From Designing for Homo Ludens to Ludic Engagement:

a Data-enabled Design Story

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ABSTRACT

In this pictorial, we share a data-enabled design process in which we designed to support ludic engagements enabled by indoor climate data. We propose "Bon Voyage", an artefact that invites for ludic engagement with air quality through using sensors as a way to explore.

The concept was developed in a data-enabled design process which consisted of two phases: the contextual phase and the informed phase. In the contextual phase, contextual, behavioural and experiential data was gathered and used as inspiration for design. Between the contextual and informed step our focus shifted from designing for well-being to ludic engagement. In the informed step, a prototype of this concept was deployed in the field to learn about the possibilities to design intelligence into the system.

In the first deployment, a participant struggled with maintaining non-utilitarian everyday practices at home, during the Covid-19 crisis. With this takeaway, we took inspiration from ludic design as it considers more playful and open-ended forms of interaction made possible by interactive products. We learned that stimulating curiosity and uncertainty can promote exploration and help create new connections. A challenge that we comes up through our process in designing for ludic engagement over the long. We propose handles to pick-up where our pictorial left when designing for ludic engagement through data-enabled design.

INTRODUCTION

Design case

The design process described in this pictorial started with a contextual inquiry enabled by data-gathering. Our initial point of departure was informed from a health and well-being perspective that indoor air quality has implications for health, mood and productivity [2, 7, 8]. Through the following contextual inquiry we reframed our design interest and subsequently changed our theoretical stance to more constructively inform our newfound design interest. The initial framing to design for health and well-being was changed to designing for ludic engagement following considerations that resulted from stepping away from our assumption that air quality sensing should focus on directly improving (health) parameters and searching actively for the, in our opinion, less apparent design opportunities that could be tackled through indoor air quality sensing. This reframing was motivated by experiences and beliefs that were shared by our study participants and careful consideration of the possible effects our design directions might have on their everyday lives. Our focus in the process became to design an intelligent ecosystem that support ludic engagement [5] enabled by indoor climate data.

Data-enabled design

In this project a data-enabled design approach was used to design for an intelligent ecosystem that takes up the theme of health through air quality in the home. Data-enabled design is a design research methodology established by Bogers & Kollenburg [9] as a way to add to existing data approaches within design. With their methodology they draw attention and give handles to using data creatively to gain contextual, behavioural, and experiential insights regarding the design of intelligent ecosystems. They propose the use of data-gathering probes, which can be used as a means to inquire into a context and inquire into design choices through situated prototypes that can be changed in-situ by means of a data canvas that can for example allow to update functionality without visiting study participants [9]. This approach allows for quick and unobtrusive inquiry, design hypothesis testing, and data gathering in general to inform the design process and understanding the potential roles of data in the designed ecosystems. The main goal of data-enabled design is to design for intelligent ecosystems [9]. In this pictorial we share our process towards designing an intelligent ecosystem we called 'Bon Voyage', with which we want to share considerations and insights that other designers might be able to use and build further on for designing for more ludic engagement with intelligent ecosystems. With these considerations and insights we also want to inspire designers and design researchers to consider the ludic aspects their design work might embody and take on design processes and perspectives that are more open to ambiguity in the process and the end-result.

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CONTEXTUAL PHASE

In the contextual phase, we used a data-gathering probe and a cultural probe to inquire into the everyday context, behaviours and experiences of a study participant. Our study participants were students at the Eindhoven University of Technology that took part in the Data-enabled Design course given at the department of Industrial Design. For our study, we eventually became interested in how to design intelligent ecosystems that support ludic engagement enabled by indoor climate sensing. The participants greatly contributed and co-shaped the design direction and design decisions, like for example providing the motivation to reframe our design intention. In our process we were not interested in addressing or formulating a potential user group, because the design methodology we used allows for deep insights relating to the specific participants in the process. Therefore, we refrain from drawing conclusions about larger user groups from the individual perspectives, which in our opinion does not restrict others from using our insights if they might engage with other kinds of users or participants in their design (research) processes. Furthermore, the goal of the contextual phase of data-enabled design is finding opportunities to design for and find opportunities to use data to learn from situated prototypes through data gathering and data visualisation [9].

Figure 1: sensor probe at participant desk

Data-gathering probe

To investigate the indoor climate in the home environment, we created a probe consisting of multiple sensors that measure data related to air: temperature, humidity, flammable gasses and concentration of particles in the air. The probe was placed on the desk of the participant since this was a central place in the apartment (figure 1). The setup was deployed for one week.

The sensor data was visualised in various graphs (figure 3) to compare the different datasets to each other. From this, interesting data points were highlighted that could be discussed in an interview with the participant. We looked at recurring patterns of the motion sensor and temperature/gas sensor to learn more about the daily routine. Furthermore, timestamps of spikes in the particle concentration and gas sensor were pinpointed to understand which activities caused or influenced this sudden change.

Cultural probe

A cultural probe [3] was made to insights about the participant's beliefs and values to inspire our design process beyond what we could measure with the data-gathering probe. The results of the cultural probe were used as design inspiration and input for the interview with the participant. The cultural probe consisted of four open-ended tasks that resulted in self-reported data (figure 2).

- Making your own political party by assigning positions to people and arguing the choice.

