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Diri - the Actuated Helium Balloon: A Study of Autonomous Behaviour in Interfaces

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ABSTRACT
Research on actuated interfaces has shown that people respond in certain socialized ways to interfaces that exhibit autonomous behaviours. We wished to explore the elements of design that drive people to regard an autonomous, interactive system as a social agent. To explore perceptions of autonomous behaviour in interfaces we created Diri - an autonomous helium balloon, used to document activity in spaces. We implemented two different technological sophistications of Diri, to compare the outcomes of our design decisions. We present our design process, technical details and evaluation workshops, concluding with implications for designing for autonomous behaviour in interfaces.

INTRODUCTION
As the sophistication of ubiquitous computing technologies increases, with advances in processing power and decreases in size [11] users are being confronted with increasingly intelligent interfaces embedded in everyday devices. This raises an interesting challenge to consider how people might perceive and respond to technologies that demonstrate such advanced functionality. Intelligent technologies have been of interest to the Ubicomp/HCI communities for a significant length of time (as evidenced by the existence of entire conferences such as IUI [15]). Accordingly, researchers have coalesced around a set of common understandings as to what constitutes intelligence in technology. Computers or other devices can be considered as 'smart' when they are able to connect to each other and exchange information [9]. Intelligent technology also includes devices that are able to sense the environment, be context-aware, are able to be trained or learn, and be adaptive or even proactive [23].

Arguably, autonomy plays a significant role in this context; a system can only be truly intelligent if it fulfills the above-mentioned functions by itself and without major human guidance. In this paper we try to further unpack what autonomous behaviour in interfaces might actually mean for human-computer interaction and how it is experienced by people [25]. People's relationships to actuated objects have always been exceptional in comparison to inanimate objects, it has been demonstrated that we find autonomous machines 'fascinating' and 'engaging' [32]. We also feel quite comfortable in describing mechanical processes in terms of social behaviour and reasoning that such technology has an intention and motivations [3]. Research has even shown that humans will display complex social behaviour such as politeness and empathy towards technology [34].

There is much to explore about the design decisions that drive people to regard an autonomous, interactive system as a social agent and lead them to react in certain socialized ways. In particular, considering how autonomous behaviours in interactive technologies might promote certain kinds of social reactions in users. Understanding this would allow us to question whether autonomous behaviour in interfaces might be used as a resource for design to engage and promote specific user actions, perceptions and responses.

Within the remit of our enquiry we are particularly interested in Tangible Autonomous Interfaces (TAIs) [27], a class of interactive artefacts that sits somewhere between a Tangible User Interface (TUI) and a full robot (in essence they are 'smart' TUIs). These technologies are of relevance because of both their ready potential as interfaces and their potential for demonstrating autonomy. This work aims to examine 'interactive intelligence' [6] in new technologies using a practice-based approach, to explore how designed behaviours give rise to perceptions of autonomy. In doing this, we aim

Figure 1. Diri #1 and Diri #2 (from the term Dirigibles, i.e. airships) - the autonomous helium balloons.

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to discover interesting aspects of human-machine interaction and elaborate upon some directions that are relevant for autonomous interface design. We also identify the challenges that arise in this field of work and finally, we evaluate extant frameworks for designing TAIs [27].

To capture and comprehend perceptions of autonomy and embrace human social responses, we designed, developed and deployed actuated helium balloons with attached electronics that fly autonomously, supporting high-res cameras to take pictures or collect video footage (see Figure 1). The purpose of these devices is simply to document the space (which might serve a variety of potential user functions). We were speculating around how perceptions of a camera interface change as soon as it is actuated. In an age made remarkable by the rise of unmanned aerial vehicles for military use, could flying objects also be designed to become our companions?

As research through design [20], which builds on the premise of creating artifacts through a process of disciplined imagination, our aim was to create actuated, autonomous interfaces, which give users the impression that they have intentions and motivations and therefore become a social presence in the room. To be able to compare different design decisions we implemented two balloons, which differed in their designed behaviours. To evaluate people's perceptions of the balloons we ran five workshops, which consisted of a series of creativity tasks to be performed by participants, whilst two balloons flew around the room. After the tasks, participants were asked to complete some observations about the balloons' behaviour. Following the workshops, we conducted further one-on-one interviews with ten participants to gather more in-depth feedback and further explore their responses to the observation questions. Specifically our interest lies in how different design decisions influenced people's perceptions of the 'intelligence' of the balloons.

The existence of commercially available products demonstrates the interest in this class of flying technology and highlights the timely need to understand their user issues. Our study represents the first attempt to qualitatively understand user responses to such devices, and specifically autonomous implementations for workplaces. Whilst we don't assume to be definitive, we hope it will inspire other researchers to further map out the design challenges of creating tangible autonomous interfaces.

This paper delivers three contributions to the Ubicomp community. 1) We present the design and development of a low-tech, interactive flying interface for domestic or office use. 2) We present a first case study evaluating the design framework for Tangible Autonomous Interfaces presented in [27]. Finally, 3) through qualitative analysis of questionnaire responses and interviews we contribute a deeper understanding of people's responses towards autonomous interfaces.

RELATED WORK

The concept of autonomy has been evoked within a large variety of interactive objects. In this section we illustrate this diversity by providing examples and also discuss how helium balloons have previously been used as interfaces.

As access to cheap electronics, tools and knowledge is increasingly available and affordable, through maker spaces and websites containing DIY-instructions, people are exploring various new interfaces. Therefore many examples of autonomous interfaces come from the maker community, which consists of enthusiastic creatives, programmers and engineers. For example, Plotclock [31] is a small mechanical arm, which draws the current time on a white board every minute. Once a time is written, it grasps for a wiper and erases everything. Arguably, the strength of this whimsical device is its mechanical working; its embodiment is making it a physical agent and therefore more engaging to people than for example a digital animation [21]. Ollie is a blimp-based autonomous and ambient robot [28], which flies around and reacts to sound by flapping its wings. Random behaviours make its actions difficult to interpret, and hence Ollie has been described as 'awkward' but friendly and exciting.

Other devices include Little Robot Friends [24], which are tiny robots and contain several trivial sensors reacting to the environment by either sound or light output. They are also able to transmit and receive infrared signals that enable them to detect each other. Clocky [5] is an alarm clock with wheels, which rolls away and 'hides' whenever the snooze button is pressed. Roomba, the vacuum cleaning home robot, is particularly interesting as an example of the complex relationships people maintain with technology and how emotional attachments to devices can develop amongst owners over time [36].

