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Shift and Blend: Understanding the hybrid character of computing artefacts on a tool-agent spectrum

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ABSTRACT

In the context of human-agent interaction, we see the emergence of computational artefacts that display hybridity because they can be experienced as tools and agents. In this paper we propose a tool-agent spectrum as an analytical lens that uses 'intention' as a central concept. This spectrum aims to clarify how a computational object can change from being conducive to the intentions of others ('tool') to appearing to have intentions of its own ('agent'), or vice versa. We have applied this analytical lens to unravel people's experiences in two hybrid cases; guide dogs as a living mobility aid for the visually impaired and an experimental wearable object named "BagSight" as a rudimentary artificial counterpart. We compared both cases through the lens of a tool-agent spectrum and elaborate on these results by discussing some of the principles by which computational artefacts can shift across the spectrum. We conclude by discussing the limitations of this study and provide suggestions for future work.

CCS CONCEPTS

• Human-centered computing → Interaction paradigms; HCI theory, concepts and models; Empirical studies in HCI; Interaction design;

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KEYWORDS

Hybridity, intention, tool-agent spectrum, computational artefacts, interaction design

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1 HYBRIDITY

In the context of human-agent interaction, we see the emergence of computational artefacts that display hybridity because they can be experienced as tools and agents alternately, shifting from one role to another, or concurrently by the blending of their distinct features. Back in 1996, Reeves and Nass have coined the term 'anthropoeia' to address the humanness of computing systems that do not resemble humans in their appearance or behavior in a literal sense [32]. About 10 years later, Takayama describes how, to what she refers to as 'agentic objects' as "those entities that are perceived and responded to in-the-moment as if they were agentic despite the likely reflective perception that they are not agentic at all." (p.239) [38]. Both of these works hint at a kind of hybridity at play when interacting with computing artefacts that have been designed with a particular purpose and appear to have an intrinsic kind of agency.

Since then, scholars in the human-agent and human-computer interaction communities have investigated the hybrid character of computational artefacts such as smart products and robots from different angles [37, 30, 8]. For example, Schmitz discusses industrial design concepts and guidelines for life-like interactive objects based on using anthropomorphic and zoomorphic qualities [36]. Marenko and Van Allen [28] propose the notion of 'animism' as an approach to design interactions with artefacts as spontaneous and unpredictable modulations between human and nonhumans. Other scholars have focused on how the behavioral complexity of computational artefacts can be designed to provide cues to help people attribute mental states to inanimate things [19, 26]. And Löffler et al. [27] address the space between 'thing' and 'being' in the design of service robots and discuss how the interpretive flexibility that comes with this hybridity can promote the acceptance of service robots in domestic environments.

Rozendaal et al. [34] noticed how the ambiguous agentic status of a robotic ball led to interesting forms of collaborative play with children in hospital environments. At one moment, the robotic ball would be treated as a normal everyday ball, used for kicking, throwing, rolling etc. but was also approached as a creature that was spoken to, given a name, and was explored socially. They further noticed how in a more blended way, the objects that were played with as a 'pet' could make play familiar games more interesting due to their unpredictability but also how the ball was played with as a 'playing partner' in games like hide and seek. They learned how their framing of being a 'tool' or an 'agent' was determined by the properties of the robotic ball in relation to children's self-directed play and by the suggestions provided by parents.

The rising number of different kinds of computational artefacts combined with the apparent flexibility in which people are able to understand and interact with such artefacts, motivated our research to better understand the ways in which people perceive and use them. We suggest that a 'tool-agent spectrum' can help unravel the complexities at play when interacting with computational artefacts. We continue by introducing the spectrum and then elaborate how we have applied it as an analytical lens in two case studies. We conclude by discussing the spectrum in relation to the case study results on the basis of five principles that can illuminate the reasons for people to shift their perspective.

2 TOOL-AGENT SPECTRUM

We propose a tool-agent spectrum that uses intention as a central concept to help clarify how computational artefacts can be experienced to shift and blend as tools or agents. 'Intention' is a philosophical concept that has been used and researched in the field of human-agent interaction. Intentions have been described as the particular goals of agents that they can proactively act upon and communicate about [40, 41]. Bratman's work on shared intentions [7] describes the importance and necessity for shared intentions in the context of human-agent collaboration. We refer to Activity Theory (AT) to discuss how intention is fundamental to purposeful human activity in the world, and ways in which artefacts can mediate human activity as tools [25, 21]. We use Dennett's theory of intentionality [10] to understand how intentions can be ascribed to things.

