

Visualisation of affordances

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Abstract

Affordances are relations between a human being and their environments: the possible actions that humans perceive. In terms of affordances you don't see 'a table', but the affordance of 'putting stuff on top of it', 'appreciating its build quality' or 'standing on it to replace a light bulb'. These relations are dynamic, intangible and different per person, making it difficult for designers to sketch and communicate about them.

This research project explores how affordances might be visualised. I present insights from literature, analysis and evaluation and a dynamic visualisation sketch that supports further development.

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1 Introduction

Affordances are relations between a human being and their environments: the possible actions that humans perceive. In terms of affordances you don't see 'a table', but the affordance of 'putting stuff on top of it', 'appreciating its build quality' or 'standing on it to replace a light bulb'. These relations are dynamic, intangible and different per person, making it difficult for designers to sketch and communicate about them.

This report is about a research project on the visualisation of affordances. It explains explorations to visualise meaning in interaction, a new approach that could support theory development for interaction design in the future. The result of this project consists of an understanding of the theoretical issues at play, and a dynamic visualisation that is developed with this theory.

My reason for choosing this project is the appeal of the vision of Interaction Visualisation, as put forth by my project coach Matthias Rauterberg. As a designer I find it worthwhile to keep looking for fundamentally different principles to shape our relation with technology. I don't know of other developments in design research that take this particular route. I want to engage in this topic and see what a visualisation of interaction may look like. As a starting Master's student, it is also my way of developing a theoretical basis for developing knowledge in interaction design.

The report starts explaining the project vision and research question. I will then give an overview of related existing work. To give context to the theoretical discussion, I will then explain the visualisation, although the video makes it clearer. The next chapter is about theoretical considerations, of which I highlight a few. The report ends with a discussion and conclusions.

2 Research question and approach

2.1 Project vision

Design research is getting a grip on understanding users, interactive products and context. We have many ways to describe people and their experiences (e.g. personas as models, heart rate measurements), can make our products both in abstract form (e.g. CAD models) and experienceable (e.g. using microprocessors) and are developing ways to experiment in a realistic context (e.g. experiential design landscapes; Van Gent et al., 2011).

But these are all actors and circumstances for interaction. The interaction happens in between and within these factors. When we design for interaction, the best we can do right now is iterate with trial and error: create prototypes, test them to see what interactions occur, conclude with new requirements and go on. We cannot actually design interaction itself: interaction is personal and contextual, dynamic and intangible. Thus we cannot easily sketch it. We can't show interaction in research and education – so we rely on using abstraction tools (e.g. Interaction Frogger; Wensveen et al., 2004), showing only the physical 'trace' (e.g. videos) and experiencing prototypes ourselves (e.g. physical hypotheses; Frens 2006).

Interaction Visualisation (IV) is an approach to try it anyway. The stance is that it is not inherently impossible, but the theory just needs development. The aim is to develop:

- methods to visualise the dynamic relations in interaction,
- methods to gather data as content for these visualisations,
- methods to use this data in analysis and design (e.g. simulations, test toolkits),
- a theoretical basis that supports these methods.

This could for example result in a knowledge base of validated affordances, in an educational tool, or in a design method that starts with sketching the interaction and then helps to construct a suitable prototype. It will not replace hands-on prototyping, but it can inform us better for iterations during the design process.

2.2 Research question

Until this project, the first steps in this area were made by Bekker (2011). He made an tool that shows interaction between a robot and its environment. There is still a need to develop more well-informed examples that raise the interest of other designers. In this project I deal with the complexity of human-product interaction and pick a context that realistically benefits from IV.

Note that at this stage it is unrealistic to aim for the *optimal* way to visualise interaction. The project is an exploration of theories and an early step in method development. Therefore I started from the research question:

How can we visualise interaction to support analysis and design?

The initial sub questions were:

- A How does meaning come into place in the use of interactive products?
- B How can information about this be collected?
- C How can this information be represented?
- D What value may this approach have for design researchers?

As the project advanced, the focus shifted towards sub questions A and C. The research question became simpler:

How can we visualise affordances?

New questions were raised in the process of developing visualisations. The insights are discussed in chapter 5, and the accompanying questions could be stated as:

- 5.1 How can we describe the user, product and context?
- 5.2 From what theoretical foundation can we understand interaction?
- 5.3 How can we visualise subjective experience?
- 5.4 How does meaning come into place in interaction?
- 5.5 What approach can we take to address the dynamics in interaction?
- 5.6 How can the concept of affordance be used?
- 5.7 What can we learn from measured data about first-person perception?
- 5.8 How to deal with the subject-object dichotomy in the visualisation?
- 5.9 How can a dynamic visualisation be created?
- 5.10 How can action possibilities be categorised?

2.3 Approach and process

To be able to introduce the visualisation to researchers, I aimed to understand and apply existing theories about interaction. Another strategy was to experiment by making visualisations for evaluation.

During the project I read about theories and used these to formulate interpretations and questions. I discussed these with my coach and other experts. I synthesised this by sketching visualisations based on my own experiments, and gathering feedback on these. I finally developed a visualisation in order to convey my ideas (chapter 4). I showed this to design students and researchers and formulated my insights in this report.

3 Existing work

Outside interaction design, other disciplines have developed interaction visualisation methods that we may learn from. In this chapter I give an overview of existing work this and discuss what I consider inspirational or a shortcoming.

3.1 Outside interaction design

In aerodynamics, the wind tunnel made it possible to understand the relations between physical objects and its environment: what happens in between became visible. This has made it possible to go from trial-and-error to theory development (Wikipedia, 2014: Wind tunnel). The introduction of particle imaging velocimetry (PIV) made it possible to measure (and then visualise) the velocities of particles within a system without interfering too much with the system. This has yielded new insights in various fields, e.g. the improvement of aircraft wings and of prosthetic heart valves (Wikipedia, 2014: Particle image velocimetry).

This inspires to visualise interaction. Could their techniques be used to understand the dynamics between people and technology? There is no accepted theory about measurement of this yet, but once we know what to visualise, the methodology may be invented by psychologists, neuroscientists or data scientists.

A dynamic visualisation technique is proposed by Victor (2011), “to think explicitly about these levels [of abstraction], so a designer can move along among them consciously and confidently”. While his examples are still about interactions between technologies, it is a valuable and thought-provoking exploration.