All of these devices have in common that they present autonomous functioning machines, which serve as interfaces to digital content, but at the same time have the potential to establish their own social presence with a user. These examples are highly popular and show that autonomous interfaces are becoming more prevalent. Our aim herein, is to deepen understanding of the design factors influencing user perceptions of these interfaces.

Research has also previously explored movement in interfaces as a means to communicate states or evoke behavioural change [18, 16]. Even television [26] and automatic doors [17] are attributed life-like characteristics by using interactive motion. Helmes et al. [13] observed participants interpreting the functioning of autonomous machines as social behaviour. One of their three prototypes, a small camera in a plain acrylic case moving on a string by a window, follows a machine-learning algorithm to detect face shapes. Depending on one of six recognized shapes, the device lights an LED. Remarkable in their evaluation was the response of one of the participants: he perceived the persistence of the color as the device recognizing him when he came home, and greeting him. AniThings [39] is a design concept consisting of a bunch of small, plain devices, which have access to personal data from a user. Depending on the context, they replay music or suggest content for the user. The devices are proactive and aim to serve as small companions to spark creativity.

While research is aware of the attribution of intention in objects, there is still a lot to explore about how these interfaces could be designed to spark certain emotions, preferences or behaviours in users. Interesting in this area is understanding which factors lead to which perceptions in people and what is therefore important during design and development.

Helium balloons have been used for a wide variety of applications; in most instances for advertisement, but also in art and to support telepresence. Paulos et al. [30] created 'space browsers', blimps that can be controlled remotely via a Java applet in a browser. The blimps contain a video camera, a microphone and a speaker to allow wireless Internet-based communication, between the remote pilot and people close to the blimp. Equally, Floating Avatars [38] incorporated projection into a blimp-based telepresence system, and Yoshimoto et al. [41] used interactive blimps in performance art.

These projects, however, focus on the possibilities of remote control of the blimps in different applications, rather than their design and users' impressions of their behaviours.

DESIGN FOR AUTONOMY: DIRI

In very simple terms, a tangible autonomous interface might be described as a device that demonstrates independence to some degree. If the interaction purely consists of a device reacting to a user's input (a device fully dependent on the user - which would present a typical interface), the interface lacks intention, its own behaviour and therefore autonomy [39]. On the other hand, when the device is not reactive to the environment at all, fully independent of interaction, it is not 'in the world'; the mindless repetition of the task extracts all interaction possibilities [37]. Proactiveness has also been suggested as one property that supports autonomous behaviour [23]; if devices for example suggest content or direct interaction they shift from being purely reactive to devices which seemingly have interests and a motivation [39].

Another major factor of autonomous behaviour is predictability. Perceptions of autonomy arguably rise and fall with how well a user can predict a system's potential functioning. When people understand the inner workings of a system (the behaviour) and it is therefore fully predictable, there is no room for the user to wonder and make their own interpretations. In this case the behaviour is functioning and transparent, it follows a set procedure without an 'inner life'. Ambiguity in the system's behaviour can bring surprise through unexpected actions and therefore engage the user to make sense of the system for themselves [8]. In this situation behaviour is not comprehensible and repetitive and therefore invites the user to assign their own meaning to the actions that the interface presents. In return, ambiguity in the appearance might frustrate the user, it is not immediately clear how to use the device. Therefore it might be better to rely on functional design, which won't mislead the user [6].

Nowacka and Kirk [27] present a framework (illustrated in Figure 2), which outlines some key concepts further elucidating these various issues underpinning perceptions of autonomous behaviour. These set out to guide the design and development of autonomous behaviours in interactive systems. Ultimately, the aim is to understand how to design autonomous interfaces which invite social responses, but also may lead to behaviour change, frequent use and motivate people to form a relationship with the autonomous interface.

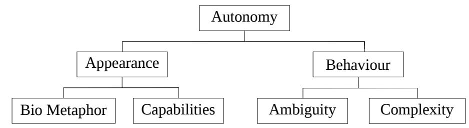

Figure 2. The framework for Tangible Autonomous Interfaces [27].

The framework consists of four dimensions, which help in the construction of perceptions of autonomy. We wish to revisit this framework in the following section and try to relate our design of flying actuated interfaces to the framework's dimensions. Four concepts are presented: *Bio-Metaphor*: a dimension which maps the outer appearance on a scale from anthropomorphic / natural to mechanical / technical; *Capabilities*: which refers to the number of actuated and sensing components prototypes contain; *Ambiguity*: which describes the transparency of the behaviour presented; and *Complexity*: referring to the sophistication of the device's behaviour.

Bio Metaphor

The appearance of an interface plays an important role for first impressions and also during interaction [36]. Although the behaviour can be as important as or even more important than the visual nature of an interface [1], zoomorphic or humanoid appearance can lead to false expectations and frustration [40]. Life-like interfaces can persuade people into thinking that they possess certain skills, like being able to speak or navigate autonomously, when in fact they are unable to do so. This leads to a decrease in believability and also to confusion and disappointment during interaction [17]. This danger is much less for objects of mechanical appearance. When something looks like a zeppelin, it is likely that it behaves like one. Therefore the aim for Diri was to create a minimalistic and mechanical-like appearance - one which is as functional as possible. To better distinguish the prototypes, they were given two colours: silver (Diri #1) and gold (Diri #2).

Capabilities

Equipping an interface with an increased number of input and output modalities extends the range of possible autonomous actions. Because we aimed to deploy Diri in indoor environments such as an office, we did not want to exceed a size of 150cm in diameter. Such constraints in size lead to a practical restriction in the weight that a helium balloon can carry. This further sets a limit on the number and kinds of components we could attach to the balloon. We aimed to create a flying balloon, which documents the space. This requires actuation of the balloon, some level of sensing and the capabilities to process those sensing signals to react to the environment. To remain stable in flight we need sensors that capture movement and rotation. We wanted the balloon to be able to displace itself to avoid obstacles; this requires proximity sensors around the balloon and multi-directional motors with propellers. Finally a controller is needed to enable autonomous behaviour.

Ambiguity

The right amount of ambiguity in the behaviour of an interface can change it from being predictable and functional to intentional and life-like. Ambiguity can be added to a device through various means. For example, by performing a random movement at times [13], through displaying visualisations and pictures [33] or changing the shape of the interface [12]. Random movements (to an extent) lead to surprise, the user wonders why this movement occurred and tries to figure out the intention. Our aim was furthermore that the balloons reach different areas in the room and would not just hover over the same location. Therefore the balloons execute random movements every 60-120 seconds. With the silver balloon we aimed to populate the rather extreme points in the spaces of the framework, we chose to make it fully ambiguous (which results in completely random behaviour). The golden balloon periodically moves in a straight line. The aim was to let it actively 'explore' the room instead of getting stuck in corners or just randomly drifting around.