- Drawing a map of the house based on activities and perception of the participant.

- Writing a postcard to a thing/activity in the past

- Photo assignment on activities and places in the house

The open-endedness of the tasks was meant to allow the participant to interpret it in a way that suits them and to surprise us with personal perspectives to deepen during interviews.

This provided us with rich insights into the personality of the participant beyond what the sensor data could immediately provide, a.o. personal values and the participant's relation to the context.

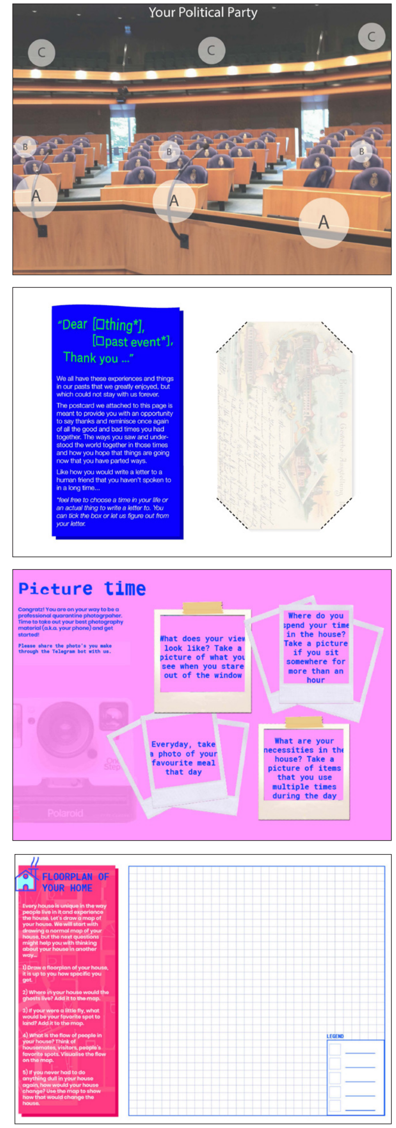

Figure 2: cultural probe tasks we used to inquire deeper into the beliefs and values of our study participant. They were titled: 'your political party', 'letter to a thing from the past', 'picture time', and 'floorplan of your home'.

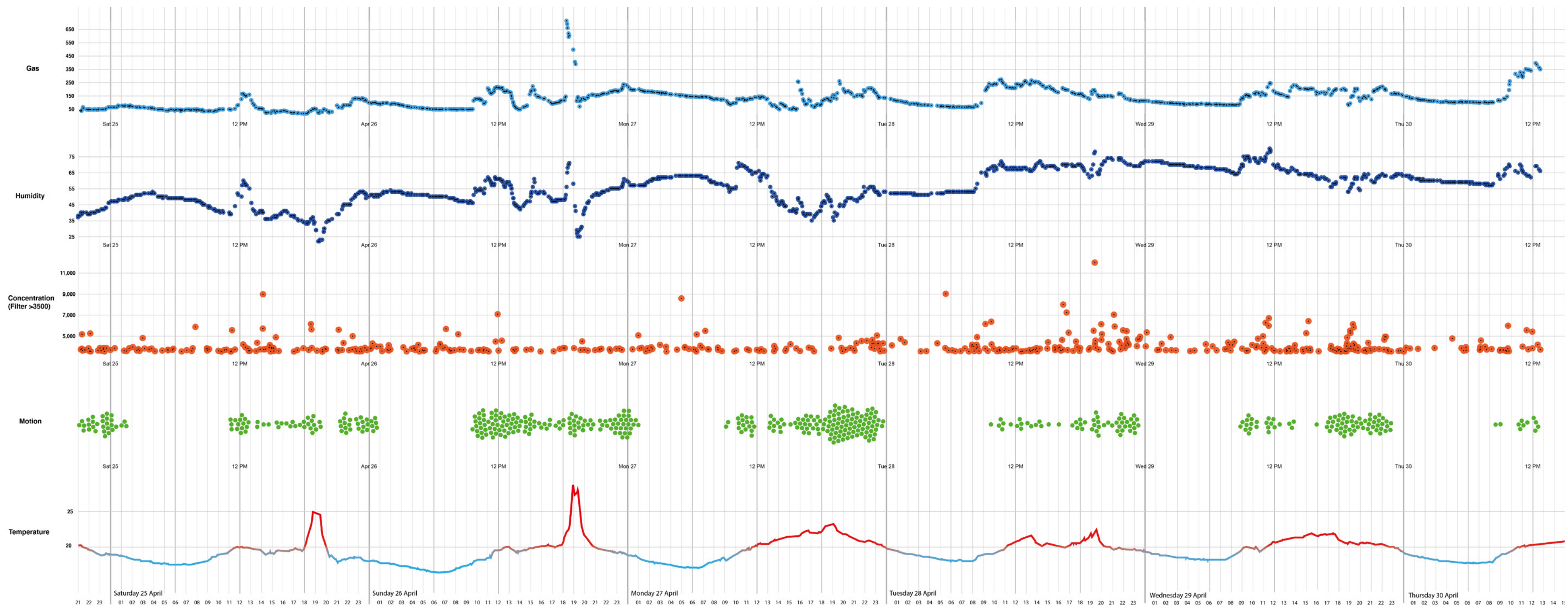

Figure 3: visualization of sensor data

Follow-up interview

After the deployment, a data-driven interview was held with the participant. Different details that related to health emerged. This varied from physical health to mental health. For example, topics such as missing social interactions in this pandemic period or healthy food choices were shared. We learned that due to COVID-19, the participant was forced to use one living space to execute multiple activities which included work-related tasks and general dwelling activities. Although the participant valued their hedonic activities, there was a struggle to switch from work to leisure, because you physically stayed in the same space where you are also working all day. Due to this insight, we explored approaches to stimulate the playful part of the participants day.