2.1 Foregrounding 'intentions'

Activity Theory (AT), originally proposed by Alexey Leontiev as an approach in Russian psychology [25] offers a comprehensive conceptual framework for analyzing human activity as a hierarchically structured, mediated, social, and developing interaction between human beings and their world [21]. Intention is fundamental to purposeful human activity as it specifies the relationship between the experiencing subject and the objective world. In AT this relationship is described on multiple hierarchical levels. For example, an intention can correspond to a person's *motive* to engage in an activity. Motives are driven by biological or cultural needs of the interacting subject that make human activity purposeful. One step lower in the hierarchy, intentions also relate to the *goals* that are required to carry out an activity, and thus accommodate motives. Goal-directed actions are subsequently performed by operations that are spontaneous adjustments to external conditions, and these operations are not considered intentional in itself. In AT, levels in this hierarchy are not fixed but can change depending on the (developing) person as an effect of learning and changing circumstances.

Activity Theory further suggests that human interaction in the world is mediated by *tools*. Humans hardly ever act directly in the world. Instead, we rely on artefacts to help us attain our goals. Tools can mediate human activity on different levels [21]. We use the example of driving a car to illustrate this. Cars that support driving by means of 'power-steering' or 'break-assist' function as tools on an operation-level because they support the driver in the actual performance of driving. Cars may also act as tools on a goal-level. For example, cars equipped with 'park-assist' can provide suggestions about the steps required to complete this particular objective. More intelligent cars might even perform these actions by themselves. Imagining cars that act as tools on a motive-level is enigmatic. In this case, cars are considered to have motives that emerge from particular, non-biological 'needs' such as selecting locations to drive to by itself (e.g., a gasoline station), bringing it into a more equal relationship with humans. How would this augment human abilities, and as what type of tool can we describe it? In more recent scholarly work in AT, Bødker and Andersen [4] refer to an automated pilot system on ships as 'quasi-subjects'; tools that appear to display need-based agency.

The intentional stance proposed by Dennett [10] can illuminate the apparent enigma of tools having need-based agency. Dennett takes a radical approach by suggesting how we can approach things from three stances; the physical, design and the intentional stance, without making a distinction between living or non-living things.

When we apply the *physical stance* to a system, we attempt to understand its behavior as caused by natural laws. When this explanation becomes too complex to be useful, we move up to the *design stance*. From a design stance, the behavior of a system is explained according to their designed purpose, developed through biological evolution or though human making. For example, we can try to explain human behavior by our understanding of the human sensorimotor apparatus or try to understand the behavior of technical devices through their functional components. Similarly, when the design stance is no longer effective, we turn to the *intentional stance*. Dennett suggests how the behavior of complex systems are best explained by assuming that systems have *beliefs* and *desires* and act *rationally* according to them, as a form of folk psychology. For example, we can predict the behavior of humans, animals or even complex machines, by assuming they will act rationally according to what they want to achieve.

To refer back to the previous example, a car that drives autonomously might appear to have *motives* when you notice how it decides itself which route to take towards a particular destination and perceive how it avoids obstacles along the way. Explained from the design stance, the car drives itself based on complex calculations about real-time traffic information (with optima for distance travelled and time of arrival) and by analyzing incoming sensor data from its immediate environment aimed to avoid collisions. Attributing motives and rationality to the car intuitively make sense, especially for the driver (e.g. "it wants to avoid a traffic jam further down the road, that's why it suggests to get off the highway here"). From Dennett's perspective then, understanding the car's behavior from the intentional stance is simply a more economic means of explanation compared to the design stance or the physical stance. Although these other two stances are equally 'true', they might differ substantially in their practical usability, e.g. regarding explanation or prediction of the system's actions.

This combination of the perspectives of AT and Dennett enables an understanding of computational artefacts as hybrid characters—moving between being tools and agents—that can provide flexible kinds of collaborative assistance and support.