3.2 Related to interaction design

Analysis of specific contexts in perception research have yielded theories with visualisations about relations in interaction. For example, McBeath et al. (1995) discovered a heuristic used by baseball outfielders to catch fly balls. This was explained using a mathematical model and static pictures that could be published on paper.

In social science, Kurt Lewin invented a (static) visualisation to communicate his ideas about field theory, a holistic approach towards social situatedness (Lewin, 1939). He even presents a way to define this mathematically (Lewin, 1943). However, in contrast to his theory his visualisation didn't catch on and the mathematisation seemed premature (cite discussion).

In virtual reality, a challenge is to model a controlled environment so that it resembles our experience of reality closely, in an efficient way. Badawi and Donikian (2007) propose a

structure to show action potential in terms of interaction surfaces and influence surfaces. These are however embedded in the environment as static product properties rather than dynamic relations.

Architecture has raised similar questions about affordances and there is a desire for a knowledge base. A challenge in this field is that buildings often are used differently than the architect intended. Also, in education, there is a need to illustrate when a design fails. Maier et al. (2009) give an overview of developments. Koutamanis (2006) suggests including affordances in design representations. The most concrete example is a tool to simulate dynamic visual fields and the affordance of accessibility (Tweed, 2001). This project has not been continued yet (Tweed, personal communication).

3.3 In interaction design

Following a similar vision on IV, Bekker (2011) has visualised relations between a robot's eyes and hands and its environment during a specific interaction. This is a simpler situation than human-product interaction, which made it possible to process actual data to generate a visualisation.

In discrete interaction, Petri nets (cite) are a successful method of visualisation, and simulation (Rauterberg & Fjeld, 1998). Petri nets can afford to be static since traditional computer programs often have static meaning. IV research is however more interested in an equivalent for continuous interactions.

Traditionally, video is used in interaction design to show just a third-person view on the physical component of interaction. A promising new method is to edit videos to convey a subjective user experience (Trotto et al., 2012). This relies on the designer's skill and sensibility to use the medium. This may however not suit development of affordance theory as envisioned.

4 Description of the visualisation

4.1 Description

The project resulted in a visualisation of affordances. This chapter summarises the visualisation to a level where the discussion in the next chapter makes sense. Since it is dynamic, watch the video as well:

<http://id.sanderdijkhuis.nl/m11/visaff-video>

The visualisation and the tool to create it are made as an example of dynamic visualisation of affordances for demonstration purposes. The goal is not yet to be a complete method or a tool that is useable by other designers. Also, the scenario is hypothetical: concrete applications were not a research goal.

4.2 Scenario

As an interaction design researcher, I am evaluating a tangible interaction prototype made by another student (Jordy Rooijackers). To this end, I give it to a test subject who sees it for the first time, and tell him to try it out and imagine how it could work as a media centre remote control. In first instance, I have my third-person perspective on his interaction over time (Figure 4.1). Using the tool, I can go back and forth and change the pacing to get a sense of what he's doing.



Figure 4.1: A third person view on the interaction.

Using a head-mounted camera with an eye-tracker, I can switch to his first-person perspective (Figure 4.2). I can't see how he perceives his environment – only what kind of light enters his retina –, but I can see the timing and locations of occlusions and disclosures he sees. The gaze fixations tell how he gathers information for his next manual actions.



Figure 4.2: A first person view on the interaction. The orange circle indicates the current gaze fixation point.

As I look back at the videos, I sketch how I see affordances coming into place to the test subject (Figure 4.3). I use my empathy, his thinking aloud and the full time scale of his actions to change the shape of the relations and involved entities. Using the gaze tracking data, I can show which actions the subject is looking at.

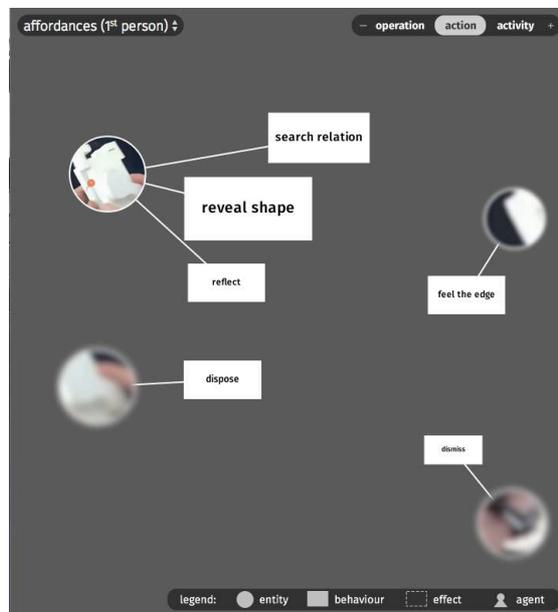


Figure 4.3: a sketch of affordances, first-person view.

I switch back and forth between a third-person perspective on affordances (Figure 4.4), and a first-person perspective. In the latter, I can express affordances explicitly as relations between the person and the product, which could be extended to compare the affordances different people perceive.

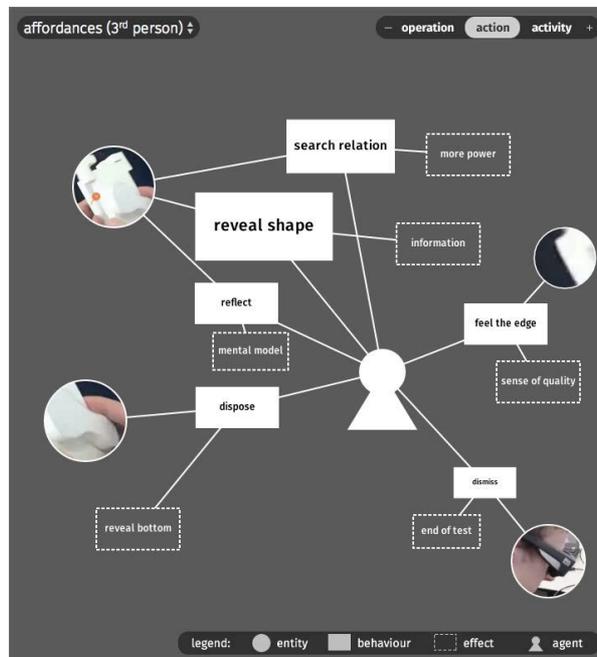


Figure 4.4: a sketch of affordances, third-person view.

