Designing for Perceptual Crossing: Designing and Comparing Three Behaviors

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ABSTRACT
Perceptual crossing is the reciprocal interplay of perceiving while being perceived. In this paper we discuss the last iteration of our ongoing research project on designing for perceptive qualities in systems of interactive products. We describe the design of explorative behavior in an artifact to enable the artifact and a person to engage in perceptual crossing. The explorative behavior is compared to the following and active behavior, the results of two earlier iterations. Through the iterations we formulated, applied and evaluated design relevant knowledge in the form of seven design notions. These notions inform design-researchers and design-practitioners on how to design for perceptive qualities in systems of interactive products. Here we specifically focus on how the artifact detects active perceptive behavior of a person, and how the artifact becomes aware of bygone perception and anticipates on future perception. An experiment shows how participants preferred the resulting explorative behavior that is closest to our theoretical framework based on phenomenology.

Author Keywords
Perceptual Crossing; Perceptive Qualities; Design Theory; Phenomenology; Product Behavior; Research through Design

ACM Classification Keywords
H.5.m. Miscellaneous

General Terms
Design; Theory

INTRODUCTION
Over the last two and a half years we worked on our research project on designing for perceptive qualities in systems of interactive products. We investigate whether it is possible to design for perceptive qualities in an artifact for perceptual crossing between person and artifact to happen. The phenomenon of perceptual crossing is the reciprocal interplay of perceiving while being perceived. We build on this work, where now we describe the third and last iteration of designing for perceptual crossing between person and the designed artifact and try to approach the theoretical framework, introduced further on in the text, as close as possible. We bring forward a new perspective on forming and framing an artifact’s intelligence from an action- and quality centered approach. Our research is inspired by and grounded in the phenomenology of perception [20] and ecological psychology [13]. In the course of the interaction the artifact shows meaningful perceptive behavior to the person and moreover the perceptive behavior of the person becomes meaningful to the artifact.

Our design-research artifact is PeP+ (short for Perception Pillar plus), an iteration on PeP (short for Perception Pillar). By designing and evaluating PeP [2] we formulated a set of seven design notions. We developed this design relevant knowledge by applying and evaluating the design notions in PeP+. In this paper we discuss two challenges for designing for perceptual crossing. (1) PeP+ has to come to appreciate it is being perceived by a person. (2) PeP+ has to engage in the active reciprocal interplay of attraction and escape with a person, characteristic for perceptual crossing. The resulting behavior is referred to as explorative behavior. We compare the explorative behavior to both the following and active behavior. These behaviors are the result of two earlier iterations. The main hypothesis is that participants feel most involved with PeP+ when it exhibits explorative behavior. Moreover we are interested to see whether the participants experience the play of attraction and escape.

The theoretical background, the designed artifact PeP+ and the definition of the design notions have been introduced more extensively in earlier publications [2, 3]. In this paper we will reiterate briefly for ease of reading and to clearly state the challenges for the current work.
Related Work
Winograd & Flores first introduced phenomenology to the broader HCI community [28]. Svanæs [27] and Fälmann [9] showed the relevance for HCI. Also in the related fields of Embodied Interaction [8], Movement & Interaction [22, 23, 25], Aesthetics & Interaction [1,14] and Social Robotic [7] the relevance of phenomenology is shown. In these works phenomenology is often used to provide knowledge on, and a better understanding of, how users are acting-in-the-world. Whereas the related work in the HCI community often tends to be more analytical by nature, our work aims to use phenomenology as a means of inspiration and input for the synthesis of new designs. Perceputual crossing has been topic of investigation and source of inspiration in field of Mediated Social Interaction [17, 4] and Social Robotics [12, 21].

DESIGNING FOR PERCEPTUAL CROSSING
Following Merleau-Ponty [20] perception is inherently interactive and participatory. Perception is the direct coupling between the actions we undertake and the sensory feedback this results in and the other way around. Perception is active [13]. The phenomenon of perceptual crossing is the reciprocal interplay of perceiving while being perceived [17, 18]. In more simple words: I can see you seeing me and you see me seeing you. As our perception of each other crosses we attract and escape from each other’s perception. We look each other in the eye to escape from this again. It is in this active reciprocal interplay that we come to understand each other’s viewpoint and build a common history in the course of the interaction; we feel involved.

Figure 1. Descriptive design relevant model on perceptual crossing between subject (person) and object (artifact).