Complexity

As already mentioned we aimed to compare devices of different sophistication and therefore the prototypes differed in complexity. Due to the additional capabilities Diri #2 was able to avoid obstacles, i.e. walls and maintain its height by tracking the distance to the ceiling. The sensors also supported stabilizing the movement of the balloon once it was instructed to move forwards. We implemented a face-recognition algorithm for the low-res video stream from Diri #2, which initiates the taking of a high-res picture. Diri #1 is much less sophisticated as it randomly moves forwards, turns left or right or flies upwards. Turning results in spinning around its own centre. It also takes a picture every minute on a fixed schedule. Both streams can be stored or displayed immediately on screens and uploaded to a server.

TECHNICAL DETAILS

The following section illustrates the construction and programming of our prototype. Step-by-step instructions on how to create a Diri and a discussion of challenges when working with helium balloons can be found on Instructables [14].

There are several reasons why flying interfaces might be useful. Due to their location and sphere of operation, they don't face the same problems as wheeled or walking actuated interfaces. They don't have to avoid furniture like tables and chairs and are less likely to obstruct people as they can fully embrace 3D space by operating at varying heights. Due to their potential vantage point, they also have a good overview of their location and are therefore quite suitable for documenting events and places. Quadcopters have become quite popular recently, and we have seen various examples of how they can be used in interactive ways [2, 22].

However, there are reasons why, in a domestic environment, they may not be the optimum solution for a flying interface. For example, most quadcopters consume significant energy and therefore have a short battery life, and when their battery life ends they fall out of the sky, which has obvious safety implications. Helium balloons, alternatively, don't consume any energy to keep themselves in the air. As a consequence the battery needed to steer the balloon lasts up to 2 hours, rather than just 10-15 minutes. Helium balloons are also quite safe, non-flammable and pose no danger of dropping on people if they run out of battery. Pragmatically, the worst-case scenario is if they escape, whereupon it can become problematic recapturing them if they move to certain heights.

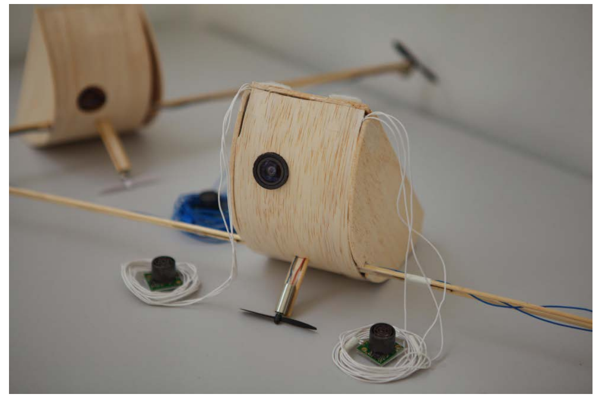

Figure 3. Casing for the electronics of Diri #2 (Diri#1 in the back), two ultrasonic sensors are placed on the front right and front left (white wires) and one on the top of the balloon (blue wires).

Hardware

Diri #1 has a diameter of 110cm x 50cm, whereas Diri #2 is larger with 142cm x 80cm, to carry more components. Diri #2 can carry about 300g. This is just about enough to carry an Arduino pro mini, a GoPro Hero3+ camera, three ultrasonic sensors, a gyroscope, an accelerometer, three motors with props and a battery. Diri #1 is not able to lift more than approximately 160g, sufficient for the core components (camera, motors, microcontroller and battery), but required us to remove the battery of the GoPro and power it from the external battery over the USB connector. The ultra-sonic sensors of Diri #2 are placed one on top of the balloon and two at the front pointing left and right. The gyroscope tracks orientation to supports the forward movement by counter steering with the motors, allowing a more stable path.

Software

The implementation of Diri #1 is simple. Every now and then, it randomly moves straight, turns left or right or moves upwards. Diri #2 interprets the readings from the ultrasonic sensor, and accordingly either moves up or down to keep its height constant (depending on the height of the room, we chose around 80cm from the ceiling), or turning away if an obstacle is detected. Once the obstacle is passed, the opposite motor counter steers to prohibit further spinning and keep the orientation stable. If both sensors detect an obstacle the balloon flies backwards. Finally, when there hasn't been any movement for a while, the balloon flies straight ahead for two seconds. Independent of these processes the camera of each balloon wirelessly streams snapshots to a computer. Diri #1 takes a picture each minute that is downloaded onto the computer. Diri #2 transmits a video stream, which is analysed on the computer using C++ and OpenCV, a Computer Vision Library [29]. If a face is detected, a picture in higher quality is taken and then uploaded.

EVALUATION METHOD

Our broad interest is in exploring how tangible autonomous interfaces might co-exist and operate autonomously in human living/working environments. Accordingly we set up two quasi-naturalistic studies, in which users were asked to perform brainstorming and sketching activities. During these activities they encountered Diri #1 and #2 for extended periods both directly and indirectly. Our first study probed user response during peripheral interaction (where the balloons operated autonomously to the users, as we felt this was a likely mode of future operation) and in our second trial, users directly interacted with the balloons to simulate more focused periods of interaction. We were curious if this direct interaction prompted a change in people's perceptions of the balloons. As we wished to develop an experiential understanding of users' perceptions and users' reactions to autonomous behaviour in interfaces, and were adopting a broad research through design approach [20], we chose a qualitative data evaluation strategy. In the following we explain our procedure and data collection methods.

Procedure

Both trials consisted of two parts, an ideation task and a questionnaire, during all of which the balloons flew around the room taking pictures. The task itself involved rounds of sketching and discussion, and represents relatively everyday design-focused activity in our lab, and was therefore an unremarkable activity for our participants. For this, we used 'Ideation Decks' [10], a creative method for exploring design problems using pre-designed cards to inspire design sketches.

Trial one consisted of three separate workshops, each with 4 people and lasting about an hour (n=12, 6F and 6M, aged 17-35). The presence of the balloons was explained to participants as being for the purposes of documenting the sessions. The differences between the balloons were not explained to the participants. Although the balloons were not an integral part of the workshop, participants were aware of, and had access to, the balloon-captured pictures via two large displays, which were positioned in the room (see Fig. 4).

