Air Quality Sculptures: an explorative development process of a data physicalization that facilitates communication of indoor air quality

Caro Heesakkers
Faculty of Industrial Design
Eindhoven, the Netherlands
c.h.heesakkers@student.tue.nl

ABSTRACT

'Air Quality Sculptures' is a design research project that explores data physicalizations as communication medium in the context of air quality data. The research aim is directed to the inherent qualities and the overall expressiveness that is recommended for a data physicalization in favor of apparent communication. The proposed Air Quality Sculpture aspires to give expression to the abstract and intangible qualities of air. The sculpture and the other prototypes explored within this research are materializations of abstract data that have both functional as artistic elements to it. The information is enclosed in a decorative aspect that is relevant for whoever may receive it. This practice led design research project follows a research-through-design approach. It explores the expressiveness and inherent qualities the research artefact requires for clear communication of indoor air quality data. Findings and conclusion.

Author Keywords
Data Sculpture; Data Physicalization; Information Decoration; Physical Visualization.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; User studies; Visualization

1. INTRODUCTION

Data Physicalization is an emerging research area that holds many uncharted but promising opportunities. In Data Physicalization physical objects display intangible information. It can act as communication tools and to explore the information from different perspectives by embracing multi-sensory experiences with its physical properties [6]. Information visualization already is an effective tool to communicate the objective, factual insight in a data set. However, the promise of physicalization is that physical objects can actually express meaning beyond the objective or factual. This is because physical objects hold the ability to be touched, although also other features that are unique to physical objects play a role here [7]. The objects can spark certain memories. It has the ability to hold an emotional meaning that is captured and implicitly represented by the object [21].

As current technological developments are pointing towards further integration into our everyday lives, our everyday environment is becoming a main source of information. After all, by merging physical objects in our environment with sensing and actuating capability it is able to contain the information within the materials' properties. Our physical environment becomes a communication channel in itself in which technology is seamlessly woven into the fabric of the real world. This can support everyday data interactions and meaningful blend into the daily routine of the user [1].

One particular interest, and the focus of this research, lies in the notion that data physicalizations can offer meaning to topics that are difficult to understand because of unfamiliar or complex scales and numbers [6]. It is able to translate abstract and intangible data into a perceptual language that is more comprehensible. The vocabulary created by this visual language is easier to perceive that data presented by tables and graphs, without it being prescriptive [16]. The objective of our study is to gain more insight in how a physical artefact, a data physicalization, is capable to make the connection to an abstract and complex issue and facilitate apparent communication. We aim to explore data physicalization in the context of the abstract context of air quality, which in terms of 'raw data' and our experience of it is highly abstract and intangible. In particular, we focus on the indoor air quality within the home environment.

We have approached this by following an explorative, iterative, incremental development process of a data physicalization that facilitates communication of indoor air quality. It specifically focusses on the inherent qualities the data physicalization should embody in order to make the connection to the abstract context. We propose physical properties the physicalization needs to have to communicate the intended information. In addition, we explore what the overall expressiveness should be for the most correct interpretation of the current air quality. There are two iterations explained. The first one involves three separate research artefacts that each represent one dimension of air quality; oxygen nitrogen ratio, particle pollution and humidity. The second iteration proposes a multi-dimensional data physicalization that communicates the same dimension of the current indoor air quality.

2. THEORETICAL BACKGROUND

2.1 The world of data capture

We live in a time where many innovations are taking place in the field of Big Data. Through data mining and new storage technologies it is possible to gather large amounts of data and analyze it to come to new insights. In this world of data capture, users are more frequently confronted with the abundance of information all around them. Especially with new technological developments that are continuously integrating into everyday life. However, this information does not present itself in an accessible manner. There is a communication gap. This gap can be bridged by presenting the data via a visual image. Data visualization is an effective tool to communicate the objective information of a data set. It is able to convey factual insights about that data in a visual format [7].

2.2 Data Physicalization

Another approach of communicating data is by materializing the data into physical objects. This way of presenting information complements more traditional information visualizations [13]. It can be seen as an enhancement of the data visualizations approach. These physical objects are materializations of abstract data that have both functional as artistic elements to it. Data physicalizations make data tangible; it physicalizes data [6].

