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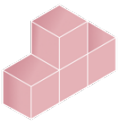

BIG DATA AND SMALL BEGINNINGS – HOW PEOPLE ENGAGE WITH DATA PHYSICALIZATIONS

JACOB BUUR
UNIVERSITY OF SOUTHERN DENMARK
BUUR@SDU.DK

JESSICA SORENSON
UNIVERSITY OF SOUTHERN DENMARK
JESOR@SDU.DK

CHRISTINA MELANIE COOPER
UNIVERSITY OF SOUTHERN DENMARK
CCOO.SDU.DK

ABSTRACT

Data physicalization has emerged on the design scene as a way of making sense of big (quantitative) data. This study explores how big-data physicalizations are designed, how people engage with them, and how that spurs innovation. Graduate student designers created 15 data physicalizations to engage bus planners and bus passengers at multi-stakeholder workshops in discussing bus services and bus designs. The physicalizations were based on passenger data from 9 city bus routes. We used dimensional analysis to scrutinize the data physicalizations as constructs and multimodal interaction analysis to understand how workshop participant interact with the physicalizations. Using the theories of Flow State and Play Moods as analytic perspectives we identified patterns of engagement that were stimulated by both material aspects of the data physicalizations and the designers' role in facilitating interaction. We contribute with a framework of how data physicalizations can scale big data insights to meaningful engagements, which in turn lead to Small Beginnings of innovation.

INTRODUCTION

With the collection of big data becoming ubiquitous practice in organizations, designers have been struggling to make sense of large amounts of quantitative data (Lu 2020). In a recent study of UX design practices in industry we heard from designers that they have difficulties *'making big data my own'*, but also that they need to take on a new role of engaging people in the organization in making sense of big data. According to De Mauro, Greco, and Grimaldi (2016), this struggle is inherent to the definition of *Big Data: "Big Data is the Information asset characterized by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value."* Data physicalizations have emerged as one such method for transforming big data into meaningful representations. While there are already many examples of data physicalizations (Dragicevic et al, 2019), it is yet unclear what people can actually *do* with them, and what role they may play in involving diverse stakeholders in innovative processes. In this study we examine a set of data physicalizations of bus service data, to find out how big-data physicalizations are designed, how people engage with them, and how that spurs innovation. The goal is to identify patterns towards innovation in interactions with data physicalizations and thereby suggest which design considerations may be important when creating data physicalizations for engagement.

The term *Data Physicalization* was coined by Jansen et al. (2015) to describe constructs designed to represent (big) data and help people explore, understand, and communicate data – as we humans explore the world around us with all of our senses. Data physicalizations may be static or interactive but have in common that they afford physical manipulation. They may convey (digital) data from systems or allow people to add or

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construct data about their own experiences. In this study, we asked designers to produce data physicalizations that instigate conversation and discussion around the bus traffic data.

Physicalization is a way to invite individuals into reflective processes. Huron et al.'s (2014) 'Constructive Visualizations' similarly enable individuals to express themselves through adding or removing data tokens. Houben et al.'s (2016) human-data design approach links data physicalization to learning: when individuals *"create, share and use data through tangible and physical visualizations"* they learn more about themselves and their environment. Knowledge is continuously constructed and deconstructed through the interactions we have with the world around us (Ackermann 1996; Kafai, 2006). This resonates with the way designers and architects work. They employ material practices, like model making and prototyping, to gain insights about how people experience the world. Hull and Willett (2017) suggest how data visualization take inspiration from architects. Buur et al. (2018) show how data physicalizations enrich conversations, shift perspectives, and help imagine "What could be" through the physical touch, juxtaposition and co-construction of data. For this study it was therefore a core criterion that in addition to eliciting conversation, the data physicalizations should invite physical interaction.

Within data visualization, research has been made on the aesthetics of "beautiful data" (Steele and Iliinsky 2010; Wattenberg and Viégas 2010), but McCosker & Wilken (2014) criticize that focusing on the end result of data visualization misses the opportunity of knowledge creation in the process. They argue that it is the creation of such diagrams, including all of the steps of planning, mapping, drawing and illustrating that generates understanding. This is relevant for data physicalization, as materiality affords manipulation and expression for active engagement.

Within ethnography, Anderson et al. (2009) show how data visualizations can be designed to involve participants in making sense of their own data, and thus diminish some of the authority that participants tend to give to the 'objectivity' of data. They claim that this makes participants more comfortable at providing explanations of the data, as they can see how some of the collected data can be misinterpreted. One quality to look out for in designing data physicalization is thus how they challenge the 'objective' look of numbers and graphs. We challenged our graduate student designers to create big-data physicalizations that go beyond representation to involve participants in making meaning from the data.

In human-centred design research it has become popular to utilize materialization to ease the conversation between designers and 'users'. The generative tools of Sanders and Stappers (2014) and the tangible business models of Buur and Mitchell (2011) both use design materials to surface memories and stories that otherwise can be tacit and difficult to put into words. In the same way data physicalizations can be understood as *boundary objects* (Star 1989) that enable people to work together and make sense of the data, even if they have different ways of understanding it.