Trial two consisted of two further workshops with 5 and 6 participants respectively (n=11, 3F and 8M, aged 21-37) with a focus on more direct interaction with the balloons. This trial used the same creative task, however in each workshop the participants were further split into two sub-groups, each group was given a laptop, which received streamed pictures from one assigned balloon (Diri #1 or #2, time or face-triggered photo capture) and they were instructed to create ideas together in sub-groups. Each group was required to capture/document their creative output (design sketches) using their assigned balloon, either Diri #1 or #2. To achieve this, the participants could move around the room to pose for the balloons or displace them physically by grabbing a balloon by the case or the balloon itself and move it at will. To be able to fulfill the task we explained to the participants that - for the golden balloon - a picture is triggered when a face is detected, the silver one took pictures randomly. However, we did not mention further differences such as the ultrasonic sensing. Participants were asked to document their work by creating four pictures: i) a group picture, ii) a picture of their set of ideation cards iii) a picture of their sketches and iv) a picture of them working in the group. After 30 minutes the groups swapped balloons and did another round of the task.

Participants had different backgrounds (arts and sciences) but were mostly researchers and PhD students from our lab. The ideation task during the workshops allowed the participants to have enough time to observe the balloons and their behaviour. We invited a subset (n=10) of the participants (randomly chosen over both trials) to a follow-up 15-20 minute open-ended interview. The one-on-one interviews gave us the opportunity to ask participants for more detail about their answers so as to deepen our understanding of their opinions.

DATA COLLECTION AND ANALYSIS

To collect the participants' perceptions of the prototypes and to create a starting point for discussion we asked them to fill out a questionnaire at the end of both trials. The questions posed to participants were as follows:

1. How complex do you think the balloons are in comparison to each other? Do you think the balloons differ in complexity? In what way?

2. Does the balloon remind you of something?

3. What were the balloons doing? How would you describe what they did?

4. Which one did you like better and why?

5. What would you feel about having an object like that in your environment (at home, in the office)?

The first question aimed to explore how people apprehend the behaviour of the balloons and how they perceive the differences in their behaviour. The second question focused on the appearance of the prototypes. We wished to find out if the participants perceived the prototype as functional in appearance (which was our intended goal) or if they saw anthropomorphic traits in it. With the third question we were exploring whether participants would use social language or suggest motivations and intentional states in the balloons. The fourth question attempted to find out about the preference of the participants and which design decisions they were basing this upon. Finally, with the last question, we intended to sample the general opinion people have about the prototype and whether they could imagine this prototype as a product in the home, again to look for signs of how aspects of autonomy might influence their broader perceptions of the technology.

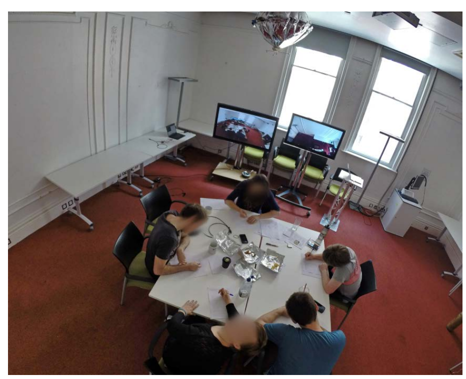

Figure 4. A picture which was taken by Diri #2 during the workshop.

To investigate the results from both the questionnaire (all participants) and the interviews (subset of participants) we used an inductive thematic analysis. Written answers were transcribed and overarching concepts/themes for each statement were distilled. Responses were then clustered into overarching themes, which are discussed below. All quotes are from the questionnaire; interview responses, which provide a more in-depth insight, are mentioned as such.

RESULTS

The results for both trials, the peripheral observation (first) trial (P1-P12) and the direct interaction (second) trial (P13-P23), are presented seperately below and coded into high-level themes. A comparison, deeper analysis and interpretation follows in the section 'Summary and Discussion'.

To shortly recap the difference between Diri #1, the silver balloon, and Diri #2, the golden balloon: Diri #1 movements are random, it moves up or down, turns left or right at various moments. Diri #2 keeps a constant height and avoids obstacles. Furthermore Diri #2 only transmits pictures that contain faces, Diri #1 takes a picture every minute.

In both trials participants were very engaged by the presence of the balloons. Most participants stated that the balloons left a strong impression, they were very present in the room and it was hard not to observe them. Interestingly, directly interacting with the prototypes (as opposed to 'passive' observation) did not appear to change participants' perceptions of the prototypes as social entities. However, the nature of the two trial tasks meant, during direct interaction, participants might have been more aware of the balloons' differing sophistications.

Trial One - Peripheral Interaction

Overall, there were three broad themes: *Mechanistic and Animalistic Associations* (responses to the general look and design of the prototype); *Sense of being watched* by something (participants' surveillance concerns) and finally, *Assuming advanced behaviours* (perceptions of the actions and the functioning of the prototypes).

Mechanistic and Animalistic Associations

Several of our participants made relatively straight-forward associations such as *"hot-air balloons"* or *"zeppelins"* both balloons were perceived as plain and as futuristic due to their metallic colour. A lot of associations however, revolved around Sci-Fi, space-ships and extraterrestrial beings.

"They seem quite 'space-age' in terms of the metallic nature." (P2)

"Erm...UFO? Spaceship?" (P4)

Although the design of the balloons was aimed to be as functional as possible with no explicit attempt at zoomorphism, participants still saw a resemblance to living beings: *"Jellyfish."* (P5), *"A clumsy child."* (P6)

"Reminds me of a Bluebottle fly, because of the noise & directionlessness. I was expecting them to try and get out the window." (P11)

We were curious about the association with Jellyfish (P5) and asked the participant to further explain this at interview. The participant remarked that for her it seemed like the balloons were *"just not flying and then sitting there, they are occupying a space, like in water you can occupy, but air, not many species can occupy that space"* (P5). We subsequently found out that she had previously created art installations revolving around jellyfish, hence her association.

Sense of being watched

One questionnaire item asked if the participants could imagine such a device in their close environment. Most people were self-conscious about the camera and its implications for privacy. They answered that they wouldn't feel very comfortable being monitored.

"Might be annoying as it took photos without permission." (P3)

"I would feel like I had no privacy as the cameras would constantly be watching what I was doing." (P1)

Participants stated that a difference to other surveillance systems is the high visibility of the balloon. Due to its size and also due to the noise the motors produce, people are always fully aware of the balloon, its location and orientation and therefore the camera cannot be hidden. Some participants stated that they were aware of the balloon 'looking' at them:

"I feel constantly observed by the balloon - it is looking at me all the time!" (P3)

"The gold balloon took a long hard look at me whilst I answered this question." (P7)

After asking him again about his statement at interview he explained his previous answer as: *"a camera is kind of like an eye ... So when the camera is kind of staring at you ... I was thinking about this question, I sort of referred to it in that way"*. Again the use of terms such as 'it' and 'watching' (rather than captured) and certainly the articulations around the devices 'looking' at the participants, arguably suggest a notion of the devices being entities with intentions rather than say passive devices. The natural association between cameras and eyes (exacerbated by the placing of the camera within the frame of the blimps) seems to have furthered this sensory impression that the devices were alive and had some kind of internal state in an animalistic way.