Data physicalization is a 'physical artefact whose geometry or material properties encode data' [6]. Although the data is not prescriptive, it is still able to make a connection to an abstract and complex issue. By creating a physical representation of the data that is situated in the users environment it could provide a clear narrative that is easier to perceive, interpretate and bring people together [16]. According to Vande Moere [7], the physical objects are even able to convey messages beyond the data itself. Another effective application for Data Physicalizations is for the engagement of a larger audience. It can bring data to a bigger and lay audience [21]. The physical, materialized representation piques interest. With interest people are more likely to spend time on complex data and are more eager to understand what it is about [6].

Data physicalizations can involve elements of embodied qualities users learned from their daily lives. The properties of a physical object could incorporate these qualities and invoke metaphorical links. This makes the understanding of the digital information and the meaning of it more assessable [5].

All facets of this type of information communication affect the perception of the data. The material qualities and properties of a physicalization enlarge the existing data set for the recipient. All properties and contextual relationships can be perceived as part of the communicated information [11]. In other words, the material properties and the context where the information is positioned is highly importance for the development and the perception of it. The physical form and shape of the object is not the only leading facet, the type of data highly influences the object as well. As Offenhuber [11] argues, the traditional notions of data, such as tables, measurable numbers and graphs, are not inclusive enough in relation to data physicalization. Not only a digital data set can map their values to a physical representation and enhance the meaning of the data through a data physicalization. Analog sources such as the material nature of the data itself can symbolize the data set. The process of collecting data can be the data physicalization by itself.

2.3 Information Decoration

With the integration of new technological developments into everyday life, the environment is a source of information. While the environment was pure consisting of static objects, it can now be identified as information carrier [10]. It creates a communication channel that allows for technology to work together with the real-world environment. This can support everyday interactions and meaningful blend into the daily routine of the user [1]. A way to support a seamless blend of data in ones life is to stage it as decoration. Information decoration is a manner of integrating data into environmental characteristics by presenting information in a decorative way. This is data that does not require to be in the center of attention. With an 'always' on quality it can calmly inform without overburdening the user. An important aspect of information decoration is seeking a balance between aesthetic and informational quality of the physical object. Data is enclosed in an aesthetically pleasing object that is only relevant for the one who is able to perceive it [3].

2.4 Context of air

To blend these interactive technologies into people everyday lives requires a good understand for the situation [1]. The context determines the content [3]. Interactions cannot be seen apart from the users everyday contexts and routines. The design needs to embrace the chaotic context where it will be integrated. This understanding needs time to accumulate in order to become a meaningful part of everyday life.

We therefore chose to explore the highly abstract and intangible data context of air. In particular, the indoor air quality of a home environment. Although the data physicalization approach has presented itself similarly in the past, little work had been found in this context. Air is volatile, untouchable but everywhere. The quality is determined by the amount of substances in the atmosphere that could be harmful for the health of human and animals. Air is polluted with gases, particulates and biomolecules coming from natural and human sources. Such as (fine) dust, smoke, nitrogen oxides and mostly caused by industry, traffic or agriculture. The current outdoor pollution in the air and the expected quantity is monitored by the government. By using an Air Quality Index the measured values are communicated to the public. Many are unaware that the indoor air is often more polluted than the air outside. To prevent diseases or allergies the air quality should be comfortable and have limited amount of harmful substances.

Individuals are responsible for sustaining the air quality in their private surroundings [19]. The proposed research artefact presented in this paper could help these individuals to become more aware of air quality inside their homes.

3. RELATED WORK

This section discusses work related to the areas of design research, as well as artwork and technologies in the context of air. These examples offer insight into the research that has already been done in these areas and show how the current research will take knowledge and inspiration from previous work.

3.1 Shape changing Interfaces

Elements of shape changing interfaces have similarities with data physicalization. Particularly, in the approach these interfaces are developed. The development has become more and more intuitive as the production shift from being a 2D digital display to flexible smart materials that can organically morph into more expressive interactive forms [14]. However, the main focus and application of the interfaces different from the data physicalization technologies. The aim for tangible interfaces is to give physical form to digital data or to control computational media. The output of the interfaces communicates the data. For data physicalizations the data is the input, rather that the output, that make data exploration and analysis possible [6]. Work in the field of physical shape-changing artefacts is Relief [9]. This actuated tabletop display is a malleable surface that allows users to physically experience digital models of for instance geographical maps.