Perceptual crossing is natural between human subjects. We investigate if it is possible to design for perceptive qualities in an artifact for perceptual crossing between person and artifact to happen. Figure 1 shows the design relevant theoretical model of perceptual crossing between person and artifact. The person (subject) undertakes actions to perceive the artifact. The artifact perceives these actions. This also works the other way around as the artifact perceptively undertakes actions to perceive the person (the dotted lines in the diagram). The perception of person and artifact crosses.

Besides affecting each other, both artifact and person also affect and are affected by the environment. Figure 2 sketches this common space by the addition of an external event. The perception of this event is also the result of the actions they undertake towards the event and the sensory feedback this results in. In this paper we solely focus on the reciprocal interplay between person and artifact.

The Designed Artifact
The designed artifact is named PeP+ [3]. PeP+ is like its predecessor PeP [2] a square pillar. The pillar functions as a housing for the electronics. The focus is on the dynamic light design in the top surface of the pillar. In the top surface a light body behaves in relation to the person. The algorithm that couples sensors and actuators is paramount for designing the perceptive behavior. PeP+ is deliberately minimalist in implementation and contextualization and is treated as physical hypothesis [11] in an experiment. We follow the so-called ‘Lab’ approach where design knowledge is generated through empirical research on theoretically inspired designed artifacts [16]. Figure 3 gives an impression of PeP+.

Figure 2. Descriptive design relevant model on perceptual crossing, including external event. Note that the lower part is a simplified representation of the model in figure 1.

Design Notions
From the process of designing and evaluating PeP and PeP+ we formulated a set of design notions. We will introduce these design notions briefly. For a more thorough description please refer to [3]. Note that for clarity reasons we changed the labels of the design notions.

Focus the Senses: sensing and acting have to be embodied together in order for the artifact to naturally focus its senses and to become more than just a following entity.
Show Explorative Behavior: the artifact should be motivated to explore, this way the person is able to perceive its presence and to engage in an active interplay of attraction and escape.

Subtleness of Movement: when designing for perceptive activity the subtleness of the physical appearance, the actual movements and their integration should be considered.

React to External Event: sharing perception of the common space, by the addition of an external event, amends the reciprocal interplay.

Recognize Explorative Behavior Subject: the perceptive activity of the person should become meaningful to the artifact in the course of the interaction.

Reflect Contextual Noise: contextual noise can be reflected in the perceptive activity of the artifact to create behavior that is not anticipated upon but is a natural result of the context.

Remember and Anticipate Perception over Time: the artifact gets, as it were, an experience; it is aware of bygone perception and anticipates on future perception.

THREE BEHAVIORS
The design notions had been developed through several iterations of designing, building and evaluating. The following and active behaviors are the result of two earlier iterations. To evaluate the development of the design notions and their influence on the person’s experience and on the interaction we compared the following and active behavior in an experiment [3]. Based on the observations and results we designed the explorative behavior.

Table 1 gives an overview of the development of the design notions in the three behaviors as applied in PeP+. Dark shading indicates a strong implementation of the design notion and a strong connection to theory.

Table 1. Overview of implementation of design notions in the three behaviors, the darker the shading the stronger the implementation and connection to theory

<table>
<thead>
<tr>
<th></th>
<th>Focus on the Senses</th>
<th>Show Explorative Behavior</th>
<th>Subtleness of Movement</th>
<th>Reflect Contextual Noise</th>
<th>React to External Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following (CHI 2011)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Active (IJDesign 2012)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Explorative (described here)</td>
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</tr>
</tbody>
</table>

Note that ‘Reflect Contextual Noise’ depends on the integration of electronics, and is identical for the three behaviors of PeP+. ‘React to External Event’ is not considered as the three behaviors we discuss here solely focus on the reciprocal interplay between person and artifact. This paper describes the development of the design notions that lead to the explorative behavior. The comparison of the explorative behavior to both the following and active behavior, evaluates the influence of the behavior of PeP+ on the person’s experience and on the interaction between person and artifact. We will briefly describe the following and active behavior and extensively discuss the design and evaluation of the explorative behavior.

Following Behavior
The movement of the light body in the following behavior is completely determined by the sensor input at that moment: the light body just follows by focusing its light on the person. Sensing and acting are not strongly embodied as the position of the light body is only depending on the input by the sensors and not the other way around (Focus the Senses). The light body does not need to act for PeP+ to detect the person. On the other hand to detect not the body image of the person but her activity, the change of sensor input is used to detect the person (Recognize Explorative Behavior Subject). The light body does show exploratory movements like tracing the environment; nonetheless these are just an impression. By these actions the light body does not actually explore as it gets input from all sensors all the time (Show Explorative Behavior). The following behavior of PeP+ directly builds on the behavior of PeP. The integration and balance of material, electronics and dynamics is improved in PeP+ (Subtleness of Movement).

