinds of autonomy we are familiar with—for example, the autonomy we would normally associate with human or animal behaviour. Instead, we've sought to investigate the possibilities for designing interactions with technologies that are autonomous in curious and perhaps very different ways.

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Naturally, an interest in autonomy and especially autonomous machines leads to a host of challenging philosophical and empirical problems. Can machines truly be autonomous? How, exactly, would a machine exhibit autonomy? What would the broader social consequences of a machine autonomy be? And so on. Rather than attempt to answer these arguably insoluble questions, however, our work pursues what might be thought of as a pragmatic, design-oriented approach. In practice, this has involved us designing three working concepts, or 'rudiments', intended to invite speculation and provoke discussion around the possibility of autonomy in machines. To obtain some initial insights, it has also involved us installing the rudiments in two households and interviewing the households' members.

Related Work
Research into social robotics and artificial agents has until relatively recently been a niche in computing. Various well-publicised projects from MIT's Media Lab have, for example, been hugely influential [3, 6], but they have also remained largely the preserve of blue-sky, laboratory research and rarely produced machines robust enough to be studied in unsupervised, social environments [14].

In recent years, however, there has been an increasing interest in building robots and agents, and, to a lesser extent, investigating their interactive characteristics in real-world settings. An indication of this is the growth of dedicated conferences such as Human-Robot Interaction (HRI) and Ro-Man, as well as a receptiveness to robotics in HCI. A cursory scan of the published work in these forums reveals much of it has focused on building systems that behave, in some fashion, like humans. For example, many systems address utilitarian concerns, enabling robots to accomplish tasks usually designated to humans. Zhao et al. [25] have designed a system using visual tags, or "Magic Cards", that designates housework tasks to robots. Other work has aimed to build robots that can interact in human-like ways, no matter how primitively. Again, the Media Lab has played a significant role in this with their 'social robotics' research [3, 4], as well work on conversational agents [16]. Elsewhere research has investigated human forms of communication with robots and agents, examining the impact of facial appearance [20], eye contact [13], emotional expression [11], etc.

It is along these lines that a small body of research has begun to part company, and where the presented work also provides a point of departure. A number of researchers have distinguished their work by adopting more exploratory approaches to studying autonomy and, in some cases, designing systems that challenge the prevailing interest in systems

that recognise and simulate human behaviour [8, 9, 15, 19, 21]. Of these works, three related areas have been of particular relevance in shaping the work we present.

One important influence has been the rethinking of some of the fundamentals in artificial intelligence (AI). A stable of researchers associated with AI have, since the 1990s, challenged the notion that AI systems must have complete representations or models of the worlds they operate in (e.g. [1, 5, 12]). Broadly, they have questioned and in some cases entirely eschewed the need for fully-fledged, *a priori* models, suggesting, instead, that artificial agents might model their environments bottom-up—that is, they might initially have a limited set of representations that 'evolve', dynamically, as the agent operates in its environment.

These developments—although seen as somewhat inconsequential in mainstream AI today—have prompted some broad proposals in interactive systems design. Leahu et al. [14] have suggested, for example, that ubiquitous computing might learn something from AI's efforts to build dynamic systems, robust enough to operate in real-world environments. To grossly oversimplify their arguments (but hopefully capture their overall gist), they suggest that ubicomp might find solutions to building robust, scalable sensing and awareness systems by looking to AI and it efforts to work with partial or incomplete representations of the world. Leahu et al. claim it is when users engage with these partial, relatively simple systems that subtleties and sophistication of interaction can emerge. Taylor [23] has built on this position, specifically focusing on intelligence as an emergent phenomenon. He makes a case that the design of interactive systems might be broadened if HCI opened itself up to systems that exhibited partial and unfamiliar forms of intelligence that were open to interpretation.

A second influence for us and one that puts some of these broader ideas into practice revolves around two concepts, 'Expressive AI' and 'Alien Presence' [17, 21]. Mateas, Pousman and Romero have used these ideas to conceive of systems that expose their computational workings in strange and unfamiliar ways. In their words, they aspire to designing 'enchanting' systems that prompt curiosity and wonder. Their approach to using AI raises a particularly compelling proposition; instead of trying to achieve the illusive 'AI-complete' system that can accurately model all human behaviours and respond to them in humanly intelligible ways, they intentionally exploit the partial models that AI systems are able to construct. Their aim, they explain, is to create a "sense of the system as an independent, non-human subject, who has its own interpretation of the activity" (p 374, [21]). Hence their use of the word 'alien'.