3.2 Data Physicalizations

The field of data physicalization builds upon previous research in data visualization but reaches beyond the limitations of traditional visual languages into physical space. LOOP[17] created an abstract visualization to physically represent activity data. The physicalization presented in this work aims to facilitates reflection on personal performances. The information about these personal performances make people aware of their data. This is especially the case when the research artefact is a dynamic object that is incorporated in the personal environment of the user. Other relevant related work is given as Econundrum[16]. This research looks into the effective way to increase awareness surrounding the relationship between climate change and human food consumption. It researched social dynamics with a shared mediating data sculpture. The data was made tangible and embedded nearby the social context. This made social comparison, and therefore personal reflection, possible in regard to their own behavior towards sustainability. The relevance to the research described in this paper is how a complex context can be visualized in a physical object and how a more constructed and better understanding can be formed.

Next to having input from a traditional digital data set, some data physicalizations are based on symbolic data sets. Information is expressed in ways of simulations that let people physically experience this symbolic data. An example for this is the project by Todd Linkner named "Breathing Injustice". The research artefact used in this project is an object that simulates a breathing situation with highly polluted air. This simulates the experience people with asthma have when being surrounded in that situation. This project is positioned in the same air quality context but physicalizes the polluted air by creating an actual experience [11].

3.3 Art Sculptures

The element of air it the main character in many artworks. By exploiting the natural movement of air, kinetic art has made possible. Kinetic art depends on motion for its true design to show. For instance Ned Kahn [8] is a kinetic sculptor that includes wind in his designs. Technorama Façade is one example. Other than kinetic architectural sculptures, Jinmei Wang has worked on a representation of air in the form of air sculptures. Jinmei Wang explored ways how this medium can be transformed into a new design material. With small-scale sculptures new tactile and visual experiences where created. She searched for ways to capture the flowing, light and intangible properties of air into physical objects [20].

3.4 Air purifier technologies

The communication of air quality has already been done by many other technologies. Indoor air quality can be monitored and purified with the use of smart air purifiers. For example, the Dyson Pure [2] air purifier is a device that monitors and purifies to clear the air of substances that could be harmful for the health of human and animals. Other air quality technologies only measure and communicate the current air quality and advice users to take action when values are insufficient. The uHoo [19] air sensor is such a device. uHoo empowers the user to take better decisions about their health and home environment by using accurate air quality data. uHoo distinguishes themselves from other air measurement technologies by giving more specific advices and better insight in how to effectively improve the air quality.

Figure 1. Sculptures of the Co-Creation Session

4. APPROACH

This explorative research has a research-through-design method. It is parted into two iterations. Previous before the first iteration, a better understanding was required of how to make the invisible visible. This was done through an explorative co-creation session. The aim of this session was to explore how situations with a particular air quality property were visualized and physicalized by people with a creative background. Participants were asked to create a sculpture that represented the predefined theme. Each theme corresponded with a situation with a distinctive air quality; At the gym, coming out of the shower. Each situation had specific air quality properties the participants could easily resonate with. The sculptures made during the co-creation each showed how dimensions of air quality were interpreted by the participants and the type of physical associations are made in relation to air quality, such as humidity or the amount of available oxygen. Some of these sculptures are shown in figure 1. The main insight we could take from this session was that the physical properties have opposite properties. (table. 1) It transitions from one to the other and have a negative or positive nuance. Out of these opposites, clusters of comprehensive qualities describing properties of air. These could be placed into a scale going from comfortable to uncomfortable air.

Open	Oppressive
Scratching	Soft
Nature	Artificial
Entropy	Synthetic
Free	Locked
Static	Dynamic/ lively
Flat	Spherical

Table 1. Transitional opposite adjectives used to explain the meaning behind the created sculptures.

Another relevant insight gathered from the co-creation session was that each sculpture created, resembled personal values and emotional affection in relation with the situation they had to physicalize. While describing the thought process of the creation of the sculptures, many adjectives were named that could be associated with a certain feeling. Adjectives like; "suffocating, contained, dynamic, free" were mentioned to describe what feeling their sculpture was meant to express.

These insights formed the formed the foundation for the iterations to follow. Three dimensions of air quality were specified as the type of data that will be physicalized; (i) the amount of pollution (particles, fine dust, pollen, allergens), (ii) the available oxygen in relation to available nitrogen (iii) and the humidity.

5. ITERATION 1

The aim of this iteration was to apply the findings of the co-creation into three prototype that each represent a different dimension of air quality. The findings were concluded into three interactive dynamic transitions for each dimension. The communication content was simplified by assigning one dimension per prototype. The purpose for these single-dimensional research artefacts was to validate whether the transitional qualities mapped to the interactive features of the prototype could be communicated and perceived as intended.