Active Behavior
In the active behavior a direct coupling between sensing and acting applies. The position of the light body is not only depending on the sensor input, but the sensor input also depends on the position of the light body (Focus the Senses). This means that the light body does not only focuses as a reaction to the activity of the person, but that it literally focuses its senses to actually detect the person. Furthermore exploratory movements are not longer an impression: the light body has to move to explore. Expectation and curiosity motivate the light body to explore different sides of the pillar (Show Explorative Behaviour). The light body actively explores the space and actively focuses when it detects a person. The expectation builds on a history of sensor input and so PeP+ has a short memory. In time the light body will get curious about what is happening in the environment and explores different sides of the pillar (Remember and Anticipate Perception over Time). The person has to be active to draw the light body’s attention again (Recognize Explorative Behavior Subject).

EXPLORATIVE BEHAVIOR
Insights
Designing and evaluating the following and active behavior showed that so far (1) the person could perceive the artifact, (2) the artifact could perceive the person, (3) the person could perceive the artifact perceiving her, but (4) the
artifact could not perceive the perceptive activity of the person perceiving it. In the active behavior the light body shows initiative to which people attribute the meaning of ‘it wants something’. This initiative actually does not directly relate to PeP+’s perception of the person. It is an intrinsic motivation to explore the (common) space, which is subjective to the activity of the person. PeP+ explores the environment rather than the person. It does not appreciate it being perceived and logically does not act upon this.

The perception of the person and PeP+ cannot cross as proposed in the theoretical design relevant model (figure 1). Nonetheless the description of participants of the active behavior that relate to ‘it wants something’ or ‘trying to get me in a direction’ show that people feel to be engaged in a rich reciprocal interplay. PeP+ influences the interaction and thus the person’s behavior in the active behavior; the difference in the explorative behavior is that PeP+ has the directed intention to do so.

To implement the idea that PeP+ appreciates it is being perceived the design notions ‘Detecting Active Behavior Subject’ and ‘Course of Perception in Time’ are developed. Although it was clear before comparing the following and active behavior, that some design notions were more strongly developed than others, it is because of the experiment and our observations that we came to understand how to develop these design notions further.

Perceptual crossing is characterized by the attraction and escape from each other’s perception [18]. When we are in a dialogue I will look you in the eye and then escape from this again. This force of attraction and escape or following and leading is characterized by strong dynamic qualities. We implemented these qualities more thoroughly in the explorative behavior. The dynamics and appearance of the light body in the explorative behavior show to the person that PeP+ is aware that they perceive each other. In other words this moment of appreciation -we see each other- reflects in the perceptive activity of the light body. The form and dimensions of PeP+ are unchanged.

Summarizing the challenge is to (1) design the algorithm in such a way that the light body comes to appreciate it is being perceived (Recognize Explorative Behavior Subject). Moreover (2) the appearance and dynamics of the light body are considered. How can the light body lure the person in a game of attraction and escape (Remember and Anticipate Perception over Time)? What dynamics motivate the person to not only attract but also follow the light body?

Recognize Explorative Behavior Subject
As the interaction with PeP+ is mainly visual one can argue that PeP+ should be enabled to ‘see’ that the person sees it. Yet the implementation of ‘seeing’ is complex and we do not want to add to PeP+’s physical and technical characteristics. Movement plots, that are a result of the experiment in which we evaluated the active and following behavior, are used as inspiration. We made movement plots [19] of the activity of all participants. Apparent from all these movement plots was that (1) participants have a certain approach that is recognizable in both the behaviors they experience and (2) that there are different parameters that characterize the exploration. These are parameters like alternating between walking and standing still, moving around the pillar and varying the distance to the pillar. Participants explored and observed, i.e., they moved and than saw what happened. What stood out was that participants that felt not to be perceived by PeP+ tended to be more observing than actively exploring in the interaction. Analyzing the movement plots brought forward a new perspective on how to make PeP+ perceive it is being perceived. Can PeP+ perceive the exploratory movements of the person perceiving it, i.e. can PeP+ detect it is being explored?