"I miss the activities where, after a long work week, I could go and just turn my head off and have the weirdest and most spontaneous conversations" - participant of our contextual study about the things she missed most.

By zooming out and imagining where the design directions the interview findings could potentially lead us, the focus steered away from looking at air quality through a health and well-being lens. Instead, we became interested in figuring out how indoor air quality sensing could support the non-utilitarian activities in the home, which have disappeared to the background of the everyday life of our participant despite the apparent need for them which was shared in relation to what was missing in their life.

INFORMED PHASE

Ludic design

During the analysis of the contextual step we found that the participant valued hedonic activities due to the current work-life balance in pandemic times. Following these findings we sought inspiration in the approach of ludic design [5]. Based on the notion of the 'Homo Ludens': people as playful creatures [6], ludic design aims at engaging people in ludic activities. These ludic activities do not have an inherent utilitarian nature but rather place emphasis on explorative, curious and reflective behaviour. By designing for ludic engagement, technology can serve a less utilitarian role such as optimizing efficiency or productivity. Not to render them useless but in order to find new values and understandings through ludic activities. As we found that in our context this could provide value, we opted for a design of an ecosystem that allowed for ludic engagement.

Prototype

During the design process of the informed step we explored different approaches to design the probes for inviting ludic engagement. To begin with, we brainstormed on the distribution of the ecosystem (Figure 4). Dividing the sensing and feedback components, we sketched different compositions of our ecosystem. This gave us five options: A) A decentralized system with separate nodes each having their own form of expression to provide feedback. B) A centralized system where all feedback is communicated in a central point. C) A combination of the aforementioned options. D) A distribution between multiple participants receiving data from other homes. E) Separate entities for both sensors and feedback systems.

In our first concepts we went for the first approach: creating a decentralized ecosystem equipping each sensor with physical actuation capabilities (Figure 5). Through the use of motors, it was possible to make the measured sensor data tangible. By making them portable, they could be moved around the environment to explore how the probes react to the spatial differences in measured air quality. Unfortunately, due to the technical requirements of this design and the limited

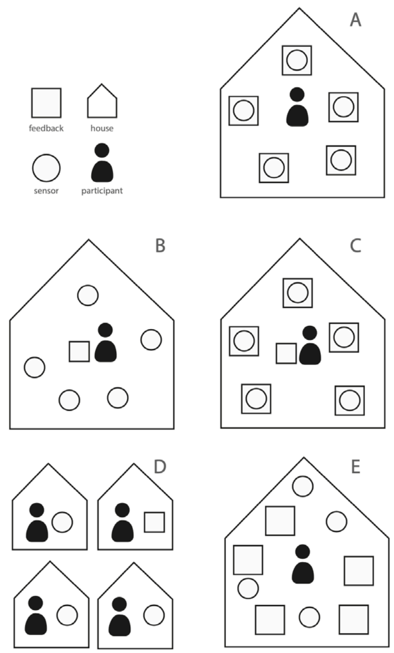

Figure 4: options for ecosystem elements distribution

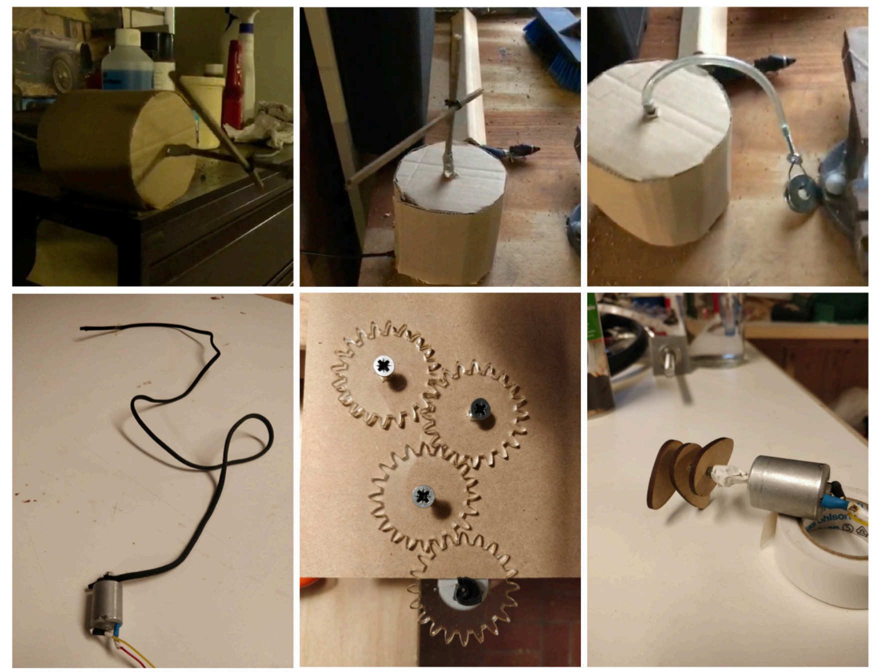
Figure 5: experimenting with motor powered actuators