In an interview we tried to imagine the differences of having Diri at home in comparison to a normal surveillance camera. One participant stated, that this would constitute a very different feeling for her:

"I think you would have some sort of more of a relationship with the balloon in a way. Like you build up some kind of idea about the little pet kind of watching you. A normal camera? I'd turn it off." (P5)

This final comment underlines the extent to which a behavioural manipulation which involved mobility, when combined with some perceptual sensory quality (the device is 'looking at me') creates an artefact with which participants felt more inclined to form a 'relationship'.

Assuming advanced behaviours

Some of the answers we received suggest that participants were imputing a mental life and mental capabilities to the balloons from observing their behaviour and ascribed characteristics:

"The gold one is oppressive." (P6)

"The silver one appears to be more agile." (P10)

"The silver one seemed 'clumsier'." (P9)

To evaluate which design decisions led to which preference between the balloons we asked the participants to write down which they preferred and why. Surprisingly, although most participants expressed that the balloons do not differ very much, in the first trial they preferred Diri #1.

Reflecting on our design decisions around behavioural characteristics we were surprised that the majority of the participants did not realize there was a difference in behaviour between the balloons. Both of the balloons were perceived as very similar. The participants had different reasons for that. People found Diri #1 'braver' and 'more active', flying quickly across the room, and therefore more interesting. Because of its smaller size it was indeed able to move faster and due to the implementation it would quickly spin around its centre every now and then. Some people noticed that Diri #2 didn't "get stuck that much" (P1). Four out of the twelve participants from the first trial did see a slight difference in behaviour though and explained this correctly with the presence of more components. They also found the smaller balloon was worse at navigating compared to the other balloon as it did not avoid any obstacles:

"The yellow one appears to move more and explore more, but it may be just an impression..." (P12)

"Silver one spins a lot, maybe it can't navigate so well." (P6)

Since Diri #1 does not have any awareness of the other balloon or the environment it would bump into Diri #2 from time to time. One participant stated that he perceived Diri #2 as *"bullying"* Diri #1. Participants would also remark that they saw the balloons *"fighting"* each other. During the sessions where colliding was rather rare, participants stated: *"sometimes they fight; don't play with each other that much"* (P6). These things indicate that some participants perceived the balloons as somehow pet-like, randomly moving, sometimes being reactive to the environment and sometimes not.

"There is something nice about the idea of them floating around like little companions." (P2)

Further to this, two participants, who coincidentally each come from a family with a lot of brothers and sisters, described the relationship between the two balloons being like siblings, for example P5 suggests:

"They seem to have a sibling relationship - they even fight! They're also quite child like." (P5)

In the interview P5 further explained: *"They look the same, they are of the same species...it wasn't aggressive between them, it was familiar in a way"*. Of particular interest here is the way our participants were using their experiences of social relationships to frame the relationships between the balloons. They were using a socialised understanding of the world to interpret otherwise mechanistic behaviours.

As Diri #2 constantly aimed to keep height despite the varying airflow in the room the motors would turn on very frequently. This consistently created a fan-like sound, perceived as very noisy (P2, P6, P8, P10, P11) and at times annoying. For one participant this was curiously framed as some kind of attention-seeking characteristic, which, she stated in the interview, is very common for children:

"The movement is quite gentle, but the noise gives them much more presence, and it's like having a child in the room that needs a bit of attention every so often." (P5)

There were more quotes suggesting that - to the participants - the balloons have intentions and an internal representation of the world - even if it is a very weak one:

"They don't know where they are" (P11)

"They seemed to be more interested in features of the room (particularly the walls) than on people." (P12)

Trial Two - Direct Interaction

In our second trial a lot of similar issues appeared, for example participants expressed very similar feelings about being watched, the direct interaction didn't seem to change surveillance concerns in the participants. Enabling direct interaction raised a few new points of discussion though. We focus here on the recurring themes which are of interest and new themes. The themes in this section are therefore *Mechanistic and Animalistic Associations*, *It was just a balloon* (perceptions of technology), *Responsibilities* (of the autonomous actions), *Playfulness* and finally *Embodied Intelligence* (how people imputed intelligence from observed behaviour).

Mechanistic and Animalistic Associations

Akin to the first trial, we received recurring associations like *"UFOs"* and *"Sci-Fi"* (P13, P20, P22), but also a lot of links to animals. People again perceived the balloons like a *"pet"* (P13, P15), *"like a machine 'social butterfly'"* (P16). One participant stated that:

"Gold definitely seemed like it was better at its job, but I felt silver was the one I liked better because I felt sorry for it, like the runt of the litter." (P15)

Although this participant was more content with the golden balloon, she sympathised with the silver balloon in the end - to her the fact that the silver balloon seemed more uncontrolled and "needed help" changed her preference.

Another participant (P13) answered in the questionnaire that the balloons are *"tortoise-like"*. When asked about it in the interview he further explained that he had hermit crabs when he was younger and felt a strong parallel:

"They sort of reminded me a little bit of the things that I liked about the hermit crabs. 'Cause they kind of, they have their own, it's like they have their own agenda, like they are doing something but they do it very slowly. So you can't really work out what it is what they are trying to do. So you know like tortoises, which sort of just decide that it's time to go somewhere else." (P13)

"I think just because they are moving, that is a part of it obviously, and I think they have one eye. Anything that moves and has got an eye, is kind of halfway to being alive really, isn't it." (P13)

Clearly, his positive memories of past pets lead to sympathy towards the prototypes and reminded him of his pets.

It was just a balloon

Three of our participants avoided any social language and indicated that they saw these devices merely as technology, which fulfilled some limited functionality:

"They were just there and doing their kind of thing. I didn't think it had a personality or something, it was just a balloon." (P19)

One participant showed interest in the balloons, but explained in the interview that he did not feel any empathy towards it:

"I didn't feel the need to take care of it. I thought that if it bumps somewhere it is its problems and to deal with it. And it was more interesting to see how it deals with it and do not rescue it or something." (P23)

It seems to be an approach to technology in general, which seems to guide perception here. The participant explained further that, for him, it is similar to other things that exist around us and that we need to be careful of ourselves, like for example automatic elevator doors:

"They close themselves and if you decide to jump in when they are closing it is your decision and you want to risk to be stuck in or hit you, just don't do it. So I think it is the same with other objects and the balloons are similar." (P23)

Responsibility

During the second trial one participant touched the propeller and slightly hurt her finger. We found that situation interesting and discussed it in the interviews. We asked our participants, if an autonomous device hurts someone, who is responsible for that?