Last but by no means least, a number of projects from Goldsmith University's Interaction Research Studio and especially their collaboration with members of Cornell University's Information Science Dept. [9] have played a significant role in our thinking. The Goldsmith's-Cornell project involved the use of sensors placed in a house to generate 'home health horoscopes': short printouts, worded like horoscopes, conveying "interpretations of domestic well being based on sensor data and simple pattern-recognition" (p 538, [9]). The research was especially concerned with the 'approximate' results achieved using sensing and inference systems. Yet, as with the alien presence work, the aim was to exploit the ambiguity resulting from the supposed limitations of the system and encourage interpretation on the part of users. This was born out in the deployment of the Home Health Horoscope; the household the system was customised for and deployed in speculated on its workings throughout the trial. Of particular relevance to the work that follows were the different ways the household members made sense of and judged how meaningful the system was for them. The research highlights the struggle and frustration that can arise from trying to make sense of a system that is ambiguous in its function. As we will see, this introduces a salient theme in our interviews.

Together, these three roughly circumscribed areas of research have helped to orient our investigations into autonomy. Crucially, however, our intention has not been to use them to narrow down the broad issues associated with machine autonomy. Instead, we have used this work alongside our designs to open up new possibilities. In this vein, we have also intentionally avoided defining autonomy in any strict sense. Our interests lay in how it is people get to grips with notions of autonomy in their own terms. What we wanted to avoid was any theorising on our part as to what constitutes autonomy, *per se*. Our sense was this would run counter to the efforts to provoke open discussion.

RUDIMENTARY DESIGN

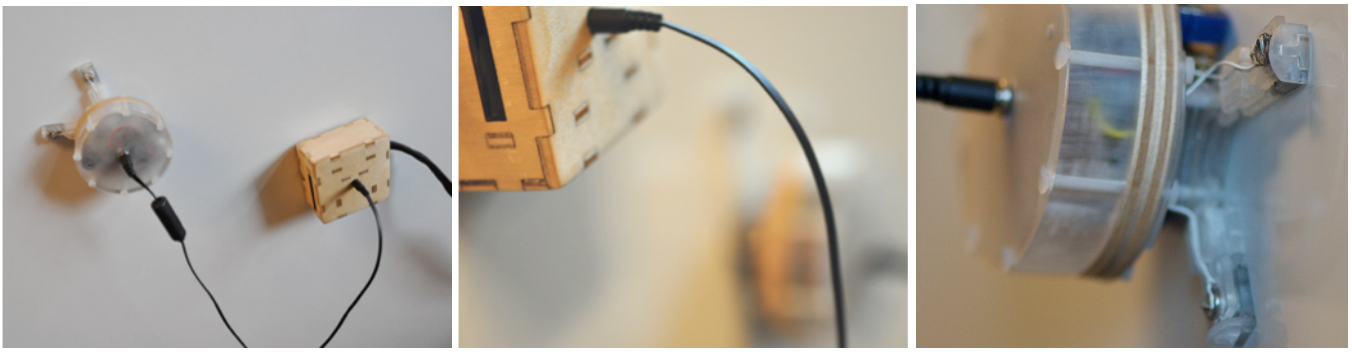
Our use of design to provoke discussion draws heavily on a speculative design approach usually associated with the Design Interactions Dept. at the Royal College of Art [7] and popularised in HCI by the Goldsmith's Interaction Research Studio [10], amongst others [2, 15, 24]. Informed by these past examples, we chose to design three relatively simple working concepts, named rudiments 1, 2 & 3—the naming intended to reflect their novel but crude and basic behaviours.

We aimed to invite a level of curiosity in building the rudiments by experimenting with a combination of different materials, aesthetics and interactions. Also, we purposefully pursued an open-ended system design, using an ambiguity in the concepts to promote curiosity and discussion [7, 10, 22]. For instance, we chose to design behaviours into the rudiments that were of no obvious benefit, but could potentially be seen as responsive to and thus reflective of people's presence and activities.