5.1 Designs

All three prototypes have a consistent and uniform look. There is aimed for a clean, white and transparent appearance to direct the focus to the transitional qualities and movements rather than to be distracted by other unrelated material properties. The prototypes variate in the physical direction of the transitional movement.

5.1.1 Prototype 1 – Harming gasses (CO2 NO2)

The prototype is based on transitional movements: (i) open to closed (ii) soft to fast and staggering, (iii) calm, slow to asking for attention. The prototype has the property of physically open and close. The hollow tube consists of two halves. The back is solid and mounted to a background. The front consists of individual moveable elements. When there is sufficient oxygen, the moveable elements move very softly and at a slow pace. The tube is open by comfortable air. When the oxygen levels diminish, the elements move faster and more staggered. The tube is closing but still dynamically moving, asking for attention. The physical direction of the transition is forward. The prototype is shown in figure 2.

Figure 2. Prototype 1 – Harming Gasses

5.1.2 Prototype 2 – Particle air pollution

The second prototype represents the harming particles in the air, such as fine dust, allergens and pollen. The transitional elements are based on gravity and the direction falling downwards. The pointy objects are a direct translation of the meaning of the dimension of particles. It is a physical representation of having something in the air. The pointy appearance of the star-like objects have a the annotation of being sharp. Sharp air is associated with uncomfortable air. This is based on the bouba/kiki effect; the mapping between speech sounds and the visual shape of objects [15]. Therefore it means that the amount of pointy object is equivalent to the amount of harming particles in the air. The more objects are active, descending and pulling down in frame, the more air pollution at that time. The prototype is shown in figure 3.

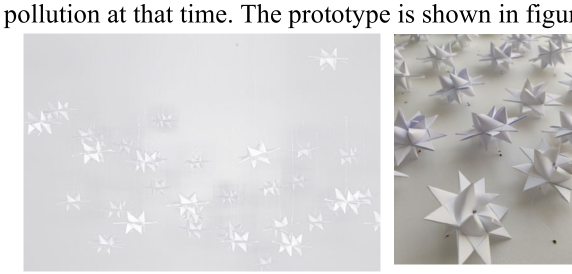

Figure 3. Prototype 2 – Particle air pollution

5.1.3 Prototype 3 – Humidity

One of the most distinctive dimension of air is humidity. This dimension is represented in the third prototype. This prototype follows the image schema of containment [5]. It was meant to communicate the feeling of being trapped, contained, and the need to escape. The transitional element is based on tension and overpowering. Two components are used in favor of this transition; a triangular frame and a balloon in the middle of the frame that can inflate and deflate. It has a free and translucent appearance when the humidity is optimal. The middle fills the frame but does not travel outside the triangles. The prototype communicates low humidity when the middle is at its smallest and the frame is completely see-through. The middle however is able to fully be stretched out through the triangular frame on the verge of breaking. This represents a high humidity. The physical direction of the transformation is 360 degrees along the whole geometric. The prototype is shown in figure 4.

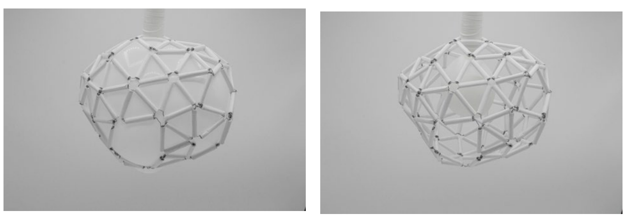

Figure 4. Prototype 3 – Humidity

5.2 Study Set-up

In order to validate whether the designed prototypes are able to communicate their values, an online questionnaire was set up. The functionalities of prototypes were captured in GIFs. For each prototype, five GIFs were made. Each resembled a different indoor air quality situation, the corresponding transitional behavior and therefore a different value. Through the animation of the GIF the dynamic transitions could be shown digitally.