"The person who deployed it, so I think it would be you in that situation in that particular context, it would be the person who was using that piece of equipment, if you want to reduce it to that." (P20)

"I don't know, I'm kind of always have the opinion that if things are really obvious hazard, that you don't have to be around, then it's kind of a little bit your fault." (P13)

Despite the perceived autonomy, and in many cases personality, of the balloons, participants abdicated the balloon of any responsibility for its actions. Though autonomous, it was still viewed as man-made and a *"piece of equipment"* (P20), with responsibility attributed to a user who was not careful enough, or whoever created and deployed the device without ensuring it was safe to use. We feel that this question is a potentially interesting litmus test for future explorations of autonomy.

Playfulness

Although not an original design intention, participants commonly perceived Diri as playful:

"I mean flying objects are just fascinating generally, I think that the interaction with, especially the face tracking one, where there is this little flying thing and you want it to photograph you have to stand in front of it and you have to look it in the eye that's really unusual, like I've not tried to do that with anything other, I've never tried to interact with something flying like that." (P13)

"So it did move and it, we had to get out of the way but it was also the idea that it had facial recognition, which was just fun." (P19)

"Honestly, it seemed like they were being playful." (P15)

One person who was in particular engaged and interacted with the balloons explained his excitement:

"I commented that felt almost playful, certainly the golden one that came down and came very close to you, it did feel a bit like a puppy or something playing with you or something like that, there was a playful element to it." (P20)

"I've got children of my own and they're obsessed with balloons and whenever they see a balloon they are very excited by it. So it brought back some of the childhood memories." (P20)

This indicates again how strongly personal experience and interests guide perception. Thinking about the good times P20 had with his kids and playing with balloons, that was almost the only thing he associated with the prototypes and this inspired his feelings of joy during the workshop.

Embodied Intelligence

Similar to the first trial, participants were attributing mental capabilities (like knowledge) to the balloons from observing their behaviour:

"I enjoyed more the one that knew where it was going." (P21)

Actions were made sense of by ascribing a motivation and events were interpreted as intentional actions, e.g. when balloons would approach the participants:

"Sometimes they seemed to sneak up." (P13)

"They demanded attention." (P16)

Particularly intriguing was the way in which participants were projecting life-like qualities onto the devices through their actions:

"I felt that the golden one was friendlier, it did more what it was meant to be doing. It was better behaved. Whereas the silver one was floating around and maybe not behaving as much." (P18)

"One of them was quite aloof and sitting back and watching and the other one was coming towards us more." (P20)

Due to the different ways by which pictures are initialized for each balloon in the second trial, the difference in behaviour was clearly more apparent for all participants. In general, Diri #2 was much more appreciated because it was easier to control in the participant's eyes, especially for the task to provide certain pictures. Interestingly though, half of the participants in the second trial also stated that apart from that, they thought both balloons were the same. Again most of the participants found Diri #2 to be noisier (P13, P17, P20, P23). In addition we noticed in the second trial that participants who were shy, introverted personalities did not engage with the balloons as much as extrovert, outgoing people and this was independent of any technical background that they may have had.

SUMMARY AND DISCUSSION

Below we present lessons learned for autonomous interface design. Following on this we re-evaluate the framework [27], reflecting on how our results supported it but also suggesting how it might be productively modified.

Interfaces As Social Actors

People will be willing to accept autonomous interfaces, similar to a pet, in their environment

People's tendency to perceive technology with an intentional character - especially when it shows indications of autonomy - is pervasive and frequently observable. Humans have a natural desire to reason about behaviour as it is of evolutionary advantage to make rapid categorical distinctions, for example predator / prey / inanimate object [34]. As we noted in our workshops, this accounts for 'passive' observations, where users and the balloons are just present together in the room, as well as for direct interaction. We saw a number of situations where our participants tried to make sense of a prototypes' behaviour by explaining it in reference to social acts - change of orientation means shifting interest, colliding means fighting. Particularly in the first trial, where there was more opportunity for the balloons to interact with one another, participants were more likely to ascribe socialized understandings to the balloons' behaviours. Perceptions of autonomy are potentially further underpinned by seeing how the devices interact with one another rather than the user.

Interestingly, and further to our discussion of imputing life-like qualities in to our mechanical objects are the strong associations to animals that our participants made, and especially to pets. This supports related work; seeing a similarity between certain technologies and animals is quite common [13, 36, 18]. We assume that these associations arise because autonomous interfaces share characteristics with pets: they co-habit space with us; we try to make sense of their ambiguous behaviour; they are partly reactive; we can't communicate with them very well (we can't talk with them); they sometimes need our assistance. We observed that as soon as the device is autonomous, people did not see the camera as a mere camera anymore, it becomes eye-like and something through which an entity 'sees'.

We also noted that people are more understanding when social technology makes mistakes because this resonates with our human fallibility [4]. For example, some participants were more forgiving of the silver balloon, the lack of navigational skills earned sympathy. We can deduce, that people might be willing to accept autonomous interfaces in their environment, like pets, presumably making similar allowances for their otherwise non-deterministic behaviours [36].

Appropriating Autonomous Interfaces

It is futile to design for certain perceptions or social reactions

From our study it became clear that perceptions are strongly coupled to individuals' life experiences (lebenswelt). We received a lot of differing opinions from our participants about the balloons. In the same way that the same movie can give rise to differing emotional responses in different people or the same movement leads to different interpretations [19], people respond differently to technology [25]. For example, two participants, who each come from a family with a lot of brothers and sisters, described the relationship between the two balloons like that of a sibling relationship. One participant recognized their past pets in the balloons. This represents a strong indication that our own life experiences influence perception strongly and can lead to projection of our own experiences onto the interfaces [25].

Therefore it might not be possible to design to promote certain perceptions or social reactions, as this strongly relies on the user's life experience. Users naturally focus on the thing that they are interested in. There seems to be a *paradox of autonomy*. The more a designer aims to create autonomy, the more room is left for users' interpretations, leaving the designer with less control. This underlines the importance of a system staying open to users' interpretations and the wide range of possible meanings to be derived from a system's appearance and behaviour [35]. During the design process of TAIs, when incorporating autonomy into interfaces, it is therefore not advisable to rely on or design for rigid interpretations. In our trials we experienced that even with radically different interpretations, an autonomous interface can still be enjoyable and the interaction pleasant, as long as it is engaging or reaches the desired goal (to change behaviour, attract attention, support well-being etc.). Frequently designers will struggle to foresee the associations that users will make. Therefore they should embrace some ambiguity in their design, such that they can create something fitting for different lives, or even something that users can fit into their lives themselves. We therefore underline the importance of openness in designing TAIs.