Implementation
The explorative behavior builds on the active behavior. The algorithm of the active behavior uses several parameters as motivation for the light body to move. Such a parameter is the curiosity that increases in time in relation to previous experience. A different parameter is the surprise that is caused by the activity of the person and expectation build upon the person’s activity. For example if the person just stands on one side of PeP+ there will be surprise on this side. The surprise will decrease if the person keeps standing there without being active. Meanwhile the uncertainty will rise on other sides. These parameters vary in relation to the behavior of the person. When the person actively explores the levels of uncertainty and surprise significantly differ from when the person is just wandering around the pillar. Based on these characteristics PeP+ will get more confident it is being explored or not over time.

The development of the algorithm was an iterative process. We first started to build a tracking system with the input of the eight sensors of PeP+. We are well able to follow the path of the person and draw information from this. Nonetheless using all sensors all the time, not taking into account the position of the light body, makes that sensing and acting are disembodied. Decisions that are made upon this information are a predefined mechanism while we like to build intelligence in the course of the interaction. It is actually the uncertainty of only perceiving a limited space that triggers the dynamics of attraction and escape that we set out to design for. The parameters that are used to detect whether PeP+ is being explored are inherent to the active behavior. PeP+ becomes certain it is being explored in the actual course of the interaction.

Remember and Anticipate Perception over Time
When PeP+ perceives it is being perceived, i.e., PeP+ detects it is being explored, it will adjust its behavior and try to engage in an active interplay of attraction and escape. In a first attempt of designing this interplay of attraction and escape we ran into the pitfall of making a mechanism of predetermined actions of the light body. To avoid this we organized a creative session in which we explored the
dynamic characteristics of the play of attraction and escape and leading and following. We did this through an exploration in movement [15].

**Figure 5. Impression movement session, leader (person in the back) builds up tension in her body to lure the follower (person in the front) along.**

It appeared that often it is not really clear who is leading and who is following. When the leader is confident that she will be followed she will dare to move away from her follower. However when the leader has to lure the other into following she will move away carefully, strongly keeping her eyes focused on the other. At a certain moment it is questionable if the leader is pulling the follower along or if the follower pushes her. It is also in this moment that the follower might become the leader. Figure 5 gives an impression of the movement session. The leader (person in the back) tries to lure the follower (person in the front) to move along. The leader turns the body in the direction she wants the follower to go but keeps her focus on her follower: causing a twist or tension in her body. The last thing that stood out in the session is the moment of appreciation, i.e. you see each other, is very important for the play of attraction and escape to start. The leader has to be certain the follower perceives her to be able to lure the other in a direction.

**Implementation**

When PeP+ detects it is being explored the parameters of the active behavior are not longer used. These parameters make that the light body is sensitive for things it is not focusing on. They make that the light body explores the environment. When PeP+ behaves exploratively the light body actively focuses on the person. Only the sensor closest to this position gathers data. The light body has to move to get input on other sensors. This ignorance is an advantage as this can motivate the light body to start moving in direct relation to the person’s activity.

Inspired on the tension we saw in the body of the leader in the movement session the light body is build up out of two layers. In other words we tread the light body as if it exists out of two parts. The first layer is ‘layer focus’. This is the part of the light body that focuses on the person. The second layer is ‘layer explore’. ‘Layer explore’ moves through ‘layer focus’ from left to right to explore the interaction space. This way the light body gains sensor input and can anticipate upon the person’s activity. As also the ‘layer explore’ only senses there where it is it has to move in order to perceive the person and to anticipate on what the person might do next. ‘Layer focus’ is adjusted based on this input. Depending on the initiative of the person the light will either follow the person or the person will follow the light. Who is following who can be rather ambiguous. The implementation of the second layer of the light body changes the dynamic qualities of the light body but also deforms the body image. The lived body and body image both change which supports the appreciation of ‘I perceive you’. Note that in its appearance to the person the light body is still one body.

When PeP+ behaves exploratively it sets out to keep closely connected to the person. It might happen that the light body moves too far away from the person when it does not succeed to lure the person along. It might also happen that the person escapes from its focus. When this happens PeP+ will set out to find the person and explore the environment by behaving active. The play of attraction and escape can happen again when the person keeps exploring PeP+. Please visit the PeP+ website for a movie (http://dqi.id.tue.nl/pep).

**EXPERIMENT**

In this experiment the explorative behavior is compared to as well the active as the following behavior to see what the effect is on the experience of people and the interaction between person and artifact. When perceptual crossing between person and artifact happens this will, following the theoretical outline, cause the person to feel involved in the situation. You will come to appreciate that you affect and are affected by the artifact. Artifact and person can build a common history in the course of their interaction.