The timing is synchronous to that in the videos, and pictures help to create links between the physical reality shown in the video and the sketch of the experience (Figure 4.5). Actions and intentions are described with text, so that they can express an action over time independently from the timeline. Just like in sketches of 3-D shapes, I choose how to arrange the composition to make sense for this context.

I show the sketch to other researchers and we can reflect on the qualities we see and make adjustments while viewing. The discussion helps us to create a common interpretation of the affordances that occurred during this interaction. We can compare this to a sketch of how we would like the perceived affordances to be, and compose requirements for next iteration.

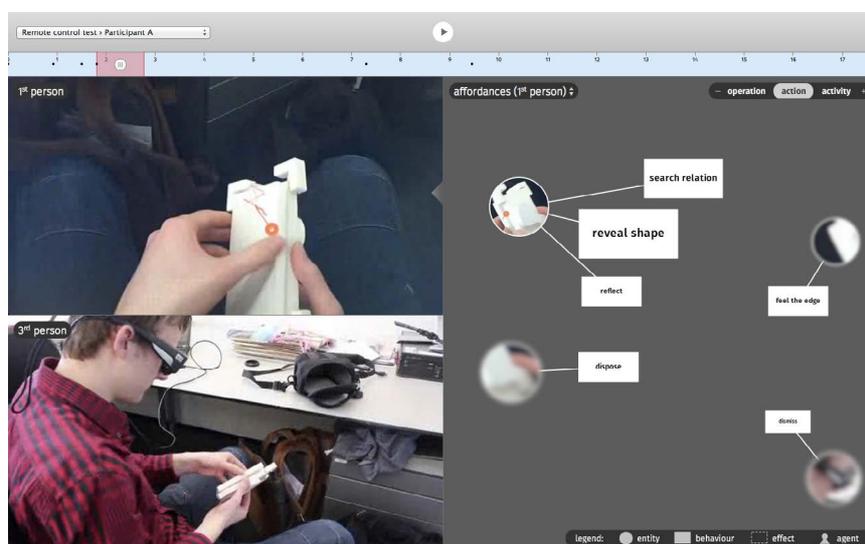


Figure 4.5: the complete interface. In the top left, an experiment can be selected. Below is a time bar with a slider that reflects the chosen time scale (section 5.10).

5 Results

This chapter explains the main theoretical issues I came across when visualising affordances. It is structured thematically and can be read in any order.

5.1 Understanding the user and the product

How can we describe the user, product and context?

There is no theory yet that explains *how* exactly meaning emerges from perception and action – how the relations between a person and their (technological) environment come into place and develop. Yet this is exactly the dynamic system that we want to show. To make the first steps easier, I looked for a context where the person and context are well understood.

To describe the way people understand their context, Norman (1988) introduced the term *user's mental model*. When considering a context for this research, I found some examples in literature where this model and the context were studied. (Table 5.1).

I couldn't find a thorough description of a mental model. The papers gave examples about how these could be studied, but I couldn't use the results or recreate the contexts easily for my visualisation. I therefore chose to stick with familiar self-created situations in the lab where I had access to eye-tracking equipment. A short description of the situations used as examples in this report is in Table 5.2.

	Context	Methodology	A. TM	B. DMM	C. UMM	D. Access	E. Distr.
Suchman, 1987	first encounters with an expert help system for a photocopier	video observation of pair usage; comparison of models in sequences	yes	yes	cognitive	similar	discrete
Johansson et al., 2001	picking up and positioning bars in a lab	comparison of measured eye & hand movement	yes	N/A	physical	similar	cont.
Sailer et al., 2005	moving a mouse cursor in a lab	analysis of measured eye movement over time	yes	N/A	physical	similar	cont.
McBeath et al., 1995	catching fly balls in baseball	comparison of model with analysis of 3rd person video data	yes	N/A	yes	difficult	cont.
Tolmie et al., 2002	knocking on the door	observation, reflection, relation to routines	no	N/A	yes	easy	discrete
Inhoff et al., 1992	typing	eye-hand coordination	yes	N/A	yes	easy	cont.
Ross, 2008	using dynamic lamps	Laban-inspired movement analysis	yes	yes	yes	possible	cont.

Killiam et al., 2000	telephone response information system	GOMS analysis, focused on satisfaction	?	?	yes	difficult	discrete
Norman, 1988	doors	reflection	(no)	yes	yes	easy	cont.
Land et al., 1999	tea making	eye-hand coordination rec.	(no)	no	yes	easy	cont.

Table 5.1. Contexts that gave some explanation of the user's mental model. Explanation of the columns: (A) Is the system's technological model (TM) explained? This includes context. (B) Is the interaction model (designer's mental model / DMM) explained? (C) Is the user's mental model (UMM) explained? (D) Can we easily access or recreate this context? (E) Is the interaction distributed in a discrete or continuous (cont.) way?

Picture	Description	1 st p.	3 rd p.
	I asked my roommate (an industrial designer) to play entering my room while I was filming him. So his actual experience was that he was following my instructions and acting out an imagined situation, but the material would suffice for illustration purposes. He knocks on the door and enters my room when he gets no answer.	no	yes
	I open the door, enter the robotics lab quietly, and close the door again, intending not to disturb the present researchers.	yes	no
	I carefully open case that I'm unfamiliar with and discover what is inside.	yes	no
	I asked a friend and ID student to try out a prototype that he has not seen before. I told him that it is designed for a project about media centre remote controls. It consists of several foam-core parts, connected using magnets and sticks. He manipulates it for several minutes to discover what he can physically do with it.	yes	yes

Table 5.2. The contexts used in this report. The last two columns tell whether first-person video and/or third-person video was recorded.

5.2 Cognitivism and phenomenology

From what theoretical foundation can we understand interaction?

5.2.1 Theory

A traditional view that developed along with computer software, is *cognitive psychology*, which takes a computational-representational and information-processing perspective (Van Dijk, 2013). It is a positivist approach: it presupposes that our mind and experience can be studied objectively using scientific methods. It also is reductionist by presupposing the existence of separate concepts, notably the (brain-)internal and the external world. In terms of meaning, one could take the view (Johnson-Laird, 1983) of either:

- realism: “meanings are determined by the nature of the world”, or
- psychologism: “meanings are mental constructions imposed on the world”.