To further encourage speculation around autonomy, different levels of sophistication were designed into each of the three rudiments. As a general rule, their behaviours and computational workings were designed to increase in sophistication from Rudiment 1 to 3. Thus, in their design, we tried to accentuate the differences in sophistication between the rudiments while expressing a common aesthetic so that they would be seen as a 'family'.

Rudiment #1: 'Wandering around'

Rudiment 1, the least sophisticated of the three machines, is made up of two modules connected via a flexible cable.



1a. **1b.** **1c.**

Figure 1. Rudiment 1 on vertical surface, with acrylic moving module connected to a wooden switchbox.

One of the modules quite literally wanders around a magnetic surface, e.g., a fridge door. Its round-shaped wood and acrylic case encapsulates its magnetic wheels and also a narrow-range IR sensor to detect nearby movement. Its speed and direction are randomly changed when the IR sensor is triggered. The second module, a switchbox (Fig. 1b), is magnetically affixed to the same surface as the moving module. It simultaneously provides power and sends signals to the moving module whenever its own wide-range IR sensor detects peripheral movement. On receiving a signal, the moving module is activated and moves for a random amount of time (limited by a set min and max). To prevent it from falling off a surface, two sensors protrude from the front of the moving module (Fig. 1c). Each sensor contains two switches, one to detect an obstacle and the other to detect when an edge is reached. If these sensors are triggered, the module backs up and changes its direction. Both modules contain Arduino micro-controller boards to control the sensors, actuation and communication.

Rudiment #2: 'Listening to the home soundscape'

Rudiment 2 consists of a plywood servomotor and base (Fig. 2a), and two acrylic microphone cases (Fig. 2c)—all three wirelessly connected using the Zigbee standard. The servomotor, with an articulated arm and pencil attached, is slotted into the middle of the wooden base (Fig. 2b). As well as its mechanical parts, the bespoke servomotor houses a customised Arduino micro-controller and an FIO board (see: funnel.cc/Hardware/FIO) with XBee module (the latter for wireless comms).

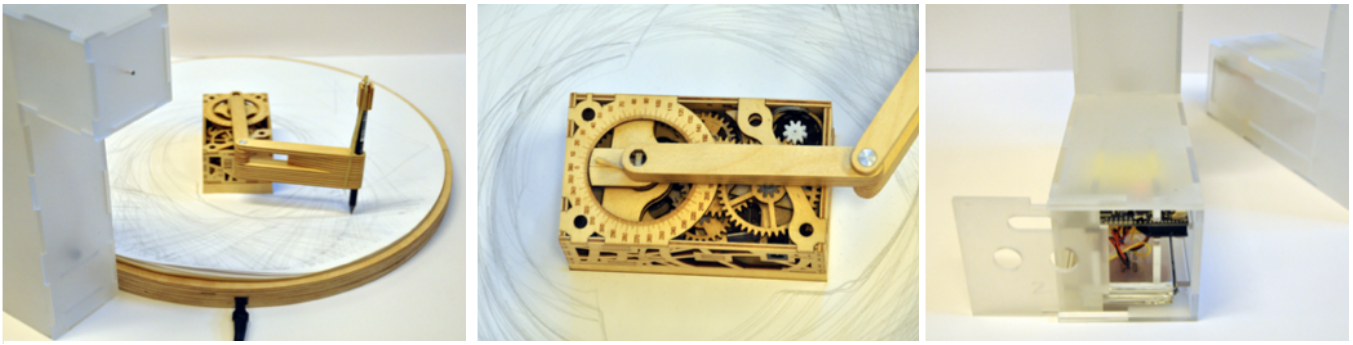
The two encased microphones function as a trigger for the servomotor and the arm/pencil attachment. The rotation and direction of the motor's arm are dictated by the level of sound input and which of the two microphones detects a louder sound. Also, the system's sensitivity is varied using a simple caching mechanism: sustained or particularly loud noises make it increasingly sensitive and consequently the motor arm's frequency and degree of rotation are increased. The intended effect is a machine that appears to draw in response to sounds but, to some degree, controls its own movements. The rudiment's output is drawn on removable paper sheets that in effect visually record a soundscape. Because they communicate with the motor wirelessly, the microphone modules can also be used to explore or further accentuate certain sounds. For example, placing the microphones relatively close to the base allows for experimentation with feedback of its own 'sketching sound'.