time and access to resources for rapid prototyping, we were not able to realise this design. Taking a different approach, we applied our second option of distribution: a centralized system. Our system consisted of a printer and three sensor boxes for measuring gas, temperature and humidity (Figure 6). The sensor boxes were designed to be portable and placed wherever the participant liked. Collected data became available by pressing the button on the thermal printer after which the latest readout was printed. Additionally, dates from the past were printed of when there were similar air quality values in the city of Eindhoven as the current measurement(Figure 7). These dates were retrieved from an external database which was compared with the measured data. We were also able to send remotely send messages to the participant, providing questions to incentivise exploration.

We aimed for ambiguity in our design. By allowing the participant to playfully record and interpret the data coming from the environment around the sensors, we wanted to find how air quality was valued. Sensors can work as an extension of the senses of our own human bodies, allowing us to see things we are not inherently able to see. However as the sensing is performed through technology, it is restricted or limited to the functionality of each sensor. By making the sensors physical and portable, the participant is confronted with the question of where this enhanced sensing is required. Considering the limitation to one sensor box per location, it depends on the participant's curiosity where to place them. As multiple locations might be of interest, the participant could explore the environment for more meaningful locations. For example, the participant mentioned wanting to place sensors in different rooms of the house to explore the differences in data. Finally by adding the external date to the print, alternative data is provided than just the sensor data. Adding an external source of data acted as input for relating and reflecting upon air quality.

Figure 6: sensor boxes and thermal printer prrototypes in context. Picture credits go to the user of the system.

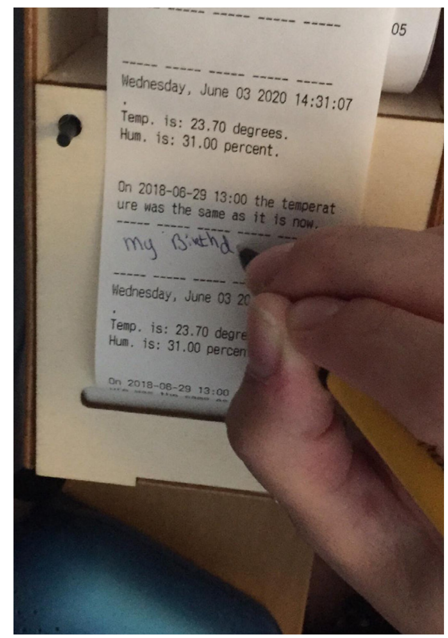

Figure 7: user writing down additional information next to a date that was printed on the receipt.

Deployment

The probes were deployed with minimal instructions to give the participant the opportunity to appropriate them freely. Unfortunately, due to the technical build of the sensor boxes, they had to resort to a wired connection for power thereby limiting their portability. We conducted two interviews during this period of deployment. From the interviews it was apparent that the probes sparked curiosity in the participant. The formgiving and the composition in itself invited the user to interact with with the system as it carried with it a certain mystery. During deployment, the button on the printer showed to be buggy causing a large delay in print being produced. Interestingly, on one occasion this happened during a social gathering of friends. The autonomous and spontaneous action of the printer caused for an aesthetic appraisal.

"When I press the button and later people join me in my room and it spontaneously starts to print, pretty cool."

The initial portability of the sensor boxes showed to incentivise the participant to explore different locations. For instance, the participant was curious to the thermodynamics of the house. By moving the temperature sensor from the bedroom to the hallway, the effects of opening a window was measured and compared between locations.

"I placed it in the hallway and there it was two to three degrees warmer. It was hot and slept with my windows opened which cooled my room off. However in the hallway it was still hot."

Unfortunately the eventual limited portability prevented further explorative behaviour. The ambiguity showed to incentivise curiosity and exploratory behaviour however the print outs were not as straightforward. As the participant found it difficult to find meaningfulness in the printed dates, it lost the attention.

"It prints the most random dates....I don't have any memories of that date and I cannot really imagine to feel 27% humidity."

Interestingly, ambiguity in imagined experiences motivated the participant to use sensors that were able to measure data that is hard to perceive through the body. Temperature is instantly experienceable, whereas subtle differences in gas levels might not be perceived.

"I thought gas was really fun because I have no idea what gas values there are and what is good or bad."

Second Iteration

Through the interview we found opportunities for enabling more ludic engagement with and through the system, and opportunities to use data to learn and start speculating on the use of intelligence in our system. The design opportunity and direction that we found and formulated earlier in our process was designing a system that enabled ludic engagement, supported by the possible need to support more playful and open-ended interactions in times of early Covid-19 crisis. Overall the goal of the data-enabled design methodology is to design for intelligent ecosystems, and as such we will strive in this iteration of the informed step towards getting insights to be specific about what elements could constitute a certain type of intelligence in our system.

Steps towards a more ludic sensing and printer system

For the previous iteration we formulated design criteria through suggestions done by Gaver et al [5] when designing for homo ludens [6]. Through the interviews we were able to more specifically figure out how ludic engagement was (not) supported or inhibited by specific design choices in the system. Below we describe briefly the design opportunities that came to light through the interviews.