2.2 Analytical lens

The tool-agent spectrum we propose functions as a lens to analyze the extent people experience an object to be *conducive to the intentions of others* and *appears to have intentions of its own.* Based on these two orthogonal dimensions a matrix is created with four quadrants (Figure 1). We refer to *things* when objects are not experienced as having any intention. We refer to *tools* when objects are perceived as being conducive to the intentions of their users, and as *agents* when perceived as having intentions of their own. Objects are labeled *partners* when they are experienced as having their own intentions and as being conducive to user's intentions as well. We can further characterize the type of interaction across the four quadrants. When perceiving objects as *things*, interactions can be considered to be *explorative*, aimed to discover the object's inherent properties, and hereby its potential to engender tool- and agent-like qualities. Interacting with objects as *tools* is considered to be *instrumental* to achieve a specific aim while interacting with *agents* is considered to be *social* (focusing on understanding the intentions of the agent and ways of dealing with it). When perceiving objects as *partners*, interaction is considered to be *collaborative* towards a shared goals or objective.

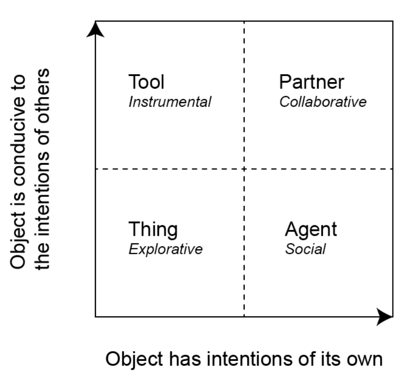

Figure 1: Depiction of the tool-agent spectrum defined by the extent objects have intentions of their own (x-axis) or are conducive to the intention of others (y-axis), hereby creating four quadrants.

3 TWO HYBRID CASES

We have applied this tool-agent spectrum to unravel people's experiences in two hybrid cases; guide dogs as a living mobility aid for the visually impaired and an experimental wearable object named "BagSight" as a rudimentary artificial counterpart. Understanding human-artefact relationships by drawing comparisons from human-animal ones can help us understand our relationship with technology [9, 13, 23, 31]. Guide dogs are of interest for our inquiry because they are intelligent living creatures displaying complex behavior that have been extensively trained to function as service dogs and that we would expect to provide rich experiences as tools and as agents. BagSight is of interest because it allows for a comparison on a tool-agent spectrum as a rudimentary artificial system that can inform about the implications of hybridity for computational artefacts.

Guide dogs are trained service animals that respond to verbal commands and are the most widely used types of assistance besides the well-known white cane. Guide dogs are trained to help guide its owner to avoiding obstacles, navigate through dangerous situations and help in locating particular objects like doors, stairs or chairs. Guide dogs are of a particular breed and need to be endowed with particular traits to be able to function as a guide dog. An intensive period of training is required from a young age, and later when in service, the dogs need to be trained with their new owners. A guide dog owner, like any other dog owner, has to provide for the dog's physical and emotional needs. Often a clear sign is given that the dog is being 'on the job' or that it is 'free'. Only in the later condition it may be patted.

We have drawn inspiration from guide dogs to create an experimental wearable object named "BagSight" as a rudimentary mobility aid. BagSight resembles a fashionable leather backpack that is equipped with two distance sensors, a light sensor, and a servomotor that allows it to move around the wearer's back by pulling or releasing its straps (Figure 2). The wearable has been programmed to avoid obstacles as sensed by the distance sensors, and to be attracted to light, as sensed by the light sensors. The backpack is programmed such that an obstacle on the right unrolls the right cord, which moves the backpack to the left, and vice versa, a source of light on the left means that the backpack will move to the left. This relatively simple behavior can trigger the

Figure 2: Image of the BagSight prototype.

intentional interpretations of the object as showing a 'fear' of obstacles and a 'love' for light [6].

3.1 Method

We studied peoples' experiences of guide dogs and BagSight by means of interviews, and analyzed their stories by means of the tool-agent spectrum. In both studies, the interviews were audio recorded and transcribed. In the guide dog study, we have interviewed six visually impaired people and one professional guide dog trainer. We asked them about the challenges they face in their daily lives, the aids they use, and in particular how they experience guide dogs as mobility aids. These interviews took about 30-60 minutes. The interviews about BagSight where held with 16 Master students (who were not visually impaired). The majority of participants studied either Mechanical Engineering, Computer Science or Industrial Design at Delft University of Technology. Short interviews were held during four use sessions after participants had interacted with BagSight. In the first session participants explored BagSight to become familiar with its functions and then in the second session learned to trust it by asking participants to use it while closing their eyes. The second two sessions involved a navigation task towards a light source, while being blindfolded. In these sessions we added the sound of 'fireworks' to suggest a 'party' as a possible destination. In the third session the location of the firework coincided with the location of the light source. In the fourth session light and sound locations were different. In that case, BagSight would pull towards a destination that participants would not directly perceive. This allowed BagSight to be perceived as an object that could display its own intentions, and hereby potentially create a conflict in the choice of destination. A more elaborate interview was held after all the sessions had been concluded. On average, each participant was interviewed for about 30 minutes in total.