5.2.1 Survey content

The survey consisted of 3 parts. The first part started with demographic questions to gain insight in the type of respondents. The second part asked for the corresponding dimension for each prototype. This verified whether the initial impression already indicated the correct dimension. There was aimed to diminish the feeling of matching one dimension per prototype. All guiding elements were decreased as best as possible. There was the possibility to give multiple answers and an option 'none of the above' for when respondents thought none of the dimensions made sense. The final part focused on each prototype individually. Each object had its own section within this part. The section contained the five GIFs with the different situations and a five point likert-scale specifically for each dimension. For the dimension of harming gasses and particles the scale went from none to loaded. The scale for the humidity was labeled on each point; too dry – dry – optimal – high – too high. The respondents had to rank the situation on their interpretation of what the value of that dimension would be. There was chosen for ranking on a scale question type rather than a matching experiment. It was important not to guide the respondents to the preferred answer. This allows for the same value for different situations and transitional behavior settings. If there was chosen for a matching experiment it would give 5 different situations with 5 values. If every situation is clear except for one, than automatically the answer would be the last remaining answer. Each section closed with an open, non-mandatory question to explain the thought process of their rankings.

5.3 Findings

5.3.1 Data Collection and Analysis

The quantitative data was gathered through the online questionnaire. While cleaning, data duplicates were detected and removed from the data set. Due to the open, non-mandatory questions after each prototype, the results opted for a quantitative analysis as well. These results were categorized in four themes; direction/form – metaphors/associations. The themes were set by the researcher and based on the earlier defined design decisions in relation to the three different prototypes used in this iteration. The quantitative data was statistically analyzed in order to validate whether the transitional behavior and inherent qualities, given to the prototypes, were perceived as intended. In total there were 122 unique respondents. 41 of the respondent answered the open questions. These answers were the input for the qualitative analysis and elaborated upon in the following sub-sections.

5.3.2 Quantitative findings

The aggregated questionnaire data revealed that the dimension of particles and humidity were interpreted the way as intended. Although some respondents gave conflicting rankings, the mean of matched the pre-defined intended ranking values. These numbers can be found in figure 5.

The prototype that represented the gasses was inconclusive. The object had two transitions that did not match the respondents interpretations. It was even conflicting each other. The more movement and chaos, the more harming gasses in the air. The open close transition was not that visible. The transition of opening was clear, but when the object was closed it was perceived as being in shape. In addition to this the movement of the individual elements were not clearly visible.

5.3.3 Qualitatitive findings

Prototype 1

Respondents identified two parts that influenced the ranking of the prototype; the overall shape and the individual 'spikes'. Because of the two dynamic features, it gave room for conflicting arguments. The individual elements can behave chaotically with more activity, the overall shape is closed. The individual elements move more calmly when the

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
particles 1	122	1	4	1,44	,576
particles 2	122	1	5	3,43	,908
particles 3	122	1	5	3,69	,854
particles 4	122	1	5	4,45	,751
particles 5	122	1	5	3,38	,973
gasses 1	122	1	5	2,18	1,128
gasses 2	122	1	5	3,41	,898
gasses 3	122	1	5	3,34	1,401
gasses 4	122	1	5	3,57	1,028
gasses 5	122	1	5	4,39	,958
humidity 1	122	1	5	2,92	,878
humidity 2	122	1	5	3,78	1,146
humidity 3	122	1	4	2,27	,739
humidity 4	122	1	5	1,56	1,076
humidity 5	122	1	5	3,89	,916
Valid N (listwise)	122				

Figure 5. Statistical case summary

shape of the sculpture opens up. This confused some respondents as their interpretation did not match these combination. 'In general I think the further the sculpture is opened the more gasses are in the air, but at the same time if the sculpture is moving more rapidly it sort of urges attention.'

The behavior was mostly expressed as being chaotic and restless when the individual elements were very active. When the prototype was 'in shape' it was calming and not seeking attention. When the sculpture represented high percentage of harming gasses, it was chaotic and not pleasant to look at.

Two relevant associations were found. It had to do with the volatile character of air. When the shape was open, the gasses could flow and stream through it. 'I think of a metaphor of an open door or window that lets in fresh air.' The sculpture represents clean air when the sculpture is open. On the contrary others thought of the harming gasses as having weight and being able to push the sculpture open. 'when the hooks are down that represent a lot of gasses because it makes you heavy and makes the hooks heavy.' This means that the sculptures is interpreted the other way around; open is a lot of harming gasses. Both interpretations were directed to the same position of an open shape, however the dimensional value was reversed.

Prototype 2

The individual objects were defined as an amount. Therefore more objects means more pollution. The distance between the objects gave not a big indication about the amount of particles in the air. 'More objects = more particles'. However, some thought when the objects were closely together, it expressed a condensed behavior. Condensed feels more polluted. 'the more condensed and lower, the more pressing it felt.'