Placing the printed messages on the spectrum of ambiguity.

In the previous iteration, two types of messages were printed:1) the actual measurements and 2) historical dates on which the measured in-situ values were the same. The actual measurement values did on the one hand not mean enough yet to be operationalised or reflected on (humidity) and on the other hand they did not give rather new insights that couldn't be felt immediately (temperature).

The historical dates that were printed, engaged the user other specific ways, for example making them think about the actual source of the measurements and the context where the historical measurement

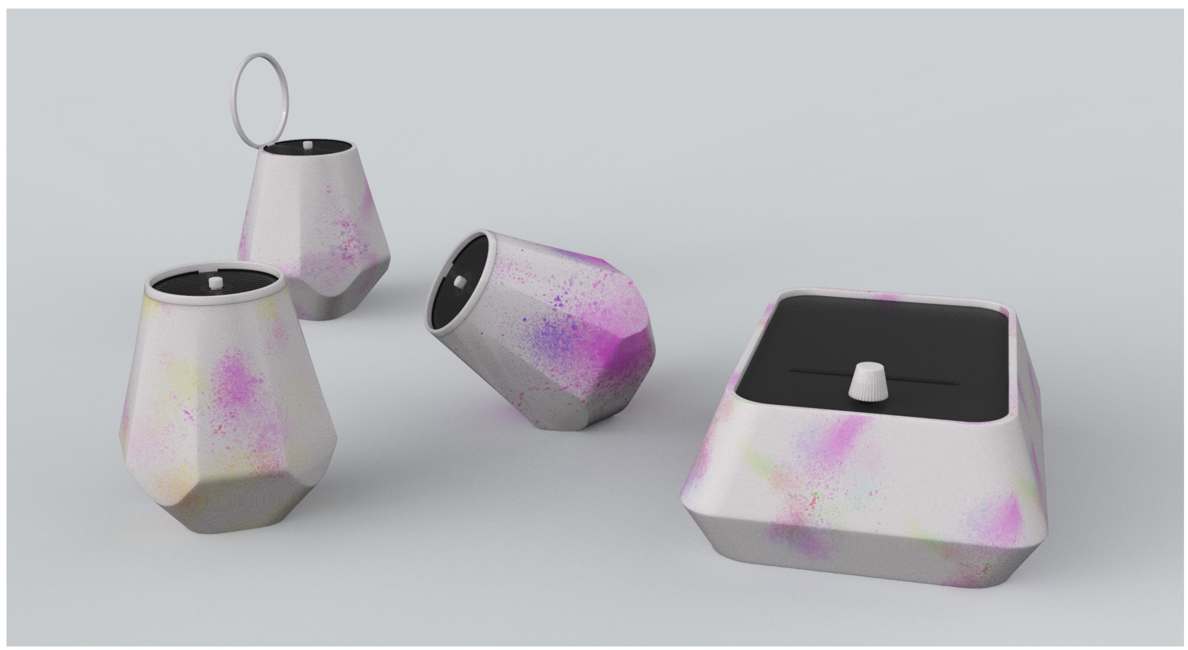

Figure 8: updated design for sensors (left) and thermal printer (right).

was made. But this wonder was not sustained or did not come back in other forms. Next to that observation it was mentioned in the previous iteration that it could not be put into practice in any way yet.

We see these two examples of representation of the measured data on the print as having two spots on a spectrum of ambiguity. The actual sensor measurements being close to 'not-ambiguous' and the historical dates being 'too-ambiguous'.

Implementing pre-interpreted representations of sensor data. For the new design we settled on selecting pre-interpreted (by us) representations of data that do not represent the data directly, but leave room for trying to find out what could have been measured. The couplings between printed data and sensor data were as follows, an example can be seen in figure 10: temperature -> songs, humidity -> plants that do well with said humidity, and gas -> remarks about the probability of combustion. With these 'interpreted' messages we set out to hide the actual values, supporting vagueness about the actual measurements, and provide information that slightly overlaps with everyday interests of the participant that they touched upon in the interviews.

Learning from the design process, we believe that ambiguity, that leads to multiplicity and openness in use [5], in our system, is supported by inaccurate, but sensor-related and user-relatable, information on the printed receipt [4]. In this most recent prototype from our design process, this inaccuracy is realized by coupling the printed information to a range of values instead of a single values, which allows for deeper inquire through other sensors, not included in our system. The relatableness of the printed information was inspired by interview insights.

Making the sensor-probes portable again and adding functionality to the probes. Due to technological difficulties in the prior deployment our initial goal of making the sensor probes portable was not achieved due to batteries dying. The portable aspect of the probes was initially meant to support exploration through displacement of the sensor probes, which we saw as possibly supporting different kinds of explorations. The participant implicitly confirmed to us that they were inhibited in exploring with the probes because of the restriction of having to connect the probes to a power outlet. We improved the prototypes by adding rechargeable 3.7V Lithium Polymer batteries and adding deep sleep functionality to the probes. This was done to save energy and not have to replace the batteries throughout the deployment.