A lot of HCI research is based on a cognitivist foundation, and takes the latter view as exemplified by Norman (1988), who described studying interaction in terms of mental models and quantitative data. A classical result is the concept of *natural mapping*, which for example prescribes that stove controls are better arranged in the same way as the stoves to reduce our cognitive load.

The scope of HCI was broadened by Suchman (1987) who showed that meaning is highly contextual, and cannot be detached from our being embodied and *situated*. Practically, this means that as a designer I cannot expect users to follow a designed plan during interaction, and I need to understand existing practice carefully.

Related is the *extended mind* theory (Clark & Chalmers, 1998) that counters the representational view and gives technology. For design, this means that interaction is less about mapping input and output, but needs to be considered one strongly coupled system.

These ideas were extended upon by bringing *phenomenology* into design (e.g., Dourish, 2004), mainly through the work of Heidegger and Merleau-Ponty. This view presupposes that instead of thoughts being prior (Descartes’ *cogito ergo sum*), our embodied experience is the first source of meaning. My world (including my ‘inner world’) exists as a meaningful environment because I interact with it, and through how I interact with it.

For designing, this means that theory and models are secondary. Meaning is subjective and constituted through bodily skills, so designing starts from a first-person perspective. I can’t know what the users will experience, but I can experience prototypes myself and empathise with users’ skills (Trotto et al., 2012).

Another value of phenomenology is that it provides useable concepts for explaining our experience with technology. For example, the distinction between *ready-to-hand* (allowing for experience-through) and *present-at-hand* (with experience-of) helps to analyse interactions and inspire design principles (e.g. Stienstra et al., 2012). In this dichotomy, the visualisation can explicitly show affordances for present-at-hand products, e.g. prototypes

that were never seen before. The interaction with ready-to-hand products is visible in how it affects the affordances in the rest of the environment.

5.2.2 Stance

For interaction design, phenomenology is a compelling starting point that allows for a more sensitive understanding of embodied interaction than extreme cognitivism would. But from this view the approach of interaction visualisation is contradictory (Lévy, expert meeting). The relations in embodied interaction cannot sensibly be studied as concepts per se, because they constitute the given background before which we would do so.

Therefore my visualisation approach keeps a cognitivist element, claiming that we can indeed develop methods to study interaction through an objective medium. However, to deal with subjectivity and representation issues, I make the first-person perspective explicit and aim for an approach compatible with phenomenology, as will be seen later in this chapter.

5.3 Visualising the lived world

How can we visualise subjective experience?

Related to phenomenology comes the concept of lifeworld or lived world (*Lebenswelt*; Wikipedia, 2014: Lifeworld). To study interaction it doesn't make sense to consider an objective world outside of our human experience. We don't experience living in a four-dimensional data structure, but in a meaningful reality. I have explored this concept by looking at and creating examples of visualisation. In use of a door (Figure 5.1), the subject doesn't perceive 'a door' but an obstruction between him and the situation he has in mind.

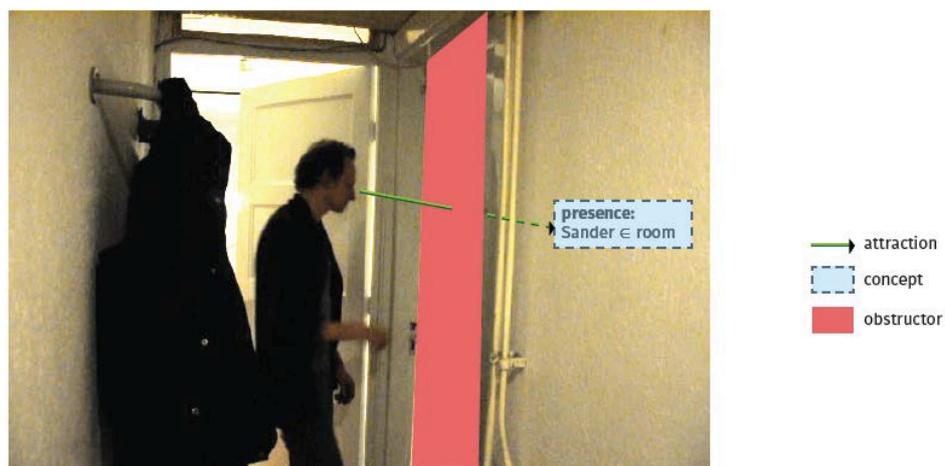


Figure 5.1: static visualisation of an intention in interaction.

But this representation is limited. The physical world is not a container of mental concepts and perception of space is just one category of perception. In the case of Figure 5.1, the

subject's experience of imagining me being in my room is not physically blocked by the door.

The visualisations by Lewin (1939) succeed better to express relations in the lived world and illustrate his field theory. In this shape the same situation could be shown as in Figure 5.2.

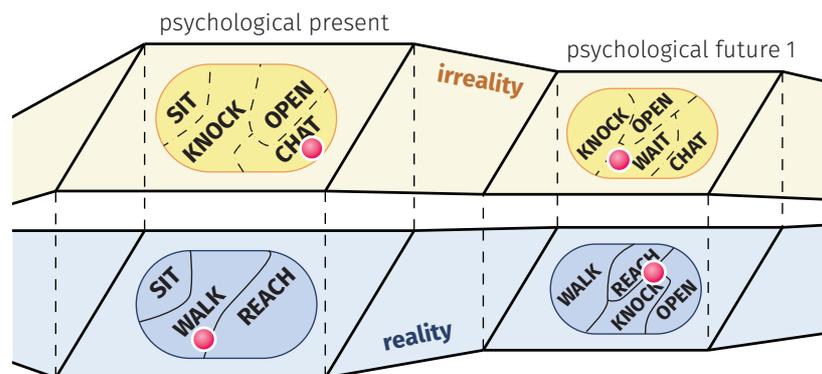


Figure 5.2. A visualisation of my roommate's door interaction inspired by field theory.

Note that the time axis is related to *psychological time* (Lewin, 1943) rather than physical time. The visualisation describes the subject's experience of past, present and future at a specific moment. It therefore is a static visualisation.