Rudiment #3: 'Dangling from a string'

Rudiment 3 consists of an acrylic cog system and casement suspended on a horizontally extended, toothed belt of adjustable length (Fig. 3c). Using suction cups, the flexible belt can be mounted on any smooth, vertical surface, e.g., a window. Under the cog system, the oval-shaped casement contains a video camera. Actuated by a DC motor, the cog system moves the casement left and right along the belt's entire length. The camera can also be rotated left or right by up to 70 degrees. These movements effectively change the viewing direction of the camera. In addition, the opaque casement can display eight different colours using three integrated LEDs (red, green, and blue).

The rudiment's movement and colour are controlled by an Arduino micro-controller, which in turn communicates with a small PC encased in a wooden box (Fig. 3c). The PC receives the video signal from the camera and triggers the rudiment's behaviour through a set of simple yet nondeterministic computer vision processes. The program, written in C++, searches for human faces in the video frame using an object detection algorithm based on the Haar classifier cascade [18]. Each time a face is detected, the rudiment will adjust itself by either moving along the belt or turning the camera (randomly choosing between the two actions), so that the face remains centred. As this happens continuously, the camera appears to follow any movement of a detected face. When more than two faces are detected, the rudiment randomly chooses one face to follow. In addition to faces, the rudiment also responds to gross motion in the camera view, momentarily turning towards it. Finally, it occasionally makes random movements, adding a degree of ambiguity to its behaviour.

The rudiment also turns one of its eight possible colours when a face is detected. The colour is chosen by comparing the detected face with eight face categories, each consisting of three sample faces. The category that contains the most similar face is chosen and the associated colour displayed. The face comparison is based on a straightforward pixel-level comparison, without leveraging any predefined knowledge of facial features. This results in a somewhat "machine-defined" similarity measure, which may or may not appear recognisable to users. With a small probability (0.05), the newly detected face may replace an old face



2a. 2b. 2c.

Figure 2. Rudiment 2 with wooden servomotor and drawing arm, and two acrylic microphone modules.

sample in the category. As such, the face categories gradually evolve as the rudiment is exposed to more faces. This simple machine learning technique allows the rudiment to adapt to the people who interact with it and present the same colour each time it recognises similar facial features.

INSTALLATIONS

As we've noted, the three rudiments were installed in two households (both in the South East region of the UK). Seb and Mari, a couple living in the first household, had the machines for four weeks. The second household, made up of Adrian and Anna, again a couple, had them for just under four weeks. From the outset, we made it clear in both households that the rudiments were designed to prompt speculation and that as researchers we were interested in the thoughts and discussions they provoked as opposed to any opinions of them as final products.

Both couples were able to choose where to install the rudiments, although, as we intended, their placement was restricted by their design. They were also asked to have the machines running as often as they wanted, but told to turn them off when they were away from home (to avoid any chance of the machines being damaged or damaging the properties). We received impromptu feedback during the installations, on the occasions we made short visits to tweak the machines, and via emails and phone conversations. Also, the couples were interviewed about their experiences with the rudiments when we removed them.

Seb and Mari had all three machines in their living room, an open plan, but crowded, home-work room populated with numerous musical instruments, computers and other electrical equipment, as well as the usual furniture. They reported having the machines turned on daily, and described extended periods in which they actively interacted with them, as well as letting them run in the background. Adrian and Anna initially had the machines in their kitchen/dining room, the space they spend most time in. Later, they moved Rudiment 2 to the sitting room, and experimented with different places for the microphones. Their reported use was less frequent than the first household, with the machines turned on for thirty minutes to an hour, for three or four days a week. However, from their interview, Adrian, in particular, seemed very familiar with each rudiment.

Perhaps the most striking result from the interviews was the contrasting views from the two households. In their interview, Seb and Mari were very positive about the rudiments. They enthusiastically described their interactions with them and openly discussed ideas around autonomy with little to no prompting from the interviewer. They appeared very willing to see the machines in poetic terms (for lack of a better phrase), treating them as curiosities with varying degrees of independence. Conversely, Adrian and Anna, although open to discussion, expressed a palpable dislike of the rudiments. In their interview, they alluded to them more than once as the cause of irritation because of their seemingly "pointless" actions. For the purposes of this initial investigation, we found this contrasting set of opinions to be especially valuable. It provided us with what felt like a dialogue between the two households, drawing attention to several provocative themes. In the remains of this section, we've chosen to present the materials relating to three of these themes because, although still preliminary, they have pointed us towards what seem to be some useful ways to begin thinking about autonomy and design.