To enable exploration through displacement more directly, we also added a press button on each sensor probe (Figure 8). When pressed, the printer will print just the message that corresponds to the pressed probe and the measurement it sent. With this we wanted to support easier and more singled out use of the probes if the participant might need that.

Updating the physical form of the system. The physical shapes of the probes in the last iteration were made update-able for a certain technological update we had in mind, but did not have time to implement at that moment. In line with our efforts for making the sensor probes more mobile in terms of adding the technology to make that possible, we also wanted the physical shape of the probes to enable 'more mobility' and therefore invite for interaction. We decreased the size of the individual sensor probes, and added rings that could be folded out from the top of the sensor probes. With these changes we intended to allow placement of the probes in smaller spots and allowing them to be hung to higher places by means of the foldable ring (Figure 8).

For the shape details and paint finish we aimed for elements that made the system stand out in the environment it would be put, but blend in as well. We did this by making the shapes recognisable through soft curves and sharper edges (allowing to blend in, but stand out on bookshelves and tabletops) and expressive paint jobs that allow for differentiation between the sensor units.

Automatic printing. In the previous iteration we included the option for us, the design team, to send messages to be printed by the printer in-situ. Our user voiced that in the few instances that it did happen she was engaged with the questions that we wrote down, like "What is the coldest spot in your room?". With regards to ludic engagement this functionality was too suggestive [5], but the fact that the printer worked without explicit intention of the user was an aspect we thought of as inviting open-ended engagement.

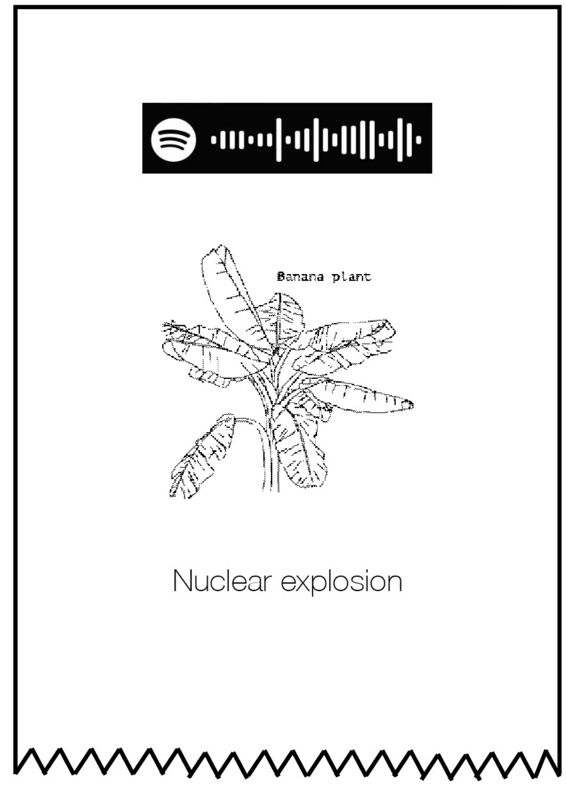

Figure 9: example of the output of the thermal printer. For the temperature we chose songs that related to the whole number of the measured temperature. For the humidity, we chose to print plants that grow well with that specific humidity level. For the gas values we chose to print sentences that make comedic comments on high levels of flammable gasses.

Like casually checking if something new was printed while away or specifically looking into the changes in printed information of a measured variable.

Steps towards a more data-enabled system

With regards to the previous iteration we were interested to inquire into the appreciation and use of the system by the user. The data that the system gathered and stored did not lend itself immediately for that use and we improved the prototypes by adding specific interactivity to the system that can be logged. These were the buttons on the sensor-probes (Figure 8), which also provided more opportunities for the printing functionality, and a rotational button on the printer that could be pressed to print. The rotational button was added to allow the participant to adjust the frequency of the automatic printer, in case it was too much or too little, depending on the use and wishes of the participant. The print functionality of the previous printer was kept by making the rotational knob pressable (Figure 8). The button presses and frequency settings were kept as data to be discussed with the participant through interviews.

Even though we weren't able to use the data gathered by the previous prototypes to learn about the use of the system, we used the indoor climate data to figure out potentially meaningful ranges and intervals to base the printed data interpretation on (Figure 10).

Learning how intelligence could be added to the system in meaningful ways to support ludic engagement. The primary goal of the data gathering through the 'Bon Voyage'-prototype is to learn in-situ how the system is used, by means of analysing the combination of use data and indoor climate data. Using the use data (button presses and frequency setting) as pointers to inquire into motivations and the climate data to inquire into possible displacements or data points to take into consideration for our secondary goal. The follow-up, but just as relevant, goal relates to the goal of data enabled design. The goal of this methodology is designing for intelligent ecosystems, which, as the name implies, make use of a form of intelligence that is embedded in the designed system. The Bon Voyage-system is the result of a design process meant to take on the challenge of designing for ludic engagement through designing a system consisting of at least several indoor climate sensors. Now that the system is becoming more and more concrete a system that could support ludic engagement in the everyday life of our user, the question of how intelligence can support that goal becomes more appropriate to ask than earlier in the process.