3.1 Results

We describe the results of both studies and elaborate on how guide dogs and BagSight can be experienced as *tools*, *agents* and *partners*. We then discuss more generally some of the reasons these perceptions might shift across a tool-agent spectrum. Participant quotes (translated from Dutch to English) are presented in *italic*.

3.1.1 Experiencing object as tools. How are guide dogs and BagSight experienced as tools, informed by how they are conducive to the intentions of others? Guide dogs are animals trained to help visually impaired find their way and as such can be perceived as mobility tools. One participant described his guide dog as an *extra sensory organ* and as an *instrument who walks two steps ahead of him*. Guide dogs can be given commands that they have learned to understand and to obey to. For instance, one participant mentioned saying to her guide dog Juno, *Juno find sidewalk* or she could say *Juno, find pole* when she needs to cross the street and needs to push a pedestrian crossing button. Commands can be given in different ways to control the dog. As the dog trainer mentioned, *you can pull the leash a bit* or *keep the dog back for a moment* and the dog knows that you indicate that it *is not doing what I hired you to do*. The guide dog trainer further mentioned how the behavior of the dog is useful for 'reading' the environment. The more sensitive you are to the dog's *pulling, wagging of the tail, and panting*, the more information you obtain about the environment.

Participants experienced BagSight as a tool in similar ways. Participants talked about BagSight as *sort of like your eyes*. For some students this effect felt natural, what we would describe as an experience of being able to look through BagSight while being blindfolded. Other participants described BagSight as an instrument for navigation *to help you find your way*. Based on its particular way of functioning, one student described BagSight *as an obstacle detector* and imagined how it could be used in combination with a white cane for visually impaired. Participants also indicated how BagSight could be used to read the environment similar to guide dogs. As illustrated by a student who mentioned that *I need to interpret this signal from the backpack like this. If it does this, I have to continue straight ahead.*

3.1.2 Experiencing objects as agents. How are guide dogs and BagSight experienced as having intentions of their own, as a form of agent? In the study, guide dogs were talked about as animals with needs, habits, and personalities. One participant mentioned how she made time to play with her guide dog, *when you come home, you don't put the dog in its cage, but you do fun things like doing a game, and giving hugs at certain moments*. Another participant mentioned another way to foster the dogs needs by letting them *have a long run every now and then*. Guide dogs can also be stubborn. One participant talked about how her dog knew a particular garden where he could find bread and how she *could shout what I wanted but he just wouldn't return before finishing the bread*.

BagSight was experienced as an agent as well. BagSight has been programmed to pull towards a light source. Participants who picked-up on this pulling behavior experienced this as BagSight 'wanting' to go somewhere. In the situation that people used BagSight blindfolded and the location of the light source coincided with the location of the sound source, one participant explained that *as I came close to the party, the backpack applied* *more tension. It wanted to go to the fireworks.* Some participants identified BagSight as an object that could display a form of animism and described it to have feelings. For instance, one participant expressed how he thought BagSight felt *confident if there is more light* and how it is *afraid of obstacles.* Another participant described how he liked feeling something alive moving around on his back, and felt a sense of intimacy towards the object when he felt *a cozy instrument dangling on your back* that could develop into *some sort of social bond when you hang out more with it.*

3.1.3 Experiencing objects as partners. How are guide dogs and BagSight experienced as partners, informed by how the intentions of dog or BagSight and human align within the context of a shared activity? Many instances of our participants point towards experiencing guide dogs as partners in mobility. *When in service, the dog and the user function as one entity.* The dog trainer described the difference in tasks and how they are divided between human and guide dog. *The dog is taking the lead, he is physically in charge but the user has the mental lead.* In moving around the guide dog learns to see through the eyes of the person, *he knows, you are 1.90 meters high and around a meter wide, so he learns to walk around things and to be larger than he actually is.* As partners, interactions between human and guide dogs take shape as negotiations. Although the dog follows commands it judges for itself if what the user wants is safe. *If you wanted to cross a street when the situation didn't allow it, then the dog would halt. You could do whatever you want, but the dog stayed.*