It should be emphasised that this component of our work was not intended as a full deployment. That is, the installations were not treated as evaluations in any conventional sense, using formal methods for data collection and analysis. Rather, our hope was they'd offer an early resource to orient our future design work. The deliberations in the interviews were seen as a means to develop our own thinking about the relationship between autonomy and interaction design. This explorative, open-ended quality to our investigations will be evident below in our concern for not only the content, but also the form and structure of the interview discussions; we discovered there were insights to be found not only in what people thought about the rudiments but also how they discussed them (hence our use of relatively long excerpts from the transcripts). The preliminary nature of our results will also be clear from the topics we have omitted, not least, the commonly considered themes of anthropomorphism and zoomorphism—the popularity of these topics being one reason why we have, at this stage, chosen to focus elsewhere.

Function and Engagement

The most prominent discussion point for both households was around the utility or function of the rudiments. As we've discussed, we gave a good deal of thought to the form and aesthetic of each rudiment. By accentuating the cabling, electronics and mechanical movements, they were purposefully designed to echo machine-like qualities. At the same time, we contrasted this mechanical aesthetic with

3a. 3b. 3c.

Figure 3. Rudiment 3 attached to a window using suction cups, and wooden box containing micro-controller and computer.

varying degrees of independent behaviour, intentionally setting up the mechanistic against allusions to autonomy.

This juxtaposition was a source of discussion for Seb and Mari. In one interview excerpt, Seb expresses his thoughts about utility by comparing the machines with a dog:

> **Seb**: I like the idea of not being a dog, but something new. Because these shapes are kind of new shapes.
> **Mari**: You get bored, no? [Laughs] You want something new!
> **Seb**: No, no, no. You already have a dog. Why would you do a dog as a robot? […] Cause I mean I like the functional side, cause that guy draws, right? [points to #2] So the whole thing is revolving. […] Their shape comes from a functional style. So the dog, it looks like a dog, cause at some point it has grown bigger teeth and a tail or, you know, and so on. So nature has this kind of reasoning. […] Cause I mean I think you get into this discussion about improving or replacing, and these are not about improving or replacing. They're about something new.
> **Mari**: You're right, yeah, about replacing...
> **Seb**: Cause I think that's one of the bad kind of views on machineries or robots, because of this fear that they might replace us, but it's not about that.

Seb's meandering thoughts are indicative of the couple's struggle to make sense of the shapes and behaviours of the rudiments. At no point are they able to draw any strong conclusions, but clearly the rudiments prompt a dialogue about issues of form, movement and function. Seb contrasts the evolving appearance of the dog, with that of the machines. He implies that, unconstrained by any need for improvement or even replacement, the machines offer the opportunity for "something new".

Pursuing this idea of newness, Mari and Seb appear to construct a particular relationship between aesthetic and function. They make reference to the functional-looking aesthetic and movement of machines but, simultaneously, discuss how they have no prescribed function or at least none that is familiar:

> **Interviewer**: What is it about them that allows you to treat…
> **Seb**: I think it is the actions. That they do stuff.
> **Mari**: Yeah, the movements, the designer one [points to #2 and starts to mimic its rotation] because he's doing so much movement and all the articulation. Actually he behaves like… he is drawing!
> **Interviewer**: But how is that different to other things you have?
> **Seb**: I think the biggest difference is, err, the fact that they don't do something for a reason, for our own good… [points to them] for themselves. They don't kind of… they're not useful. […] It's not good or bad. It's how they are.

So in characterising the movements of Rudiment 2, Mari and Seb articulate a different kind of machine-like functionality, one that might not be "for our own good" or "about improving or replacing" what we do. Nevertheless, it is the responsive movements that appeal—the 'behaviours', the 'drawing!'

Less enamoured with the rudiments, Adrian and Anna find themselves frustrated by their unclear function. They want the machines to be more directly engaging and interactive:

> **Adrian**: If something is going to be completely functionless it has to engage you at another level.
> **Anna**: Yes, it's that interaction isn't it? It's just something that connects you with the thing.
> **Adrian**: Whereas something that appears to have some irritations but is entirely pointless, it's just irritating […] No, I mean coming to this one which we haven't really talked about [points to #3], that's getting to the point where it's starting to be a bit more interesting because, whether it's real or imagined, when it looked at me it went blue. Now whether it really recognises me or not I don't know. But it tended towards blueness with me… Which is kind of cute! You know it sees me and goes blue. It's like 'ah, hello." So there's a certain amount of something to do with recognition and, you know, it's getting towards interactivity.