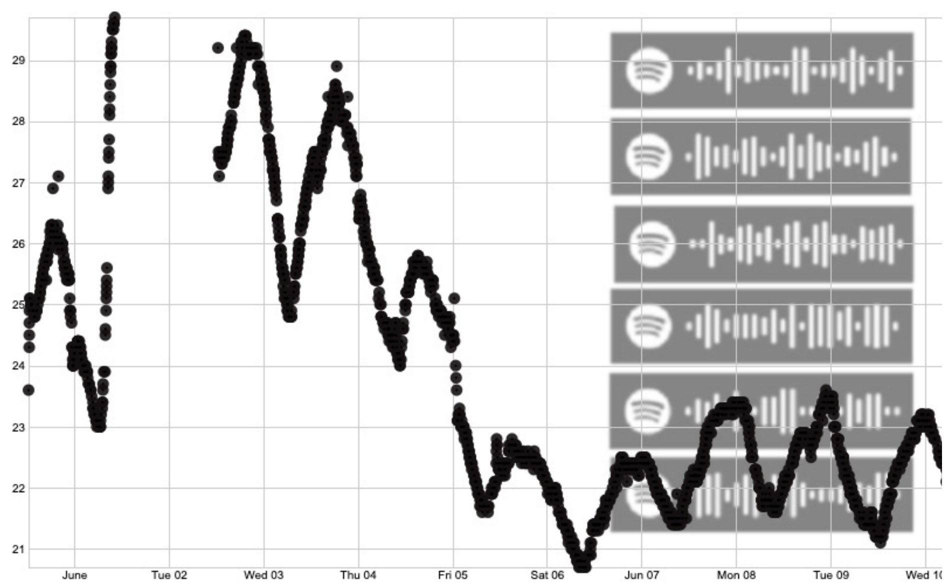

Figure 10: we mapped Spotify image QR codes to ranges of 10 decimal values of the temperature.
The total range on which songs are mapped and the smaller step choices were inspired by previously gathered indoor climate data.

Through an additional deployment of the Bon Voyage-system we aimed to learn through use and experience what potential meaningful relations can be added between existing (and possibly new) data streams. In turn, we wanted to reflect through the new ideas for possible relations on the possibility to delegate [10][11] the establishment of new relations to an intelligent agent in the system.

Additional Deployment

An additional week long deployment of the Bon Voyage-system allowed us to inquire into the fit of the design to the curiosity of our participant. By deploying the system with an explanation of how to use the system, but leaving out use-suggestions and possible goals, the participant shared that they immediately were engaged with finding out the meaning of the messages and possible uses.

"Specifically the openness of how it can be used allows for exploration."

"I was curious if more plants or songs would come out."

The first days the new system seemed to support expected forms of curiosity and exploration through the modularity of the system and the ambiguity of the messages.

"The first two days I figured out where I could place the sensors by guessing what [differences] could come out. For example when I could feel that it was wet outside I tried looking for a way to measure that. But then I figured out that the sensors weren't working, because a cactus was printed and that [climate] was not one a cactus normally lives in."

But when the system did not seem to work as intended, the user initiated print out functionality lost it's meaningfulness due to not providing the actual information that could be measured. While the user liked the combination of user initiated and automatic printing, which helped the user remind the existence of the system, a role of the automatic printing for supporting ludic engagement is not clear due to lack of experiences that could point out different ways of using the automatic print functionality in an open-ended way.

The participant had set up experiments with the prototypes to learn about its functioning and purpose. However, as soon as the participant understood the underlying mechanisms or when the data remained unchanged, the curiosity faded.

"I specifically put one [of the sensors] next to my window and one next to my plant and on my desk. I was curious about the humidity around my plant, and the gas near the window, and the temperature at my desk. I swapped the sensors to see if that would lead to different data, but I did not find out which sensor measured what data."

The participant shared that the curiosity resulted in active the exploratory activities. The system required a level of attention in order to understand is functioning, which in turn resulted in an increased awareness:

"Because you're interacting with it[s printed images], you're also more aware of the space around you, and if it's numbers it as if you're looking at your watch. You're not really looking and when somebody asks what time it is you have to take a look again.

Altogether, the interview seems to confirm that the initial explorative behavior is the result of a curiosity that is induced by uncertainty and ambiguity. As soon as the feedback remained unchanged, and the conclusion was made by the user that the system did not work properly, the system became uninteresting for them. It appears as if ambiguity drove the participant to explore the underlying mechanisms of the system until these were understood. From that point the drivers for use are mostly external rather than intrinsic. This learning suggests that a certain unpredictable element in the underlying mechanisms of a system could induce a sustained experience of novelty which, in turn, can cultivate an explorative attitude.

Figure 10: The printerbox of the additional deployment with the printed data on the right. One of the sensors on the left.