In the following behavior the light body is very reactive and can’t engage in the rich reciprocal interplay of attraction and escape. It only follows. The hypothesis is that people will feel more involved in the explorative condition than in the following condition.

In the active behavior the light body is exploring the environment rather than the person. As in the explorative behavior the light body is more focused on the person the hypothesis is that people will feel more involved in the exploring condition than in the active condition.

As in the explorative situation the play of attraction and escape can happen we are interested to see if participants indeed feel that they can attract the light body but that the light body also sets out to lure them to follow it.

**Set Up**

**Participants**

The 24 participants are students at the department of Architecture. These students are trained in giving design critiques but are not aware of the ongoing research project and are unlikely to know about the theoretical departure.
Comparisons
The explorative behavior is compared to the active behavior and the following behavior. Each participant compares either the following (N=12) or active (N=12) to the explorative (N=24) behavior, the order is counterbalanced. Note that we compared the active and following condition in a forgoing experiment (cf. Deckers et al. 2012). For this experiment we use the same procedure as in the forgoing experiment.

Procedure
Before entering the lab the participants get a short introduction to the experiment. In this introduction it is explained to the participant that she will encounter PeP+ when entering the lab. The door to the lab is shortly opened to give the participant an impression of PeP+’s physicality. The participant is told that PeP+ has two different behaviors and that she is asked to compare the two behaviors. It is emphasized that the participant can freely explore while in the lab with PeP+. The participant enters the lab to experience the first behavior and is asked to leave the lab whenever she feels ready. The experimenter tells her to wait a few moments and prepares the next situation. The participant enters the lab again to freely explore the second behavior. The experiment ends with an interview about the experience of the participant in the both conditions. Both the exploration and interview are filmed.

Table 2. Example three types of data, participant 14

<table>
<thead>
<tr>
<th>Participant 14, explorative - active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative Data</td>
</tr>
<tr>
<td>Participant feels to be perceived in both conditions</td>
</tr>
<tr>
<td>Participant prefers the explorative condition</td>
</tr>
<tr>
<td>Participant finds the explorative condition most pleasant</td>
</tr>
<tr>
<td>Participant feels most involved in explorative condition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualitative Data Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. “I found they are quite similar. I had the idea that he tried to indicate where you are in the room. In the second he lets go of that quicker and went its own way”</td>
</tr>
<tr>
<td>e.g. “Second is least pleasant, I did not really have the idea that PeP+ was really focusing on me, that I was really influential.”</td>
</tr>
<tr>
<td>e.g. “In both I thought that he was trying to go in a direction, that he clearly said go in this direction.”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualitative Data Movement Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explorative - participant 24</td>
</tr>
</tbody>
</table>

Measurements
We gather three types of data by interviewing and observing the participants. (1) We gather quantitative data on the feeling of being perceived, preference, pleasantness and involvement. (2) Qualitative data in the form of the participants’ descriptions and (3) qualitative data in the form of movement plots of the interaction. Table 2 gives an example of the three types of data we gathered.

In the interview participants are first asked to describe the both behaviors they encountered, compare them and to elaborate on the next aspects of the condition: feeling of being perceived, involvement, pleasantness and preference. Furthermore they are asked if they gave themselves a task and if PeP+ might have had a goal. The last set of questions addresses the possibility of PeP+ having a preference for one of the two behaviors. To get a deeper understanding of the participants’ experience we based our questioning on the laddering technique [24]. A list of open, guiding questions was used to make sure that all relevant topics are discussed and to drive the participants descriptions.

We plotted the movement of as well the participants as the light body in one overview. To indicate the time passing the line diverges from yellow (light) to purple (dark). In the forgoing experiment we focused on the movement of the participant but we realized that, especially to investigate the play of attraction and escape, the focus should be on the relation between person and light body. The play of attraction and escape can only be seen when both the movement of person and light body are plotted. To make the movement of the light visible in the plot the pillar is enlarged in the visualization. To make it possible to plot both the movement of the light body as of the person clearly in one overview the movement of the person is distorted over the distance from the pillar (compressed). We verified that the data is still correctly readable.

Feeling of being perceived
We are interested to see if participants feel to be perceived in all three conditions, as it will change our view on other data. Analyzing this data we consider the order by which the conditions are experienced. Table 2 shows an overview of how many participants felt to be perceived, seriously doubted if they were perceived and how many did not feel to be perceived by PeP+ for all conditions.