Prototype 3

The containment factor essential to this design was clearly observed by the respondents. An inflated balloon represented a higher humidity. It appeared more easy to identity the extremes; when the air was too dry or too humid. The expression of being on the verge of breaking was observed as feeling the tension of the balloon stuck in the frame. The situation with the balloon being deflated, gave the feeling of being dehydrated and felt uncomfortable 'The dry one is very very strong I feel, I immediately get that feeling of not being able to breath, grasping for air.' The optimal situation was difficult to find. Some noticed the alignment of the inner balloon to the outer frame. 'I imagine if the bubble is perfectly filled it is the right amount of humidity in the air.' The movement of the balloon within each situation was not mentioned, it rather seemed to be a distraction. 'For me it starts feeling uncomfortable when the balloon makes the structure around it move.'

5.3.4 Defined Interactive dynamic transitions

Interactive dynamic transitions were defined based on the findings of this iteration. These form the foundation of the following iteration where all dimensions come together in one multi-dimensional data physicalization.

The most distinctive transition that could be extracted from the humidity dimension was the inflation and deflation of the balloon. The more inflated, the higher the humidity.

The most conflicting results appeared with the first prototype with the dimension of gas pollution. There is chosen to focus on the open-to-close transition only. Although the statistical results showed that open stood for a poorer air quality. However, we believe that this is due to the dynamic behavior of the individual elements because of the explanatory answers. The metaphor of opening a door to let in fresh air the deciding factor to define the transition for the dimension from open to close. The dimension is changed in definition as well. It shall be explained as the ratio of oxygen relative to the nitrogen in the air.

The dimension of particle pollution mostly accentuated the measurable physical objects. The more objects, the more particles. The density and movement of the objects only slightly affected the rankings. The oppressive feeling was less when the objects were more spread across the image. Due to the conflicting results of the first prototype, the transitioned defined for this dimension shall be from calm to restless. The measurable aspect of the dimension of particle pollution will support and complements this transition.

6. ITERATION 2

In the next step of this explorative process, the findings of the single dimensional data physicalization were the input for the development of the multi-dimensional object. For each dimension, a dedicated scale was defined. The research artefact include these three interactive dynamic transitions.

(i) dimension of oxygen levels : open to close

(ii) dimension of humidity : swollen to creased

(iii) dimension of particle pollution : calm to restless

6.1 Design

The transition from swollen to creased appeared to be the most complicated to realize. Therefore this transition initiated the ideation phase. For the design of the final air quality sculpture inspiration was found in art; sculptures, structural wall art and graphic work of dynamic smoke and many more. The overall design of the final prototype was inspired by an art sculpture from Barbara Hepworth named Spring [4]. Each dimension has its own interactive dynamic transition as described above. The three interactive functionalities of the sculpture are;

- the outer edge, green colored

- the inner circle outlined with the white area

- 6 LEDs in between the inner white area

The outer edge represents the dimension of the amount of air pollution. It transitions from inflated to deflated. This is realized by an inflatable pool band that is manually operated by an hand air pump. This pump is connected via a tube at the back of the object.

The entire object is stabilized through a core attached to a hollow column. This core consists of two metal rings with the dimension of the inner circle of the inflatable pool band. The rings are connected by six steel crossbars evenly distributed over the circumference of the rings. At each crossbar a LED light is attached. The lights are programmed in five settings, from calm to restless. These settings are operated by a potentiometer.

1. Six lights are always on, in pairs the lights slightly dim to a lower intensity and back to full intensity. This appears to be a breathing gesture.
2. In the same pattern as setting 1 the light dim to an off state and back to full intensity. The change between pairs is at a higher pace.
3. This setting is in essence the same as the previous one, however at a higher pace and without any pause in between the dim stages.
4. The lights go off and on again in pairs of two. The rate of motion is similar as setting three. The distinction is in the pattern of the motion. At this setting the pairs are programmed to be randomized.
5. This setting is meant to represent a restless feeling. The lights have a blinking effect that are programmed to be randomized at a higher pace than before.

The inner circle transitions from open to close. The white area is made out of highly stretchable fabric. This is fabricated in two cones attached in the middle to create a circle. Because of the stretchable property of the fabric, the circle can pulled together, making the circle become smaller. This is realized by a small rope that is looped around the inner circle. The one end is fixed to the steel frame of the core. The other end is at opposite site attached to a steppingmotor. By the rotation for the motor, the rope winds around the point of attachment. This point acts as coil for the rope. The rope is getting shorter and pulls the loop smaller and thus allows the circle to close. The sculpture can be seen in figure 6, 7 and 8.