Figure 11: One of the three sensors. The sensor could be placed on multiple angles or hung on the ring

DISCUSSION

This pictorial describes a design process where the designers used a data-enabled design methodology to initially explore a context to design for and a design & problem space, which was defined as designing for ludic engagement in times where work and play have been forced to happen in the very same context. In this contextual phase [9] we enriched the data gathering with a cultural probe, which allowed us to inquire beyond the sensors we used for data gathering. This enabled us to come up with creative uses for the set of indoor climate sensors that we started with, which would not have been as straightforward to come up with without the cultural probe. While the indoor climate sensors allowed us to inquire into the indoor climate, the cultural probe allowed us to learn about the work/play balance that was disturbed because of the Covid-19 crisis regulations. This balance was what led us to take a ludic approach towards data-enabled design. By inviting curiosity and exploration, the participant could find meaningful relations with air related data. Because the operationalisation of the ludic design approach within the prototype was labour intensive, we limited ourselves to a small amount of sensors and data. Even though the aspects of ludic engagement [4][5] are recognised in the interaction with the deployed prototypes, longer deployment could unveil more meaningful relations for which new artefacts and sensors could be introduced. This way it is not only up to the designers to analyse the context with the system to introduce new artefacts (e.g. as in [1]), but the user is invited to unveil meaning in the context him/herself. Once it becomes clear how the system can grow through exploration by the user, the next step would be to look into how intelligence could be used to further support ludic engagement in the user.

Considering the current state of our system, it might be too early to implement an intelligence into our concept. However, through the use of the printer we see room for experimentation with autonomous behaviour to support ludic engagement. The printer provides a simple representation based expression which could be generated by an intelligent agent. Through this expression, we can experiment with autonomous behaviour in the system to explore how this influences the interaction. Through machine learning, intelligent agents can recognise patterns in data, but what these patterns mean is relative to the label that humans attach to these patterns.

In our prototype we were not able to generate actual patterns between measured data and external data, leaving the output restricted to pre-programmed options (e.g. plants). Therefore the level of intelligence in the prototype can be considered to be minimal. Future design steps might provide more insights into the possibilities and restrictions for ludic engagement in intelligent systems. From a utilitarian perspective, intelligent agents recognise patterns in order to reach a certain preset goal in the most efficient manner. Machine learning algorithms such as Supervised Learning or Reinforcement Learning can be utilized to reach this goal through labelling or giving rewards making agents selectively look for patterns. However, in ludic design this goal is non-existent, due to the lack of prioritisation of a certain use over another, and therefore it is not known what needs to be found beforehand. Unsupervised Learning detects patterns without labelling them, leaving them open for human appraisal. It is this open-endedness of the meaning of the unlabelled data that could be interesting for ludic engagement. Similar as in Neural Networks, through ludic engagement humans detect patterns in the world and label them according to what they mean to them. Probes can be designed to invite exploration [6][7] but human perception only goes so far. Using intelligence as a material to find patterns in the world that go beyond direct human perception (e.g. through a gas sensor) can provide a deeper view into processes that make up everyday life (e.g. air quality) and what it means towards the individual. An agent might find unseen or underlying patterns that are invisible to the naked eye, but what these patterns mean depend to whom they relate to. For instance, fumes emitted from cooking might be meaningful for somebody that is used to a cuisine that uses a lot of oil (e.g. Chinese) however it might receive negative appreciation from someone who is used to a clean air environment with strict cooking standards. When an agent would then detect similarities in air quality between home cooking routines and Chinese cuisine, this pattern could be used as a reflective tool to learn more about one's own cooking practices, namely how would the pattern be labelled by the individual? An attempt towards such a reflection could be seen in the informed step. In the first deployment of the informed step measured probe-data was accompanied by historical data extracted from an external dataset. This comparison could be seen as a recognised pattern between measured data and external data. However, as this weather data was chosen beforehand and unalterable, it showed that it was hard for the participant to look for meaning in the output. Ideally in a functioning intelligent system, this output would be highly variable thereby increasing the opportunity for providing output that actually is meaningful for the individual. These questions and possibilities pertaining to intelligent agents that support ludic engagement are the building blocks to better understanding how intelligent ecosystems for the home can be designed to be open-ended in their functionality in the first place, but we believe that the findings of our study can inspire more utility-focussed data-enabled design processes as well by showing that open-endedness is a valuable aspect in itself, be it in the process or the product. The ideas about intelligence in the Bon Voyage system should be seen as directions we see potential in, but in the current state they are but just speculations that need to be made and deployed to see if and how this potential to support ludic engagement might be materialised.

CONCLUSION

In this pictorial we describe the data enabled design process that resulted in the design of the 'Bon Voyage'-system. Through several deployments in multiple iterations, the system became one that invites for a novel interaction with air quality by taking inspiration from lucid engagement [5]. The system allows a person to explore the indoor air quality by moving sensors throughout the living environment. The sensor data is communicated by means of a thermal printer, which uses creative and open ended interpretations to inform the user about data (i.e. printing images of plants to communicate humidity, QR codes of songs to communicate temperature and messages with the probability of combustion to communicate gas levels). These interpreted messages hide the actual values, supporting ambiguity about the actual measurements, and provide information that slightly overlaps with everyday interests of the user. The deployments show promising results in supporting ludic engagement through indoor climate sensing. We argue that the design choices and rationale can be used to inspire more open-ended interactions in the process and end-result of data-enabled design process.

In an additional deployment of the 'Bon Voyage' prototype, we explored potential possibilities for intelligent systems to support long-term ludic engagement. Findings suggest that ludic engagement helps to create awareness and curiosity and that explorative behavior is driven by elements of novelty and ambiguity. The researchers suggest that intelligence can be a means to cultivate sustained novelty by augmenting explorative possibilities using pattern finding algorithms in machine learning. Further research is needed to learn more about opportunities and limits an intelligent agent can bring to supporting long-term ludic engagement.

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