This route is continued by the visualisation in chapter 4: its structure is not forced into the space of reality, but creates a conceptual space that also allows for affordance relationships with imagined entities (e.g. thoughts), illusions or entities in different spaces.

5.4 Meaning in interaction, affordances

How does meaning come into place in interaction?

Interaction for our purposes is presupposed to consist of dynamic relations between a person and technology. Sub questions for visualisation are then: what are the meaningful relations in interaction? What is meaning? Dourish (2001) analyses meaning in terms of *ontology*, *intersubjectivity* and *intentionality*. He argues that meaning emerges in action, from the *coupling* between people's action and the product's function (Overbeeke & Wensveen, 2003). This idea is closely related to phenomenology and motivates to consider the lived world in terms of action possibilities.

This perspective is made operational through the concept of *affordance*, that I use for the visualisation (see chapter 4). Although the concept was introduced by Gibson to create a theory of ecological perception, it can be extended to describe emotions, imagined concepts, etc. (Sanders, 1997). I can experience the affordance of dancing on my table, but

also the affordance of solving the equation $y = ax^2 + bx + c$, or of arranging my thoughts about affordances.

With this extension, affordances allow for a holistic consideration of experience. As argued by Shaw and McIntyre (1974), a goal of theory development may be to understand the structure and symmetries of affordances. An important notion they introduce is *attensity*: an experienced level of significance, related to cognitive salience and action probability. This is expressed in the visualisation by size (Figure 5.3).

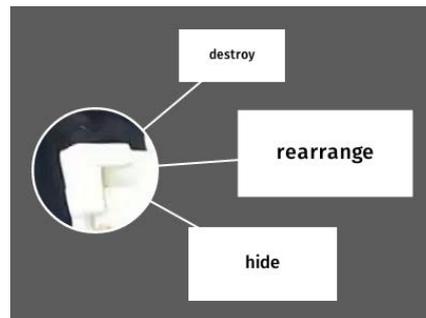


Figure 5.3: Multiple affordances with different levels of attensity.

5.5 Dynamic systems approach

What approach can we take to address the dynamics in interaction?

5.5.1 Introduction

The mission of ID at the TU/e (Overbeeke, 2007) states a direction of our design expertise towards interaction as a dynamic structure $I = f(U, S, C)$ that relates U = users, S = systems in a C = context of use in space-time. Could this structure be approached mathematically to inform an interaction visualisation? The closest attempt that I could find is in a theory about cognitive development (Thelen & Smith, 1994).

The authors Smith propose to use dynamic systems theory to study the relation between cognition and action over time. For each study, they model a continuous state space, spanned by the degrees of freedom considered relevant. Interaction is seen as the trajectory of one point through this state space. This trajectory has momentum and is influenced by the space's intrinsic dynamics. For each individual, these dynamics differ and develop. *Meaning* – in its motor, perceptual and cognitive senses – is represented in the personal state space as attractors, that direct an interaction's trajectory. Theorists can use this model as a common language and visualisation technique to explain phenomena in cognitive development.

5.5.2 Experiments

In a similar way I visualised entering the robot lab room through a door (Figure 5.4) in a state space spanned by the door angle relative to its frame (0° – 160°) and the angle of my gaze direction relative to the door frame, when viewed down from the ceiling (0° – 360°) (Figure 5.5). I have estimated the angles using the gaze tracking video, and connected

them to draw the trajectory. When looking subjectively at this trajectory, I recognise meaningful state space segments, like 'close the door carefully'. I expect next instances where I enter the room to look similar, revealing an underlying attractor structure in state-space.



Figure 5.4 (left). Screen shot from a gaze tracking video. The orange circle indicates the current gaze position.

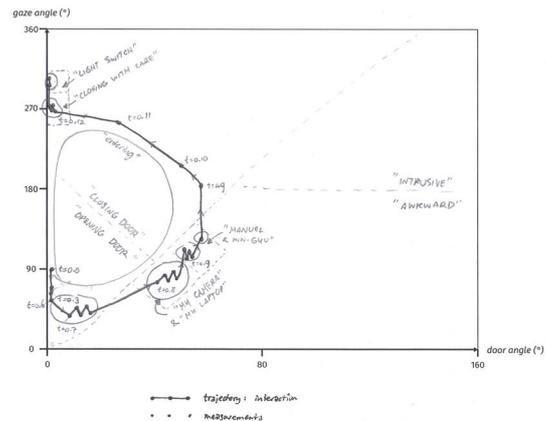


Figure 5.5 (right). Visualisation of a 2-D state space in which the experiment is analysed.

A simpler attempt is in Figure 5.6, based on the same approach. Here state space is one-dimensional, a mapping of the distance between my house mate's room and myself (horizontal axis). The trajectory is the trace of the red ball over time (vertical axis). The state space structure at each point in time is shown as a blue line, showing attractive points in space (valleys) and repellent points (hills). A metaphor to understand this could be a marble going over a deforming track. The track shape at time $t + \Delta t$ is determined by the shape at time t and the interaction occurring over Δt . For example, in the first instance the subject is attracted to a place in the middle of my room, as shown by the deep valley. When he sees that my door is closed, a repellent hill arises at the door's position, obstructing his way into my room. While he interacts with the door, the landscape changes so that he can ultimately 'roll' towards an appropriate location.