Here, Adrian contrasts the "pointless" behaviours of the other two machines with Rudiment 3's intelligible interactions. The couple explain that their interest or engagement is a result of direct interaction. However, perhaps inadvertently, Adrian expresses a subtlety in this:

> **Adrian**: … whereas something which appears to have some irritations but is entirely pointless is just irritating [cat makes noise behind him] just like our cat [laughing].

With the help of a pet (again), Adrian mocks the value of having a cat—irritating because it is pointless. Clearly, however, he and Anna are fond of their cat.

Of course, it's of no coincidence that both couples make reference to pets in their interviews. The rudiments, even though intentionally designed not to resemble anything animal-like, provoke questions about machines that might be autonomous in pet-like ways. As with pets, we find debate around the value of machines that have no apparent function. Whatever one's personal inclination towards pets, these discussions point towards a possible way of thinking

about the rudiments and, more generally, autonomy. We see a tension being worked out by the interviewees as they speak about the rudiments in terms of how engaging they are, and their functionality and independence (or autonomy). Moreover, we find the relationship between these qualities is constructed in a fluid, evolving fashion as the particular characteristics of the rudiments are reconciled.

For the purposes of this paper, the point we wish to draw out, then, is how notions of autonomy turned on the ways function and engagement were seen, understood and articulated. It is not that there was one definitive definition of autonomy that the couples were able to judge the rudiments by. Instead, they used the qualities of function and engagement to make sense of the machines and, in part at least, how they were or were not autonomous.

Temporality and Persistence

In the excerpts above, Adrian also explains his preference for Rudiment 3 in terms of its ability to recognise him. "Whether it's real or imagined", the machine's choice of colours suggests a recognition of sorts. It's this apparent persistence of behaviour that appeals to Adrian. A visible response by Rudiment 3 persists over time so that he is able to at least imagine a kind of relationship with the machine.

Mari expresses a similar interest in Rudiment 3, although she does so rather more enthusiastically by playfully mimicking how her friends have responded to its colours:

> **Mari**: Everyone is enjoying the colours, [points to #3] because maybe it was the shape of this one, cause it looks a little bit… the curves, and it looks like, I don't know, a character. And people are coming and we're telling them, now this one is going to show you a colour, and it's moving. And they're like, "oooh, ooh, hello! Oohooh, I'm here, what colour I have? Hmm? Show me."

Later, she and Seb explain their experimentation with Rudiment 3's colours:

> **Mari**: It was interesting to plug [it] in and plug [it] out [gestures pulling the power plug in and out], and leave it in a little bit to see how it was working and then when it started to move, to plug it out to see when it's stopping, and then to plug it in again.
> **Seb**: Yeah, actually I did try that, I was kind of curious whether my colour would be changed.
> **Mari**: And?
> **Seb**: And, errr, it wasn't
> **Mari**: Oh, but your colour was all the time blue? Or no… It was blue and violet.
> **Seb**: No it is blue and before it was green.

Mari and Seb are responding to Rudiment 3's adaptive system for categorising facial features. They describe their attempts to test the system's persistence over time and, in their banter with one another, demonstrate their grasp of the system's capacity to adapt to the faces it has seen. It is, then, the seeming persistence of Rudiment 3's recognition, a 'memory' of sorts, that appears to be a source of interest and engagement in both households. However, Mari and Seb, appear equally interested in different forms of persistence in the rudiments. For example, Mari also describes their experimentation with Rudiment 2:

> One day we played with the sounds, different sounds and also with the voice, big sounds, small sounds, and we wanted to see how it's moving. And it was really fun to develop movement and how he responds to different sounds.

Again, Mari expresses a curiosity in the machine's behaviours, yet this time the engagement isn't so much associated with a persistence of some observable response. Her interest is in the general rules or patterns of behaviour, and how these might persist across different encounters.