The accounts of people experiencing BagSight as partners were less clear. We believe this has to do with the limited range of capabilities of BagSight compared to the innate abilities of guide dogs. Still, some participants talked about how they could cooperate with BagSight to achieve the goal they were given and how they used terms like *partnering up with it* and seeing it *as a buddy.* In particular, one participant mentioned by being guided by BagSight's *fear* of obstacles and how this perception could be triggered by the way BagSight is designed to express obstacles, i.e., by *crawling* up your back. Participants further did mention how using BagSight could feel scary and required a high level of trust, *you just had to give yourself over to the device.* This suggests how people felt like they interacted with something that is autonomous and outside their direct control.

4 DISCUSSION

We now continue to elaborate on these results by discussing more generally how computational artefacts can shift across a tool-agent spectrum. Based on our findings, we discuss five principles that might be at play when people shift their perspective. These proposed principles are not meant to be exhaustive or definite but are proposed to generate discussion and suggest departures for future research.

4.1 Traversing a tool-agent spectrum

Our analysis suggests that guide dogs and BagSight can be experienced as tools and agents in a flexible manner; alternating between being a tool or an agent or in some cases appearing to display qualities of both. We discuss some of the possible shifts across this spectrum by discussing *attribution*, *conduciveness*, *alignment*, *unification* and *breakdowns* as suggested principles driven by varying intentions of the person and a dog or object in the context of interaction that is shaped by the person, features of the object or animal, and the particular circumstances of use (Figure 3). For each principle, we reflect on the study findings, discuss the related work, and discuss the broader implications for designing computational artefacts as hybrid characters.

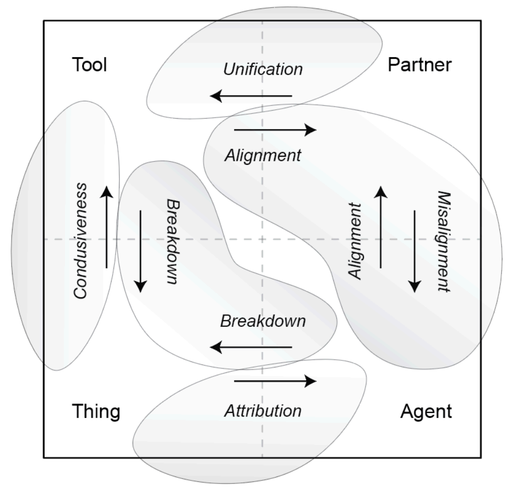

Figure 3: Depiction of multiple shifts across a tool-agent spectrum.

4.1.1. Attribution. The shift from Thing to Agent can be ascribed to the principle of *intention attribution.* Heider and Simmel [17] demonstrated how the spontaneous movements of objects can trigger us to attribute intent and emotions to them. When reflecting on our two cases, guide dogs as domesticated and trained animals show behavior that is more complex compared to the rudimentary behavior of BagSight. Yet, we noticed how people attributed intentions to both of them. Particularly for BagSight this was triggered by its pulling towards the light and by its lively movements and tactile impressions these movements made on the back of the wearer. Levillain and Zibetti [26] showed how the movement complexity of artefacts can trigger people to attribute agency on different levels. A simple form of animacy when movements follow varied and unpredictable patterns and how they can trigger the attribution of higher levels of intelligence when they are perceived to move in goal-directed ways and appear to demonstrate awareness of the environment. Our findings support these results, and offer a means to design hybridity by tailoring the movements of computational artefacts [18].

We further found an interesting difference between guide dogs and BagSight concerning how intention attribution was associated with social interaction. The guide dog owners mentioned feeling affection for their dogs, cared for them, and experienced companionship. For BagSight these social associations were mostly absent, and when it was mentioned briefly it came across as being artificial. When understanding the hybrid nature of computational artefacts, a topic worth discussing concerns how social interaction should be interpreted and approached morally. Friedman et al. [12] who studied social human-robot relationships by investigating people's experiences of a pet robot dog did find strong cues for social interaction. They found how the robot dog evoked conceptions of life-like essences, mental states, and social rapport but seldom evoked conceptions of moral standing. They characterized the social relationship as being remarkably one-sided, enjoying the companionship of a pet but "...since the owners also knew that [the robot dog] was a technological artifact, they could ignore it whenever it was convenient or desirable." (p.278). This suggests how attributing intentions to computational artefacts and the social interactions they afford can be seen as fictional [35, 11] and still have moral implications.