Figure 6. Final Air Quality Sculpture (1)

Figure 7. Final Air Quality Sculpture (2)

Figure 8. Final Air Quality Sculpture (3)

6.2 Study Set-up

The study set-up was situated in the researches living room. The aim of this study was to validate whether the designed data physicalization communicated the intended air quality data. Participants were asked to give meaning and evaluate the air quality sculpture through a semi-structured interview. The participants were acquainted with the context of the data physicalization, however the mapping of the dimensions to the transitions was unknown in the beginning. The researcher sat beside the sculpture and across the participant. The participant had clear vision on the sculpture and were aware of the changes that were being made by the researcher. The researcher changed the settings of the three dimensions. Each setting represented a fictive situation that would be a possibility of the indoor air quality at that current moment. This was informed to the participants. The main question this study was meant to answer is how does the sculpture make you feel that the air quality is? After the third setting, the researcher explained the mapping of the dimensions to the transitions that the sculpture had made. The interview continued with three more settings of the data sculpture. The last step in the study was for the participants to change the sculpture that it represented the most optimal air quality. This setting was captured by an image that ended the user study. For each participants the setting and the sequence were the same.

6.3 Findings expressiveness

During the study, qualitative data was collected through semi-structured interviews with the participants during the user study. All interviews were audio recorded with the consent of the participants. The recordings were transcribed and the quotes categorized by the researcher. The study had two pilot interviews to adjust the structure of the interviews. After this, 11 more people participated. Three clusters were defined after open coding, done three times; first to see ways of categorizing, then to set clusters and sub-clusters. The third time validated the clusters by performing another final thematic analysis with the use of the clusters previously defined.

6.3.1 Associations

6.3.1.1 Objects

Participants often use metaphors to make sense of what they perceive. This was also the case for the air quality sculpture. The appearance of the sculpture in neutral position got references to animated characters or objects. The combination of the white and green colors looked like a Pokémon character, Snorlax [12]. When completely inflated, the object was perceived as a donut. One participant mentioned a Michelin man. When the sculpture represented a very low humidity participants thought of it as being sad or as shriveled.

6.3.1.2 Locations

The metaphors also referred to a specific location or environment. Participants positioned themselves in an imaginary environment with the same climate as the communicated air quality. For instance, a tropical rain forest was mentioned when the humidity was interpreted as too high: *"It feels as a rainforest, with little oxygen so it feels humid, stifling landscape."*(P7) Perceived in reverse the same setting was associated with a sauna or a desert, as they interpreted the humidity as dry. The characteristics of these environments are extreme and specific and thus participants were able to relate to those specific characteristics.

6.3.1.3 Events

Participants tried to make assumptions of events leading to the setting that the sculpture was positioned in. 'The sculpture looks like,, as if..' *"it looks like a mop, as if it was drenched with water."* (P8) Most events had to do with the transitional elements of the middle circle. This was often seen as an opening for fresh air. The opening was compared to a trachea; the more closed the more difficult to breathe through. It even got a comparison to smoking cigars: *"Maybe it has to do with the fact that I smoke cigars. How bigger the cigar, how tastier I smoke."* (P2)

6.3.2 Adjectives

The aim for this study was to validate whether the data physicalization was able to communicate the air quality intuitively. The interviews collected the way how the participants described their perception of the physicalization. The conversation was guided towards how the specific setting of the sculpture made them feel. The verbal explanations used to describe the what the sculpture expresses consisted of many descriptive words. These can be identified as both positive and negative adjectives in relation to the context of air. The positive adjectives describe the air quality as comfortable whereas the negative ones were relate to uncomfortable air.