It's these different forms of persistence exhibited by the rudiments and the different kinds of interactions the rudiments afforded during the installations that raise some further ways to reflect on autonomy. In general, it's evident there is a temporal quality to the interactions the couples had with the machines. As we've seen above, in both households there was an interest in how the machine's behaviours changed or persisted over time and, in some cases, the couples experimented with this. In short, the sorts of things that persisted had some bearing on the relationships the couples had with the machines.

Although perhaps obvious, this insight allows us to see how particular forms of persistence might have been instrumental. If we consider the comments above, the machines appear to differ in terms of the qualities that persist. We see that sometimes it is the persistence of individual behaviours that provoke curiosity and, at others, it is an apparent set of rules. So with Rudiment 3, it was a consistency in response to individual faces that triggered interest, whereas with Rudiment 2 it was how its movements in response to sound were governed by perceptible and persistent rules.

Rudiment 3, however, adds a further aspect. In this case, the rules are open to relatively long cycles of change as new facial features are detected. In effect, while the rules persist over time, they do eventually change as the rudiment is exposed to new facial features. This is in notable contrast with Rudiment 1; although it has a random element built into it, for the most part both its individual behaviours and rules persist. On detecting motion it moves, and on detecting edges or obstacles it turns.

For the purposes of this research, what we find particularly interesting is how Rudiment 3 engaged the couples more and appeared more compelling (particularly for Adrian and Anna, even in light of their skepticism). We would need to investigate this further, but there seemed to be some correspondence with how the rudiment's rules persisted but also how this persistence was dictated by the machine's response to its surroundings. What seems key is that the change in rules could be associated with a recognisable input (i.e., detection of facial features) and that the changes were understood as part of a continuing sequence of intrinsic modifications in the system. In short, the system appeared to have stable states, where interactivity was consistent, interspersed with intelligible changes in rule-state and then behaviour.

Accountabilities

We've seen, so far, that the installations led to direct engagements with the rudiments and, in some instances, sus-

tained interactions. Reflecting on the interviews further, we have also begun to wonder about other possible dimensions of interactivity. As well as prompts for interactivity at the human-machine level, we've started to think of the rudiments as triggers for particular patterns of talk between the couples and, at an even more abstract level, as active constituents of an overall character to the households.

A pattern to the discussions between the couples was especially pronounced with Rudiment 3, where exchanges revolved around recognition and the persistence of colours:

Anna: It didn't like me…
Adrian: No, it didn't really like you did it, for some reason… It wouldn't really kind of lock onto you in the way it did with me for some reason.
Anna: I think it's hair… [said with mocking sad face]
Adrian: Hair, because of the hair [also said with sad face]. [Pause] It seemed to prefer me with specs on… [Turn to interviewer]. Yeah, so it would be kind of random red and purples and then [for me] it tends to flash blue or go hard blue. It could be that I was imagining it.
Anna: No, it was going blue.
Adrian: Certainly more often than not.

Between Seb and Mari, these two-way exchanges developed into broader discussions. Below, for instance, Seb tries to develop his earlier thinking about usefulness:

Mari: You think of a person as useful?
Seb: I mean as a first thing? When you meet someone, you don't think "oh, this person might be useful". But when you look at an object that's what you do.
Mari: Ah right, differences between person and…
Seb: I mean that would be the difference between, I don't know, the camera that makes photos and the keyboard that…
Mari: But this one [#3] shows you colours and is moving.
Seb: Yeah, but it shows me *its* colours […] I mean I'm not controlling him, that's what I'm saying.
Mari: Umm, you can control…
Seb: … It's more like a discussion, not a control.

Of course, these exchanges and others like them took place during our interviews, so will have not surprisingly focused on the rudiments. However, what we believe we see is an inkling of the sort of talk that occurs between people who are trying to make sense of their relationships with an entity. In this case, the sophistication of the rudiments (or lack thereof) is of less importance. What we think we catch sight of is a way that something exhibiting a degree of autonomy, no matter how slight, might engage its audience beyond its immediate interactions. Not unlike a pet, one source of interest or even pleasure appears to be the mere speculation of what it might be doing or even 'thinking'.