4.1.2. Conduciveness. The shift from Thing to Tool can be ascribed to the principle of *intention conduciveness*. Here we refer back to the notion of mediation in Activity Theory, referring to how artefacts empower people in mediating them with their world. Results show how guide dogs and BagSight empower people with visual impairments by translating environmental visual information into auditory and tactile information to help them move around. In other words, they allow the person to read the environment through the objects as *functional organs* that augment human capabilities [42]. This does require new skills in order for people to use them, and these complementary abilities develop within the context of a shared activity [21].

Furthermore, guide dogs can provide other kinds of support besides mobility. Participants mentioned guide dogs as helping with their motivation to go outside and companionship to battle loneliness. This makes us reflect on how people *appropriate* tools in order to empower themselves [2]. The notion of *affordances* in Gibson's ecological perception is relevant here [15]. "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill." (p.127). Gibson further states that affordances are relational, providing opportunities for action. The kinds of use that computational artefacts afford is therefore not dictated by designers alone but also depends on the interests, concerns and creativity of their users.

An interesting question for future work is about how increasing the behavioral complexity of computational artefacts may increase the range of possible uses. A related issue is whether designing for the usability of computing artefacts should then be more concerned with their collaborative qualities rather than about maximizing human control. We will talk more about this when discussing the principles of *intention alignment* and *unification*.

4.1.3. Alignment/misalignment. The shift from Tool to Partner can be described by the principle of *intention alignment*. The intention ascribed to object and the intention of the human can align in the context of a shared activity. A shift from tool to partner can be caused by the increasing autonomy and behavioral complexity of the tool. For instance, Krüger et al. [22] describe how human-machine interaction can be approached as a form of cooperative assistance that blends the distribution of tasks and responsibilities between humans and systems. Thus, in our words, these particular tasks and responsibilities should be carefully aligned to the person for the tool to be able to function as a partner. New design methodologies are explored that carefully identify this distribution of tasks and how they intersect [20].

We would like to discuss the shift from Agent to Partner and vice versa—by the principle of *intention (mis)alignment*—in light of continuous negotiations required in human-agent collaborations. This may involve overruling, accepting or ignoring the behavior of the agent. In the case of the dog going for the bread instead of following the desires of the owner, the intentions of the human and object misalign and the human can take action by giving commands that the guide dog then accommodates to. In the case where a guide dog stands still, and will not move further whatever its owner says or does, it is the person that needs to accommodate. For instance, the dog senses a threat ahead that the person cannot see. In this case, the perceived disobedience of the dog is actually beneficial when accommodating to it, although this might not be immediately clear to the dog owner. A particular example comes from BagSight where both intentions misalign but one of them can be ignored. A person might not want to follow BagSight to the party with fireworks but the soft pulling behavior of BagSight can be easily ignored and does not interfere with a person's intention to travel to other destinations.

The hybrid character of computing artefacts leads to the question of how to design for negotiation and requires an emphasis on the importance of human control and continuous feedback when these shifts in relationships happen [1]. Designers may need to consider the 'freedoms' that the human and the object allow each other, and the 'efforts' that are required to influence or persuade the other during interaction [33]. The friction between different intentions of human and object can be useful when designing for behavior change, reflection, and learning [24].

4.1.4. Unification. The shift from Partner to Tool can be described by the principle of *intention unification*. Intention unification occurs in a situation in which the computing artefact becomes so well-attuned to a person's particular needs and goals that it feels like the human and object become *unified* in a particular activity. Examples are provided by the dog trainer who hints at how the guide dog and user can function as one entity. Verbeek [39] speaks of 'hybrid intentionality' when human and object form a new experiencing entity going beyond the human.

We can speculate how this might happen when interacting with computational artefacts. The actions of a computing artefact might be so well-attuned to the needs of a person that it anticipates on human actions before they are performed, or by the artefact acting in such subtle ways that this remains outside or disappears from the awareness of the person. Guide dogs provide an example, because they are able to processes much more about the environment than is accessible by the dog owner with a visual impairment. From the perspective of the person, intention unification might happen as the outcome of a learning process. In such a case, both actions of human and object are carried out in concert, and from the perspective of the person integrate into one fluid action and become a *gestalt* [21].