Anthropomorphising Intelligence

Functionality is attributed to the object of interaction

Striking to us was how the participants saw the balloons as self-contained entities and perceived that they - like any living being - solve their tasks independently. For example, apart from two participants who were familiar with face-recognition algorithms, the participants assumed that Diri #2 performed the face recognition, although the pictures were streamed and processed on a separate computer. This underlines that, at least a part of, the participants perceived technology as one; no matter how distributed the technology might be, for the participants the device is the one solving the tasks. It's a similar notion which exists with software agents like Siri. Users assume that its their phone, although this system consists of millions of shared processes, executed and transmitted between a plethora of servers and devices.

Again, participants relate a system to what they know from real life - entities, which can't be invisibly controlled remotely or distributed. Dennett [7] suggests that when we don't know the physical details of the device, we treat it as one of our fellow living beings. We can't help it and try to predict the actions of a device, driven by possibly shallow assumptions about its inner workings. The implication for design is, that people tend to take things as a whole, even if the processing is invisibly distributed between different technological artefacts. Data analysis can be outsourced, the user will still attribute the functionality to the autonomous interface with which they are interacting.

Exploring different Sophistications

Similarity in appearance can obscure difference in behaviour
Perceived differences between the two implemented behaviours were less apparent for participants than we initially anticipated. In evaluation we conclude, it is challenging to implement different characters and sophistications amongst devices with highly similar interfaces. One thing to keep in mind when designing with autonomy is that, under certain conditions, humans strongly impute intelligence and might ascribe qualities to objects that these in fact can't offer [37]. Our participants demonstrated this notion of imputing intelligence into our devices. Although Diri #1 was arguably less intelligent (because it contained less complex sensing capabilities), people still seemed to project intelligence onto the device, despite actually lacking abilities, as it was highly similar in appearance to Diri #2. To our knowledge this is the first attempt to compare two autonomous interfaces that show such similarity in appearance, but possess different levels of internal sophistication and therefore behaviour. We suggest this as a challenge for designing with autonomy: differences in behaviour in devices, highly similar in appearance, can be too subtle and hard for users to spot, because people will look for socialized explanations of differences in the behaviours.

Helmes et al. [13] attempted to compare different levels of sophistication, through three visually distinct autonomous devices. The observed participants showed higher engagement and interest in the most sophisticated rudiment. In contrast to rudiments 1 and 2, which followed very simple rules, rudiment 3 clearly changed its behaviour over the course of the deployment. It learned to 'identify' faces but remained to an extent ambiguous. Not only was it reactive to the presence of individuals, it also actively adapted to the users and the environment. Both our devices followed pre-programmed rules, resulting in being reactive to the environment and at times acting randomly, but otherwise showing persistent behaviour over time. We believe that an adaptation over time, as an observable change in behaviour, makes users more likely to ascribe an additional level of sophistication to a device.

Revisiting the TAI-Framework

Through the process of designing our TAIs we found the framework presented in [27] to be very helpful. It aided us in identifying design 'ingredients' to achieve autonomy. As suggested by the framework we have received various social responses from our participants that relate to the appearance of Diri and the ambiguity in their behaviour. However, based on the experience gathered in this project we propose to adjust some aspects of the framework.

Firstly, even though it has been suggested [27] that the dimensions in the framework are interlinked, we found it difficult to tease apart individual effects that each aspect has on perceived autonomy. For example, we found that many users do not notice a difference in behaviour if two interfaces have very similar appearances. Therefore, putting interfaces on different points of a scale in the framework does not necessarily lead to a stronger perception of autonomy. Instead, our results suggest that personal experience has the most significant effect on the perception of Diri, and hence also the largest effect on the social response. Although this is an important argument to be made, it, however, does not weaken the framework as a design reference for autonomous interfaces. The scales in the framework should therefore not be seen as distinct, independent attributes, but should instead be viewed as interlinked measures that create a merged constellation of autonomy.

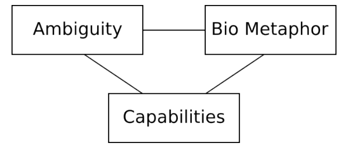

Figure 5. The modified framework for Autonomy in Interfaces.

Secondly, we found no indication that users make a distinction between the *Capabilities* of an interface and its internal *Complexity* as suggested by the framework. Although the authors of [27] acknowledge that these two scales are heavily related, from our experience, i.e. during the development but also during evaluation, they could be taken together and seen as one. It may be more helpful to view increased *Complexity* to be a consequence of increased *Capabilities*, instead of two related scales. We would unite these two, and use only the term *Capabilities* to describe the system's sophistication of software and hardware. We therefore propose to restructure the framework as illustrated in Figure 5. *Bio-Metaphor* still significantly impacts on appearance, and *Ambiguity*, as before, is needed in the behaviour of an autonomous interface. *Capabilities* now spans appearance and behaviour, and all aspects reside on the same depth.

Thirdly, we also realised that the dimension *Capabilities* must include the potential for inter-device communication, e.g. TAIs capable of interacting with each other, as we felt that this changed the users' perception. If a device can visibly interact with other devices, it has to be placed higher on the scale than a device that does not comprise these capabilities.

CONCLUSION

In this paper we presented actuated helium balloons with an aim to explore autonomous user interfaces. We described our design process and hope to contribute to discussions of autonomous interfaces in interaction design. Through our evaluation of participants' responses to the balloons we recorded a diversity of opinions, which we have used to develop further understanding of users' perceptions of autonomy. Our results show that autonomous technology will be more acceptable to users, in a similar way that they are towards pets. Since every user brings his own life experience into the interaction, it is futile to design to prompt certain social reactions. Our participants ascribed all functionality to the object of interaction, which opens interesting opportunities for design. And finally, through our study setup we realized that it is difficult for users to spot differences in behaviour of prototypes which look alike. We used our findings to review the TAI framework and presented a modified version. Consequently, we begin to bridge the gap to understanding how to design to support perceptions of autonomy at the interface.