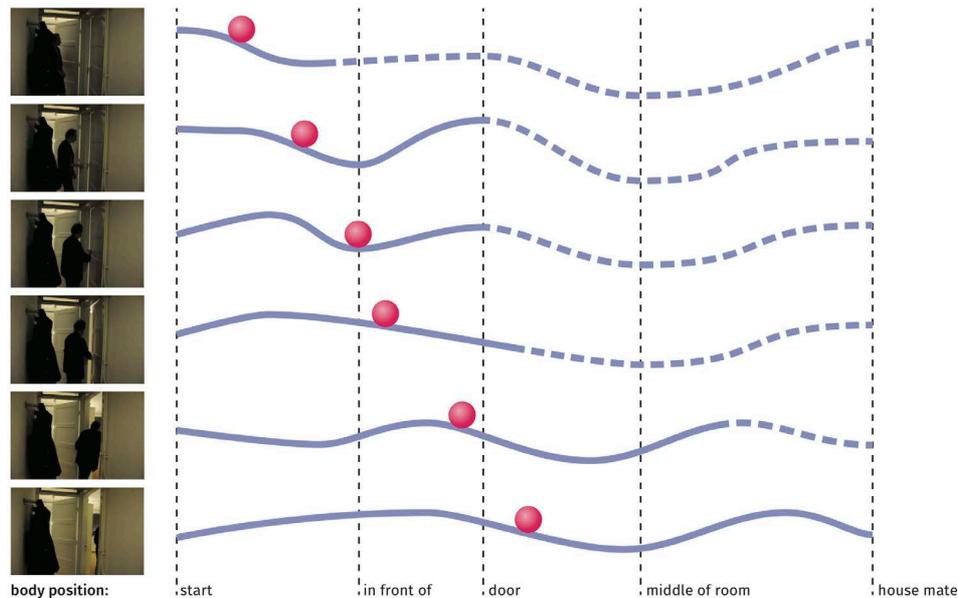


Figure 5.6. The uninterrupted line is a part of 'state space' that the subject has knowledge of by perception during this interaction. The dashed part of the line is based on intention and expectation.

5.5.3 Discussion

Abstractions like this could support descriptions of movement and provide a structure to discuss meaning. These movements can be bodily movements, but also a movement through emotional states or a change in parameters of an interactive product. It is a mathematical interpretation of 'meaning emerging from action'.

But it falls short to support a general visualisation of meaning in interaction. It is a method of abstraction: the process starts by selecting a set of state space parameters, throwing away all other information. For example, when I analyse the meaning in opening a door only using physical angles, I miss all meaning related to my intentions, other people's reactions, etc. The resulting visualisation is a more limited view of the interaction than we already had. This appears to be a pitfall of starting from an abstract model rather than an open-ended description.

Another way in which this approach falls short is that it is a static visualisation. It flattens down the potential richness of interaction. This makes it difficult for designers to develop an intuition for the movements involved.

Finally, in the given examples, only the dynamics of user properties and product properties were modelled. The vision for IV is to show the dynamics of the relations between the user and the product instead. While these are related, it is not clear whether these can be expressed in the same state space structure.

This abstraction approach may become useful for IV when we start to detect perceived affordances from measurement data. This could then be used to create the content of a

visualisation. A promising result in virtual reality studies (Renaud et al., 2003) suggests that affordances may be recognised mathematically from a characteristic signature in trajectories as described above.

5.6 Models of affordance

How can the concept of affordance be used?

Affordances were introduced to design by Norman (1988). The concept was severely misunderstood by designers (Norman, 1999). The main misconception was that affordances were considered properties of products rather than relations in the person-environment system. This makes a discussion about affordances difficult, especially with other disciplines like engineering which are less used to taking subjectivity into account.

Scarantino (2002) gives a precise definition to talk about affordances. However, this doesn't tell about the structure of an affordance relation. This is discussed in detail by Şahin et al. (2007), who provides definitions from three perspectives (Figure 5.8). He makes the perspective towards the relation explicit and uses equivalence classes to deal with the fact that each action is different.

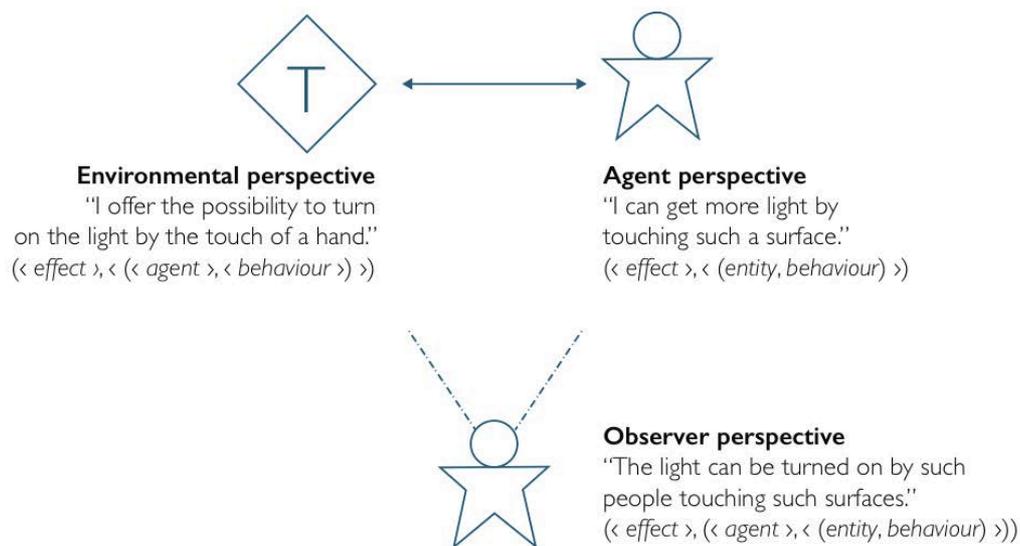


Figure 5.7: Three perspectives on affordances.

This informed the structure used in the visualisation (Figure 5.8). A first-person and a third-person perspective are available. They show the same action possibilities (since the data is provided using the third-person perspective), but the first-person perspective emphasises the individual perception of affordances (by blurring out entities in peripheral vision, Figure 4.3) and the third-person perspective includes the possibility to show and compare multiple actors (Figure 4.4).

In the first-person view I have also hidden the effects. Even though they are part of the affordance relation, they are not perceived directly. Also, note that the entities (the circles) are not perceived as entities either: in the visualisations they are just an end point for the affordance relations.

Affordance relations need to be carefully visualised. For example, the representation in Figure 5.9 is misleading. The intent was to show agent-entity relations labelled by behaviour, but the introduction of a connection point suggests that the relation has a centre. The examples in chapter 4 communicate the role of action better.

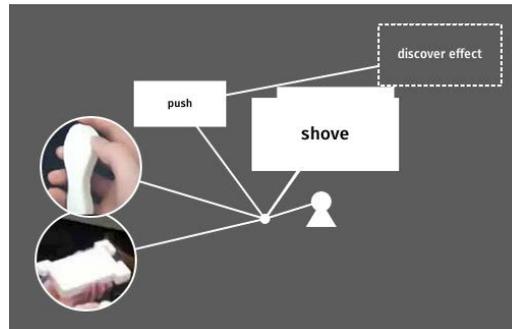


Figure 5.9: a view in the earlier visualisation, with a centre point to connect relations.