These are interesting design directions for next steps in human-computer integration [29]. It will be important to consider human technology symbiosis and fusion by discussing mixing human and technological agencies with respect to human functioning across bodily, individual and societal levels. One set of challenges Mueller et al. mention involves dealing with *implicit interaction*, *variable agencies* and *perceptual transparency*. These are relevant issues for further exploration when designing computing artefacts as hybrid characters. For example, *implicit interaction* that involves "interaction issues that stem from operating just beneath or just above the user's awareness as well as just ahead or just behind the user's intent" (p.8) is of interest to understand interaction moving from the foreground into the background of awareness, as part of a process of co-adaptation between human and artefact. *Variable agencies*, which involve the ways in which control is distributed to its users is of interest in case this distribution might become blurred as human and artefact are experienced to become unified, and may lead to a concealment or confusion about who has agency and to what extent. The authors describe *perceptual transparency* as the extent the design of an artefact allows it to be interpreted as mediating physical actions or as mediating the existence of another 'mind'. However, what can be first experienced as a collaborative activity with another entity (i.e., the partner), can later transform into an instrumental activity (i.e., the partner becoming a tool). It is therefore interesting to understand how—what the authors describe as two distinct interpretations of artefacts—can be designed to transform into one another.

4.1.5. Breakdowns. With *breakdowns* we refer to shifts that might happen when objects perceived as Tools or Agents are suddenly experienced as Things. The shift from Tool to Thing is well-described by Heidegger [16] who described the 'hammer' as different, i.e. as an object moving from *zu handen* to *vor handen*, when the object that felt like an extension of the self becomes a thing separate from it, and loses its intention conduciveness for a particular task. The shift from Agent to Thing can be described as a situation of breakdown when the intentional stance no longer functions appropriately (e.g. for effective prediction or explanation), and a design or physical stance is required to predict the functioning of the object. This implies that the object needs to be re-evaluated as a 'thing'. What also matters here is the design quality of the expressiveness of computational artefacts, expressing computation in animistic and lively ways is delicate and when not designed just right, can break the suspension of disbelief. Breakdowns can also be interpreted in a positive way, brought about by human creativity and exploration, and human ability for re-interpretation. Ambiguity can play an important role here, especially for design [14]. Ambiguousness can be an invitation of the object to be experienced and re-experienced through its sensuous or aesthetic properties, from which new explorations can start. Ambiguity has, for instance, been suggested to lead to partnerships that allowed for different types of play [5] and may also lead to different forms of appropriation [3].

4.2 Limitations

The findings and discussions resulting from the use of the tool-agent spectrum as an analytical lens are constrained by our particular cases. Focusing on guide dogs as 'living' aids in mobility in comparison to BagSight as a rudimentary type of computational artefact, involves a large difference in behavioral complexity and sentience. To strengthen the generalization of our results, we suggest to include other organisms, with more or less complex behaviors and cognitive or emotional capacities, yet are able to engage in a symbiosis with humans, such as plants or fungi. We also propose to compare simple versus complex computational devices through the lens of the tool-agent spectrum to obtain more depth in understanding the means by which perceptions of being tools or agents can shift and blend. The choice of participants in the BagSight study might have been a confounding factor. Most participants studied a Masters in Engineering and together represent a population that is higher educated and feels more comfortable with technology compared to the general public. It could well be that technical expertise could increase the adoption of the design stance and affect the extent to which computational artefacts are perceived as tools or agents. It would also be useful to explore hybridity in other domains besides mobility. For example, applying the concept of hybridity might help in understanding the changes in the experience of intimacy and trustworthiness during the use of eHealth applications or productivity-tools during habit change.

4 CONCLUSION

In this paper we have discussed how computational artefacts can display hybridity because they can be experienced as both tools and agents. We have proposed a tool-agent spectrum as an analytical lens that uses 'intention' as a central concept. This spectrum aims to help clarify how computational objects can shift or blend into tools or agents. We have applied this analytical lens to unravel people's experiences in two hybrid cases; guide dogs as a living mobility aid for the visually impaired and an experimental wearable object named "BagSight" as a rudimentary artificial counterpart. We have compared qualitative reports of user experiences in both cases through the lens of a tool-agent spectrum. We have elaborated on these results by discussing five principles (attribution, conduciveness, alignment, unification and breakdowns), that can influence the perception of computational objects as things, tools, agents or partners. We hope this work provides an interesting point of departure for illuminating computational artefacts as potentially hybrid systems and that it will help the discussions about their merit and the particular challenges in their design.

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