REFERENCES

1. Bartneck, C., Kanda, T., Mubin, O., and Al Mahmud, A. Does the design of a robot influence its animacy and perceived intelligence? *Social Robotics 1*, 2 (2009), 195–204.
2. Bouabdallah, S., Murrieri, P., and Siegwart, R. Design and control of an indoor micro quadrotor. In *Proc. of ICRA'04*, vol. 5, IEEE (2004), 4393–4398.
3. Braitenberg, V. *Vehicles: Experiments in Synthetic Psychology*. Bradford books: Psychology. MIT Press, 1986.
4. Breazeal, C. L. *Designing sociable robots*. MIT press, 2004.
5. Clocky. `www.nandahome.com`.
6. Dautenhahn, K. The role of interactive conceptions of intelligence and life in cognitive technology. In *Proc. of CT '97*, IEEE Computer Society (1997), 33–40.
7. Dennett, D. C. *Kinds of Minds: Towards an Understanding of Consciousness (Science Masters Series)*. Basic Books, May 1997.
8. Gaver, W. W., Beaver, J., and Benford, S. Ambiguity as a resource for design. In *Proc. of CHI '03*, ACM (2003), 233–240.
9. Goddard, N. D. R., Kemp, R. M. J., and Lane, R. An overview of smart technology. *Packaging Technology and Science 10*, 3 (1997), 129–143.
10. Golembewski, M., and Selby, M. Ideation decks: A card-based design ideation tool. In *Proc. of DIS '10*, ACM (2010), 89–92.
11. Greenfield, A. *Everyware: The Dawning Age of Ubiquitous Computing*. Pearson Education, 2010.
12. Grönvall, E., Kinch, S., Petersen, M. G., and Rasmussen, M. K. Causing commotion with a shape-changing bench: Experiencing shape-changing interfaces in use. In *Proc. of CHI '14*, ACM (2014), 2559–2568.
13. Helmes, J., Taylor, A. S., Cao, X., Höök, K., Schmitt, P., and Villar, N. Rudiments 1, 2 & 3: design speculations on autonomy. In *Proc. of TEI '11*, ACM (2011), 145–152.
14. Instructables on how to make a Diri: http://www.instructables.com/id/Diri-the-actuated-helium-balloon/.
15. International Conference on Intelligent User Interfaces. `http://www.iuiconf.org/`.
16. Jafarinaimi, N., Forlizzi, J., Hurst, A., and Zimmerman, J. Breakaway: An ambient display designed to change human behavior. In *Ext. Abstracts CHI'05*, ACM (2005), 1945–1948.
17. Ju, W., and Takayama, L. Approachability: How People Interpret Automatic Door Movement as Gesture. *International Journal of Design 3*, 2 (Aug. 2009).
18. Jung, J., Bae, S.-H., and Kim, M.-S. Three case studies of ux with moving products. In *Proc. of UbiComp '13*, ACM (2013), 509–518.
19. Jung, J., Bae, S.-H., Lee, J. H., and Kim, M.-S. Make it move: A movement design method of simple standing products based on systematic mapping of torso movements & product messages. In *Proc. of CHI '13*, ACM (New York, NY, USA, 2013), 1279–1288.
20. Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., and Wensveen, S. *Design Research Through Practice: From the Lab, Field, and Showroom*. Morgan Kaufmann Publishers Inc., 2012.
21. Krzywinski, A., Mi, H., Chen, W., and Sugimoto, M. Robotable: a tabletop framework for tangible interaction with robots in a mixed reality. In *Proc. of ACE '09*, ACM (2009), 107–114.
22. Kumar, V., and Michael, N. Opportunities and challenges with autonomous micro aerial vehicles. *Robotics Research 31*, 11 (2012), 1279–1291.
23. Kynsilehto, M., and Olsson, T. Intelligent ambient technology: Friend or foe? In *Proc. of MindTrek '11*, ACM (2011), 99–106.
24. Little Robot Friends. `http://www.littlerobotfriends.com/`.
25. McCarthy, J., and Wright, P. Technology as experience. *interactions 11*, 5 (Sept. 2004), 42–43.
26. Mortensen, D. H., Hepworth, S., Berg, K., and Petersen, M. G. "it's in love with you": Communicating status and preference with simple product movements. In *Ext. Abstracts CHI '12*, ACM (2012), 61–70.
27. Nowacka, D., and Kirk, D. Tangible autonomous interfaces (tais): Exploring autonomous behaviours in tuis. In *Proc. of TEI '14*, ACM (2014), 1–8.
28. Ollie. `http://meandollie.com/`.
29. OpenCV - Open Source Computer Vision Library. `http://opencv.org//`.
30. Paulos, E., and Canny, J. Prop: Personal roving presence. In *Proc. of CHI '98*, ACM (1998), 296–303.
31. Plotclock - A Mechanical Clock That Plots Time. `http://wiki.fablab-nuernberg.de/w/Ding:Plotclock`.
32. Poupyrev, I., Nashida, T., and Okabe, M. Actuation and tangible user interfaces: The vaucanson duck, robots, and shape displays. In *Proc. of TEI '07*, ACM (2007), 205–212.
33. Pousman, Z., Romero, M., Smith, A., and Mateas, M. Living with tableau machine: A longitudinal investigation of a curious domestic intelligence. In *Proc. of UbiComp '08*, ACM (2008), 370–379.
34. Reeves, B., and Nass, C. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Cambridge University Press, 1996.

35. Sengers, P., and Gaver, B. Staying open to interpretation: Engaging multiple meanings in design and evaluation. In *Proc. of DIS '06*, ACM (New York, NY, USA, 2006), 99–108.

36. Sung, J.-Y., Guo, L., Grinter, R. E., and Christensen, H. I. *My Roomba Is Rambo: Intimate Home Appliances*. Springer, 2007.

37. Taylor, A. S. Machine intelligence. In *Proc. of CHI '09*, ACM (2009), 2109–2118.

38. Tobita, H., Maruyama, S., and Kuzi, T. Floating avatar: Telepresence system using blimps for communication and entertainment. In *Ext. Abstracts CHI '11*, ACM (2011), 541–550.

39. van Allen, P., McVeigh-Schultz, J., Brown, B., Kim, H. M., and Lara, D. Anithings: Animism and heterogeneous multiplicity. In *Ext. Abstracts CHI '13*, ACM (2013), 2247–2256.

40. Weiss, A., Bernhaupt, R., Lankes, M., and Tscheligi, M. The usus evaluation framework for human-robot interaction. In *Proc. of AISB '09*, vol. 4 (2009), 11–26.

41. Yoshimoto, H., Jo, K., and Hori, K. Designing interactive blimps as puppets. In *Proc. of ICEC '09*, Springer-Verlag (2009), 204–209.