Table 3. Overview of participants that feel to be perceived

<table>
<thead>
<tr>
<th></th>
<th>FO1</th>
<th>FO2</th>
<th>AC1</th>
<th>AC2</th>
<th>EX1</th>
<th>EX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feels to be perceived</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Doubt to be perceived</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Does not feel to be perceived</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

It stands out is that when the explorative behavior is experienced first, relatively many of the participants doubt if they are perceived or even feel not to be perceived. This indicates that it might be valuable to consider how quickly PeP+ is certain it is being explored and changes from active to explorative behavior. Not only PeP+ has to be certain it is being perceived also the person has to
appreciate she is affecting PeP+’ behavior before the play of attraction and escape is appreciated by both. In case the explorative behavior is experienced second either the following or active behavior might have been of influence on the expectation of the person.

14 out of 24 participants feel to be perceived in both situations. These participants are considered when comparing preference, pleasantness and feeling of involvement. When participants feel not to be perceived in a situation this influences their experience. As people feel relatively as often not perceived in the explorative, following and active condition we will only consider the data from the participants that feel to be perceived in both conditions.

Preference, pleasantness and feeling of involvement
Table 4 gives an overview of how many participants preferred, found most pleasant and felt most involved in each condition. It is also indicated how many participants made no distinction on these three topics. As all participants experience the explorative behavior and half of them either the following or the active behavior the percentages are given to provide a more immediate overview. The data shows that participants prefer the explorative behavior over the active and slightly over the following behavior. Furthermore it indicates that participants find the explorative condition more pleasant and feel more involved in the explorative condition. The chi-square test for non-parametric statistics shows that the explorative sample differs significantly (p<0.001) from both the active and following sample. Table 4 shows the direction of the effect.

Table 4. Overview data on preference, pleasantness and involvement

<table>
<thead>
<tr>
<th></th>
<th>FO (n=7)</th>
<th>AC (n=7)</th>
<th>EX (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred</td>
<td>3 (43%)</td>
<td>2 (29%)</td>
<td>8 (57%)</td>
</tr>
<tr>
<td>No preference</td>
<td>0</td>
<td>1 (14%)</td>
<td>1 (7%)</td>
</tr>
<tr>
<td>Pleasantness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleasant</td>
<td>2 (29%)</td>
<td>2 (29%)</td>
<td>8 (57%)</td>
</tr>
<tr>
<td>No Distinction</td>
<td>2 (29%)</td>
<td>1 (14%)</td>
<td>3 (21.5%)</td>
</tr>
<tr>
<td>Involvement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most Involved</td>
<td>2 (29%)</td>
<td>2 (29%)</td>
<td>8 (57%)</td>
</tr>
<tr>
<td>No Distinction</td>
<td>1 (14%)</td>
<td>1 (14%)</td>
<td>2 (14%)</td>
</tr>
</tbody>
</table>

We found that there are three main categories why people prefer, find more pleasant or feel more involved in a condition. We will exemplify the three categories with descriptions of participants.

(1) The first category exists out of descriptors that relate to the feeling of control or understanding of the participant. For all the three behaviors this reason can be found multiple times (table 5).

(2) As a second category we see that the explorative behavior is preferred over the following behavior, as the result of its playfulness or own initiative (table 6). This corresponds strongly with the design variables as the explorative behavior actively explores the person and sets out to lure the person in the play of attraction and escape.

(3) Furthermore the explorative condition is preferred over the active condition because of a feeling of being ignored in the active condition (table 7). This strongly corresponds with the design of the behavior. As explained before, in the active behavior the light body merely sets out to explore the space rather than focusing on the person.

Table 5. Overview of descriptors and movement plots category control/understanding.