5.7 Eye-hand coordination

What can we learn from measured data about first-person perception?

Since meaning is subjective and emerges from perception and action, access to first-person perception is valuable for our visualisation. Visual perception is the easiest to achieve and in this project, this was done using an SMI Eye Tracking Glasses 2.0 kit and BeGaze software.

The literature provides promising ways to use this data. However, for the purpose of the current visualisation, the use was limited to capturing video and using the gaze position to interpret the appearance of affordances. Also, in the first-person view, physical entities that are not looked at, appear blurred.

In eye movement analysis, *saccadic eye movements* and *gaze fixation* are studied (Johansson et al., 2001). Interesting results that relate to primacy of action is that fixations are mainly on action control points rather than intrinsic object features; and saccades are often directed to sites offset from the physical objects. In an overview of recent results, Land (2006) mentions more relevant insights:

- Gaze seems always ahead of the action, gathering information for the next action.
- Tasks have characteristic but flexible patterns of eye movements.

Another kind of analysis is done in *egocentric vision*, an engineering discipline around head-mounted camera images. In measurements for affordance visualisations, this could provide ways to recognise actions and activities (Fathi et al., 2012).

5.8 First- and third-person perspectives

How to deal with the subject-object dichotomy in the visualisation?

In IV, two challenges arise with respect to the subject-object dichotomy. The first is: *how can I visualise subjective experience in relation to an 'objective environment', a world consisting of artefacts, events, etc.?* Phenomenology helps to deal with this by stating that the subjective and the objective interrelate: consciousness is always intentional towards an object, and reality primarily discloses itself through conscious phenomena. From this paradigm I can visualise interaction from a first-person perspective (Figure 5.10): I perceive and act upon action possibilities, shaped and organised by my present embodiment.

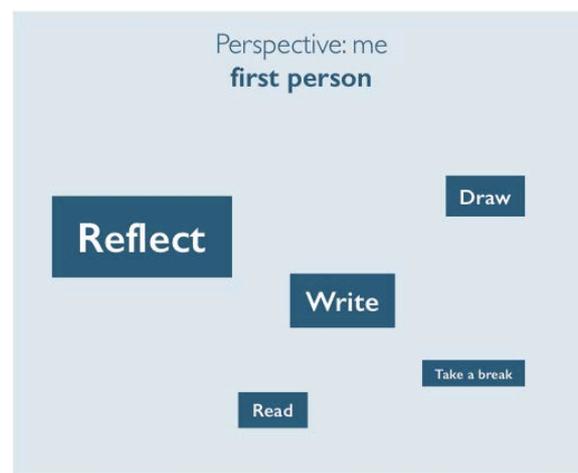


Figure 5.10. First-person perspective on action possibilities.

This kind of visualisation could inform *phenomenological design* (Hummels, 2012), especially when richer and more sensuous descriptions are used than 'Write', 'Draw' etc.

It does not yet show the human-product system in terms of relations. This limits its usefulness for analysis and theory development. The second challenge is: *how can I show relations between a human being and a product?* The paradigm of post-phenomenology (Verbeek, 2010) enables me to do so. It considers the relations between subject and object as a process of co-shaping, mediated by technology (and other structures?). Within this paradigm, it makes sense to take a step back and look at the relations between myself and my world. I can make explicit:

- the life-world: action possibilities the subject sees;
- the co-shaping relations between the subject and the life-world;
- the technological structures that mediate this co-shaping process.

When combined, this is (almost) a visualisation of affordances (Figure 5.11).

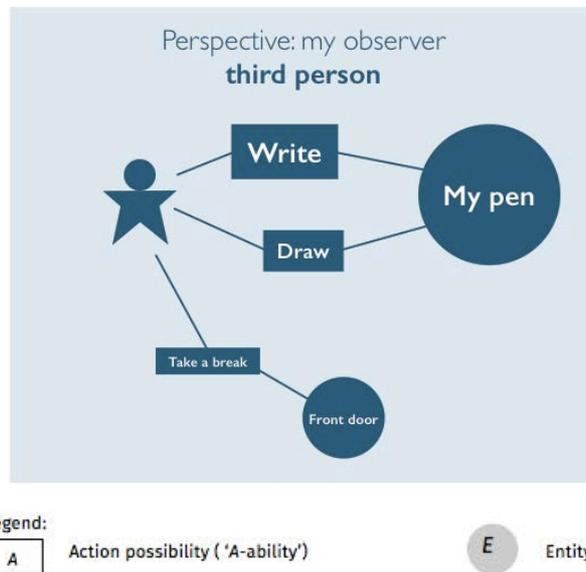


Figure 5.11. Third-person perspective on action possibilities.

5.9 Technology for dynamic visualisations

How can a dynamic visualisation be created?

There are only few design tools available to visualise dynamics in interaction, except for prototypes and video. With a growing interest in the aesthetics of dynamics, alternative ways of looking may help. For example, Figure 5.12 shows dynamics of action in an Euclidean projection of space-time.

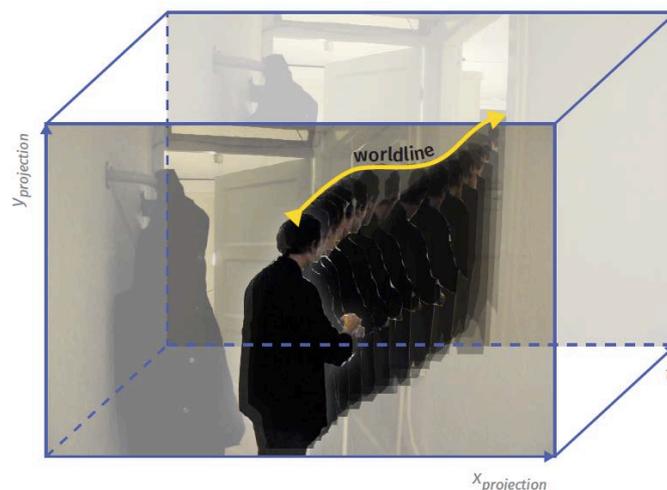


Figure 5.12: a static space-time visualisation of movement through a door.