Its continuing along these lines, that we see how the rudiments can be embedded in the ideas the couples had of their homes and how they are made sense of in ways that echo or characterise their households. For instance, the more utilitarian perspective voiced by Adrian and Anna appeared to reflect their overall relationship towards technology. We found Anna's thoughts particularly telling:

Anna: Maybe I don't have enough imagination. I can see… I can easily compromise with the noise [of #2] if I get benefit from it. So if it's something that entertains me or does something useful then, yeah, fine. But I just didn't find it very interac… I wasn't getting anything from it […]. Noise was definitely the problem.
Adrian: I seem to remember you saying "I'm going shopping now. Please make sure you turn that off by the time I come home." [Both laugh].
Interviewer: So in the beginning, the fact that you didn't switch them on, was because you thought they were fragile, or…
Anna: It was mostly Adrian who switched them on, and as I said, I didn't… I knew they were there, but I didn't, you know, I didn't miss them.

A feel for the home is thus captured in Adrian and Anna's discussions of the rudiments; a place is articulated in which intrusions, particularly of the pointless or noisy variety, are guarded against. By contrast, Seb and Mari seemed far more open to the rudiments' intrusions. Indeed, they expressed a willingness to be drawn into their behaviours:

Seb: Now of course they're three and you kind of… because they're in the same place we do feel in a unitary way about them. But it might help to put them all together so you can… So perhaps the drawing machine [point to #2] is at the end of the camera [points to #3] and the fridge stuff is also connected somehow it makes to the other people seeing them or interacting with them, it makes it more… it's like a narrative in the end cause you keep discovering things.

Thus we find the rudiments expose the appreciation for silence and control in one home, while in the other an openness to very present, almost visceral intrusions.

Although oversimplifying matters, what we feel these insights achieve are a sensitivity to autonomous machines and how they will likely have particular roles in shaping people's accountabilities. That is, people are likely to find themselves accountable in ways that go beyond the immediate interactions they have with the machines, and that reflect the machines' broader roles as autonomous 'social agents'. So for Anna, we see her having to account for her appearance and, indeed, powers of imagination as a result of her overall reaction to the rudiments. Likewise, the rudiments persuade Seb to rethink his relationship to objects.

Of course, many things in our homes take on this role—our choices of furnishings and general tastes say much about who we are (or wish to be). The interesting possibility with autonomous agents, however, is that as Seb struggles to articulate, they provide the possibility for playing a more active and dialectic role in that process. In some sense, one may become accountable to the objects as well as other people one lives with.

DISCUSSION AND CONCLUSIONS

In this paper, we've tried to give particular emphasis to the use of design as a speculative resource. Our hope has been to demonstrate a concern for the material and interactive qualities of machines and how such a concern can be used to open up new possibilities for further design-oriented, research investigations. In short, the decisions we made around form, interaction and the different levels of computation in the three presented rudiments were elaborated on to illustrate how design, in practice, can be used to provoke speculation. In this sense, we hope the work to have made a

methodological contribution to the small but impactful speculative design movement in interactive systems design.

Beyond this, our design thinking and the interpretations of the early installations have been directed towards opening up compelling ways of imagining autonomy in interactive systems. Hopefully we've illustrated our experimentation with design as a means to explore alternative ideas of autonomy. Also, we hope to have shown that a lightweight approach to getting early feedback to speculative designs, and specifically to the three rudiments, provides some alternative ways for thinking about autonomy and design.

What we've aimed to capture in discussing the divergent opinions resulting from the installations are the fluid ways that people construct and articulate their interpretations of unfamiliar machines. We found, perhaps unsurprisingly, that opinions can vary widely around issues of utility, and the temporal character of what machines, as it were, 'remember'. However, also apparent were the internal tensions that can arise in people's own dialogue. We've seen how people can grapple with the role machines play by setting up various dichotomies associated with autonomy to make sense of the possibilities, and that these varied ideas of machine autonomy introduce some quite different ways of people accounting for themselves in their homes.

It's these dialogues and ideas, then, that we've found constructive and that we hope to use as guides in future designs. As opposed to narrowing down a design so that it conforms to familiar relationships between the different design elements, we hope they offer alternative trajectories along which an autonomous machine might be thought about. It's hoped such trajectories might provide us with a basis to ask, for instance, how we could re-design the rudiments to appeal to Adrian and Anna, but in ways that begin to suggest the uneasy or unfamiliar. Thus, our hope is they offer a starting point for us to go beyond the supposed prerequisite ideas of "improving or replacing" and of machines "for our own good", to a possibility of interactive machine's that might exhibit autonomy, but not as we know.

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