<table>
<thead>
<tr>
<th>Control/Understanding</th>
<th>FO (n=7)</th>
<th>AC (n=7)</th>
<th>EX (n=14)</th>
</tr>
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<tbody>
<tr>
<td>e.g. I prefer the second (following), it is nice to have control.” (participant 6, explorative-following)</td>
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<tr>
<td>e.g. I prefer the second one (active) because it really stops with you. So you really know it is going with you.” (participant 20, explorative – active)</td>
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<td>e.g. I had the idea that the second (explorative) reacted faster and I like that better. It is quicker clear which you could say is a nicer feeling.” (participant 7, active – explorative)</td>
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</tbody>
</table>

Table 6. Overview of descriptors and movement plots category playfulness/initiative

<table>
<thead>
<tr>
<th>Playfulness/Initiative</th>
<th>FO (n=7)</th>
<th>AC (n=7)</th>
<th>EX (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. The second (explorative) was nicer, more surprising. If he comes to you at once (following) the game is over, you immediately know how it works. The second time (explorative) I had to find it out more. (participant 13, following-explorative)</td>
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<tr>
<td>e.g. In the first (following) I had the idea that it was a kind of camera, the feeling someone was watching. The second (explorative) is more explorative, more the feeling of an interactive object. The second (explorative) is more pleasant because you are not just being looked at but it makes more curious.” (participant 17, following-explorative)</td>
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<tr>
<td>e.g. I felt more involved in the first (explorative), the second (following) could do it all by himself”. (participant 10, explorative-following)</td>
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</tr>
</tbody>
</table>

Table 7. Overview of descriptors and movement plots category feeling of being ignored.

<table>
<thead>
<tr>
<th>Ignorance</th>
<th>FO (n=7)</th>
<th>AC (n=7)</th>
<th>EX (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. “I felt more involved in the first (explorative), in the second (active) it is like he lets go again after he notices you.” (participant 8, explorative –active)</td>
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<td>e.g. “I prefer the first (explorative), because in the second (active) I got the idea that he did no have that much interest anymore in my presence. In the first (explorative) that was more.” (participant 24, explorative-active)</td>
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</tbody>
</table>

The play of attraction and escape
For both the active and explorative behavior participant use terms as ‘steering’ or ‘trying to get me in a direction’, although slightly more for the explorative behavior. On several occasions people find it hard to really describe the difference between active and explorative. In relation to the
following condition the explorative condition is more convincing described in terms of ‘giving directions’. Table 8 exemplifies this observation. In table 8 also the movement plots are given to provide more insights on the participants’ interaction with PeP+. They will be discussed next.

The movement plots show the (physical) relation the participants and the light body, have in the different conditions. In the following condition it shows that the activity of the light body is minimal compared to as well the active and explorative condition.

Table 8. Descriptors and movement plots on ‘steering’ or ‘giving direction’

<table>
<thead>
<tr>
<th>“Giving direction” explorative/active</th>
<th>“Well somehow in both you think quite quickly that it is trying to give a direction because in the beginning he first focuses on you and than moves away again: that is a kind of follow me instruction. …” (participant 16, active-explorative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“In the first (explorative) one it was alternating who kept an eye on who.” (participant 12, explorative-active)</td>
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<tr>
<td>“Giving direction” explorative/following</td>
<td>“The first time (explorative) he tried to steer me more, tried to force one side by moving the light in that direction. Did it work? If I say no I would lie.” (participant 6, explorative-following)</td>
</tr>
<tr>
<td>“Maybe in the second (explorative) he tried to get you to another side, now I think about it, because he was more vague and moved away. In the first (following) solely the idea it followed me.” (participant 5, following-explorative)</td>
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</tbody>
</table>

In the active condition there is a lot of activity by the light body through the middle of the surface. When the play of attraction and escape happens, in other words the behavior is explorative and not active, the light body focuses on the person. This is strongly visual in the movement plots: the angle between light body and person is small and the light body moves along the sides of the pillar. Figure 8 shows these different relations between person and light body in the different conditions.

Table 9. Descriptors and movement plots on ‘following’ or ‘giving direction’

<table>
<thead>
<tr>
<th>Active and explorative behavior</th>
<th>“He reacts to movement and where you are standing. I had the feeling he reacted less quick, different, I do not know exactly. That he moved a bit more freely (explorative). The first time (following) he quite quickly came to me.” (participant 13, following-explorative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainly explorative behavior</td>
<td>“The first one (following) the light was following, the second (explorative) I had the idea he was pointing where I should go. In the second (second) it took a while before I figured out does it follow me or does it give a direction?” (participant 1, following-explorative)</td>
</tr>
</tbody>
</table>

CONCLUSION

In our design-research project on designing for perceptive qualities we designed, build and evaluated several artifacts with perceptive qualities. Through these iterations we developed a set of design notions relevant for designing
perceptive qualities in artifacts. We more specifically investigate if and how to design for perceptual crossing based on these qualities. All the iterations showed the state of the art of the design notions at that moment in the process: from formulating the design notions to truly designing for perceptual crossing in the last iteration that is described here. The earlier iterations were needed to not only know which design notions to develop but especially to understand how to develop them further. In this paper we show that we designed an artifact with perceptive qualities that engages in a strong reciprocal interplay with the person of perceiving and being perceived.