6.3.2.1 Positive annotations

Stability was interpreted as a comfortable air situation to be in. The sculpture was perceived as calm, stable and serene. The object had a pleasant and inviting appearance when set in neutral position. *"It is more balancing that the previous setting. Less erratic. It is still pulsing but much more calm."* (P5)

6.3.2.2 Negative annotations

When the air quality was perceived as uncomfortable the humidity was low and therefore the exterior was deflated. The sculpture was described as lifeless and sluggish in that situation. The middle circle gave the most negative annotations when being closed. It gave an oppressive, stifling and suffocating feeling. *"I'm very fascinating with the middle circle. Uh so little air."* (P6) The lights were the most distracting factor of the sculpture, especially in a higher setting. In the highest setting, it was interpreted as an alarming situation that needed immediate attention. The uncomfortable air quality settings triggered the main actual phenomena of the designed effects, such as the swollen feeling of the inflatable edge, the oppressiveness of the closed middle circle, and the restless chaotic features of the lights. “I think it has little oxygen because the object looks so lifeless.”(P4)

6.3.3 Feelings vs Logic

The aim for the study was to gather the intuitive interpretations the participant perceived in different data physicalization settings. However, after the initial perception of the object, the participants started to think about the definition of the different dimensions and their own knowledge about what the values should be. Although the researcher guided the interview to the overall expression and the look and feel of the object, the participants rationalized their answers. This gave conflicting answers but complemented the initial interpretations and senses as well.

The conflicted thoughts of the participants were tackled by how it feels logical. The impression was given that the answers were based on logic, however, it resulted in an explanation when one image was more pleasant to look at than the other. It feels logical. *“Knowing how the air quality should be is different than what I felt initially. First I just noticed what was pleasant to look at, but the moment you really think about it, it is different.”* (P6)

6.4 Findings – Optimal Air Quality setting

The verbal expressions of how the sculpture was interpretated by the participants allowed for a qualitative analysis on the spoken words. However, all participants were asked to change the settings of the data physicalization in a situation that represents the most optimal indoor air quality. This images give an immediate overview how the dimensional values are interpreted by each participant individually.

In the most optimal state the sculpture is nice to look at. It has a calm appearance with no tension in the white area of the object. The green edge is blown up but not fully. The air needs room to just be there. It was mentioned that the sculpture was perceived as most pleasant when the shape is full, round without any creases or wrinkles in the fabric. Two participants preferred light setting two. The feedback that the object is ‘measuring’ has a calming and therefore optimal feeling. All other participants were satisfied with light setting one. Every participant wanted the middle circle to be open as far as possible, expect for one participant that wanted the circle fully closed. The three dimensions should give a balancing impression, one dimension should not hinder the other one. When the balance is stable, the data physicalization communicates comfortable air quality.

7. DISCUSSION

Limitations

The prototype. Manually operated. Participants saw it happening and could hear it. The peripheral factor could therefore not be tested. The prototype should be improved that transitions could happen seamlessly and without attracting attention in order to verify peripheral factor. A longitudual study for habituation is needed for this factor as well.

The participants group. There are no exclusion criteria for the research population, apart from that the participants should be able to see the physicalization. Ideally the group of participants should represent a cross section of society, but due to limitations related to COVID safety and practical availability the participants will likely be a convenience sample.

The different single dimension sculptures each have data physicalization elements but lacked the complexity a data physicalization can include. Still there is an enhancement of these sculptures in terms of expressivity and metaphorical meanings. Thus it is still an improvement and a step upwards compared to a simple slider that shows the current air quality dimension value.

The transition swollen to creased of the final air quality sculpture was not materialized as supposed to. The deflated setting was clearly visible and communicated the right value. However, due to the limitations of working with an inflatable pool band, the impression of be swollen on the verge of breaking did not communicate as well as desired. The fabric did not give enough resistance to convey this swollen feeling.

Interpretations and associations are highly personal and resonate with personal values and experiences. Three out of the thirteen participants interpreted the humidity dimension the other way than intended. In their eyes the humidity was very high when the sculpture was deflated. The object was drenched with water that made the outer edge to be sluggish and lifeless. As if a bowl of water had been poured over it. All the water of the humidity weighted the outer edge down and was therefore deflated.

8. CONCLUSION

The data physicalization that is proposed at the end is aimed to communicate three different dimension of air quality in an apparent way. The three dimensions are; (i) dimension of oxygen levels, (ii) dimension of humidity, (iii) dimension of particle pollution. Each dimension has an interactive dynamic transition that is implemented through a materialization of a physical object. This qualities that match the transitions and the dimensions are extracted from other explorative iterations. First a co-creation session created a better understanding how the characteristics of air are interpreted by others. During an iteration with three separate prototypes, these understandings were validated. The final iteration resulted in an overall expressiveness a data physicalization needs to embody in order to communicate the air quality data. The interpretation of this expressiveness is highly dependent on the personal values and experiences of the recipient. It would be interesting for future research to approach this development of a data physicalization similarly but in an different context that has the same abstract element to it as the context of air.

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