But this is a static representation, and shows the subject and no interaction relations. The dynamics are flattened, which makes it difficult to develop an intuition. Victor (2011) proposes looking at multiple levels of abstraction, for which no design tools exist yet

To keep options for extension open, the visualisation chapter 4 was sketched with a tool I developed using D3.js (Bostock, 2014). It allows for exploring a synchronised timeline and (re-)composing affordance structures at any time.

5.10 Ontology for interaction

How can action possibilities be categorised?

Even though action precedes the concept of action, in the visualisation I choose to use words to signify action possibilities. Richer expressions may be available and explored further, but words can describe the dynamics of action sufficiently for our purposes.

Lewin (1943) discusses issues with time for understanding experience. Since meaning is in movement, the method needs to consider a *moment* as a period of time rather than a unit-less instance. Also, it needs to be considered at multiple scales. On a micro-scale, I'm saying 'A', on an intermediate scale I'm giving my computer the 'Paste' speech command and on a macro-scale I'm editing my report.

In relation to affordances, a scale level hierarchy was defined in the *nested affordances model* (Pols, 2011):

- opportunity for manipulation (e.g. hitting a glass pane),
- opportunity for effect (e.g. breaking a glass pane),
- opportunity for use (e.g. obtaining an emergency hammer),
- opportunity for social activity (e.g. escaping a crashed vehicle).

This however focuses on social and ethical issues in interaction, rather than the user experience. I therefore turn to a hierarchy in action theory (Frese & Zapf, 1994):

- sensorimotor level,
- level of flexible action pattern,
- intellectual level,
- heuristic level.

In this theory, actions on the latter three levels are guided by subgoals, goals and standard or metagoals. For compatibility with affordance theory, I choose to discard the separate intellectual level and interpret that in terms of actions, following the argument in section 5.4. In the light of embodied cognition and advanced knowledge of complex unconscious thought (Dijksterhuis & Nordgren, 2006), the distinction (and ranking) between action and intellect is dated. The used hierarchy is:

- operation level (Figure 1, sensorimotor, e.g. rearranging the pen and paper),
- action level (Figure 2, flexible action pattern or intellectual, e.g. writing a word)
- activity level (Figure 3, heuristic, e.g. finishing a report).

To classify behaviour on action and activity levels, it is common to work with a context-specific ontology (e.g. for western kitchen activity: Helaoui et al., 2013). Actions on an operation level can be classified with generic categories. In the example (Figure 5.13) a verified hand-object interaction ontology is used (Wörgötter et al., 2013):

rearrange, destroy, break, take down, hide, construct



Figure 5.13: visualisations on three different levels.

6 Discussion

6.1 Use of this work

In expert meetings (Appendix A), I asked design researchers outside of this project for their view on the use of this kind of visualisation. These were suggestions (personal interpretation and summary):

- Use it to educate students about affordances (Emilia Barakova).
- Extend it to explore multi-user systems and social affordances (Emilia Barakova).
- Add parameters of bodily skills (e.g. leg height) to discover relations between different people's embodiment and affordance perception (Jelle Stienstra).
- Show the affordances as distortions in the first-person video to get closer to the subject's perception (Jelle Stienstra).
- Use it to analyse a situation where your interactive prototype is not used in the intended way (Pierre Lévy).
- Iterate by looping between the visualisation and prototyping. Compare the effect of taking either one as a starting point (Pierre Lévy).

6.2 Status of this visualisation

The visualisation in chapter 4 is presented as a sketch on which further iterations can be made. The structure will for example likely not scale easily to more complex interactive systems. Also a more complete consideration of context (including e.g. the presence of an observer) may add new requirements.

A first way to allow for more complexity is by adding dimensions. The current visualisation takes place on a 2-D plane, but this already makes it less rich than the video of 3-D space.

Also, more rigid requirements could be set to positions in the visualisation. It is currently left open to the researcher who sketches an affordance visualisation, just as the composition of a 3-D form sketch depends on the designer's judgement.

6.3 Theoretical basis

In this report I combine theories that seem incompatible, sometimes by discarding premises that seem out-dated with regard to design research. As a designer I am used to relating perspectives and to working with inconsistencies. I have tried to provide valid arguments or earlier research where I choose to involve theories. The result is my critical interpretation of how to visualise affordances. As a more general theory, it requires further development.

7 Conclusions

The project started from the idea that interaction visualisation can become a valuable method to inform design. This idea is supported by theory development in other disciplines based on such visualisations.

To explore the topic, familiar contexts with simple interactions are used. Theories from both cognitivism and phenomenology are applied where they are productive for designing. A shared concept is central: affordances provide a useful structure to consider how action possibilities determine experience. The perspective from which they are presented is important to consider: failing to do so commonly causes thinking errors which render the concept of affordances problematic for design. A visualisation of affordances should their dynamicity and multi-level scale.

The exploration resulted in a sketch of an affordance visualisation. This has shown to be a useful platform for discussion and further development of the interaction visualisation method.

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Appendix

A Expert meetings

I have discussed the visualisation with several researchers, asking how they consider its value for design, how it relates to their concept of affordances and what further development they recommend. Below are main insights that influenced the presentation and visualisation.

Emilia Barakova

- The visualisations could be used to educate ID students about affordances.
- To present the value of this approach, you need clear examples.
- An alternative to affordance theory may be common coding theory, which may have less of a distinction between perception and action.

Jelle Stienstra

- Important aspects of affordance theory are direct perception, attensity and bodily skills.
 - I added dynamics in action size based on the concept of attensity.
- It may be more valuable to give designers better tools to experience the user's skills than to see a visualisation modelling their perceived affordances.
 - This changed my focus in presentation towards research and education initially.
- The visualisation could do a better job at showing the influence of context.

Joep Frens

- There's a risk of stretching the term *affordance* too much by making it a container for all experience.
- A good point for reflection is why I as a designer take on a project with this theoretical difficulty.

Pierre Lévy

- Be clear about how decisions are made about composition of the affordance sketch.
- It could be a tool to think and discuss more clearly about affordances, without making errors about their nature.
- The concept of 'visualising affordances' is full of contradictions, but that can be a nice source for creativity.