The person can perceive the artifact, the artifact can perceive the person, the person can perceive that the artifact is perceiving her and the artifact can perceive that the person is perceiving it. Their perception of each other crosses.

We show this interplay of attraction and escape in the so-called explorative behavior of our artifact PeP+. We compare the behavior to two earlier iterations: the following and active behavior. We evaluated the effect of the implementation of the design notions on the experience of the person and the interaction between person and artifact. We show that people feel more involved in the situation where this play of attraction and escape is possible and where their perception of each other crosses. The movement plots of the interaction between person and artifact visually show the moments that the play of attraction and escape takes place.

We found that a behavior is preferred over another because of a feeling of control or understanding. Correlating to the design variables the data shows that the explorative behavior is preferred over the following behavior because of its playfulness and initiative. Moreover the qualitative data shows that the explorative behavior is preferred over the active behavior as people feel to be ignored in the active behavior. Again this corresponds strongly with the design variables.

In this last iteration we especially developed the design notions ‘Recognize Explorative Behavior Subject’ and ‘Remember and Anticipate Perception over Time’.

**Recognize Explorative Behavior Subject**

In the interaction not only the designed artifact shows perceptive activity, also the subject will show explorative actions to perceive the artifact. It are these actions that should be meaningful to the artifact. In as well the following as active behavior this was implemented by making the light body sensitive to a change in sensor input. By doing so the light body is sensitive to movement. Holding still will result in the fact that PeP+ not longer perceives the lived-body but the body image of the person and that the person becomes an object in space. In the explorative behavior PeP+ is sensitive not only to the movement of the person but also if this movement is explorative in relation to itself or not. By using intrinsic parameters of its own behavior PeP+ becomes more certain it is being explored in the course of the interaction.

**Remember and Anticipate Perception over Time**

The artifact gets, as it were, an experience; it is aware of bygone perception and anticipates on future perception. We consider time as a subjective phenomenon [20]: a continuum of activity. In line with this experience is here considered the continuum of perceptions and thus the awareness of bygone perception and the anticipation of future perception [26]. It is in this design notions that the artifact, as it were, builds and experience based upon other design notions. In the following condition PeP+ does not rely on history or anticipates on what could happen next. In the active behavior a first idea of course of perception in time is implemented by building expectations based on memory. Forgoing activity or the lack thereof in relation to the time passed motivates the light body to move. In the explorative behavior we build further on this. By enriching the design notion ‘Detecting Active Behavior Subject’ PeP+ is able to perceive if it is being explored and adjusts its behavior in relation to this. When it feels the person perceives it, PeP+ more closely focuses on the person. By creating a layer in the light body that focuses on the person and a layer that sets out to explore the person the light body is able to lure the person along and anticipate on the activity of the person. When the person stops following the light body or manages to escape from its perception PeP+ will adjusts its behavior again and set out to find the person.

**DISCUSSION**

We do realize that the design of PeP and PeP+ are decontextualized as a result of our deliberately minimalistic approach in implementation and context. This is done to focus on a quality- and action-centered perspective to interaction design. Therefore the current finding that people prefer the explorative behavior cannot be extended to any context or functionality, but should be seen in the context of our theoretical approach. We do however, investigate the practical relevance and extensibility [10] of our work, where the theoretical outline and design notions are used as inspiration and input for synthesis in industrial and educational projects. Together with an industrial partner we use existing production techniques to create PeR, short for perception rug, an interactive and perceptive carpet [6]. In our education we introduced interaction design students to the fundamental design knowledge on perceptual crossing as a source of inspiration and means for synthesis of new designs. These educational projects and shorter assignments show promising results [5], where more theoretical knowledge is implemented in the fields of Supporting Physical Activity and Wayfinding (please visit the perceptive qualities website for more examples, http://dqi.id.tue.nl/ perceptivequalities).

Although it is not the main focus of this project to investigate approaches to Research through Design, it does
aim to be a showcase in this field, to follow what Zimmerman et al. propose [29]. We have made an intentional choice for the RTD approach as a methodology and both describe and critically examine the process with the intention to create theory and build a body of knowledge on designing for perceptive qualities from a phenomenological perspective. We feel that a strong facet of this work is that it shows how to synthesize from theory.

REFERENCES