The question we ask ourselves in this study is: What makes some data physicalizations more inviting for engagement than others? And does engagement lead to innovation?

BUS SERVICE DATA PHYSICALIZATIONS

In order to explore the potential of data physicalizations to engage people toward innovation, we tasked graduate student designers with creating big-data physicalizations based on quantitative data supplied by a regional traffic authority. We collaborated with the traffic authority's data analysis section to explore 'what one can do with the data'. Rather than ask the designers to come up with 'ideas' themselves for how to improve bus operations, we challenged them to prepare the data as physicalizations that trigger discussions about innovation. We ran the project three times with different cohorts of designers and developed our design criteria from rather open in the first round to more specific later on (e.g., targeting particular stakeholders: traffic planners, politicians, bus-interior designers, bus-stop designers, bus non-riders). We explicitly asked them to design for *interaction* to engage participants (as opposed to physicalized pie charts and bar graphs as mere static representations).

The traffic authority supplied us with fare data spanning one week for 9 local city bus routes. The main source of data was the national transit cards that are checked in and out of busses and trains. The High-Volume dataset included more than 50.000 data points, which the traffic authority collects at a Velocity of 10,000 points per day. Designers were given access to a select dataset via the traffic authority's Business Intelligence (BI) platform. The BI platform allowed designers to organize or filter data, e.g., by specific bus lines, trips, or stops. The data could also be exported as comma-separated values for analysis in spreadsheets. Alongside the quantitative data, the designers had free passage to do their own ethnographic studies on the busses for a 2-week period, including observing, counting, and interviewing. These qualitative datasets were used to bring Variety and context to the designers' understanding of the quantitative data. For instance, the quantitative data would tell how many passengers are on the bus, but not where they are seated. Or they would tell how far passengers travel, but not for which purpose.

The designers produced a total of 15 data physicalizations, four of which we include in this paper as illustrative examples, Figure 1.

Figure 1. Four data physicalizations: Bus Route Map (top left), Travel Worms (top right), Bus Stop Crowd (bottom left), Corona Touch (bottom right).

Bus Route Map aims to support politicians in making decisions about the levels of bus service they want to offer based on traffic data. It is a map of the municipality with needles for each bus stop and colour codes for each city district. The needles hold coloured beads representing 5 (small beads) or 50 (large beads) passengers waiting at the bus stop, who want to travel to the district indicated by the colour. The challenge for the 'politicians' (participants) is to buy enough bus routes (with monopoly money) to connect bus stops (with pieces of string) in the most efficient ways, collecting passengers (beads) along the way.

Travel Worms triggers discussions of the variety in passengers' travel patterns, from home to destination. For 100 bus passengers the designers made strings of coloured beads with each bead representing 1 minute of travel, and colours depicting walking, train, or one of the bus routes. The participants pick a number of 'worms' to compare travel patterns and then place them in a physical model of the bus to discuss seating.

Bus Stop Crowd supports bus stop designers in finding ways of preventing crowding when passengers enter the bus. The designers projected their mapping of dynamic passenger behaviour onto the pavement in front of a scale model bus. Participants were given diverse materials and figurines to invent ways of nudging passengers to keep a distance while entering the bus (during the corona pandemic).

Corona Touch directs attention to passenger behaviour on the bus: How many times passengers touch the handrails, grab-handles, arm rests, their face mask, their cell phone, and stop buttons. Participants are asked to estimate their own behaviour, compare it to the data (in the form of colourful vira tokens), and suggest ways of reducing the risk of viral contamination on the bus.

At the end of each of the three design projects, we invited a mixed audience of professionals to attend a 90-minute multi-stakeholder workshop. Participants included traffic authority employees, municipality bus planners, and bus passengers (university faculty and students). Small mixed teams of 3-5 participants rotated between five stations with a data physicalization at each. The designers had prepared an activity to engage participants with their physicalization for 15-20 min. Presentations were not allowed, only facilitation. Each station was video-recorded from two angles. We gathered documentation of at least three teams of participants interacting with each data physicalization.

There was quite a variety in how the activities and tangible physicalizations captured the attention and active engagement of the participants. We used two methods of analysis. Dimensional analysis was used to achieve an overall understanding of the qualities of the data physicalizations and to characterize participants' interactions. Multimodal interaction analysis was used to identify patterns of engagement with the data physicalizations and their innovative potential.

DIMENSIONAL ANALYSIS

Dimensional Analysis (Kools et al. 1996) builds on a grounded-theory epistemology for organising empirical data along different 'dimensions' to come to a deeper

understanding of the phenomenon studied, Figure 2. As empirical data points we first used images of the data physicalizations, then condensed 2-min video edits highlighting how workshop participants interacted with each of the 15 physicalizations. Our collaborative analysis sessions included both researchers who had been part of the design projects and colleagues who saw the material for the first time. We reviewed the material and ordered images and videos along alternating scales in a comparative exercise. After discussing 15 different dimensions, our analysis had reached a level of nuance sufficient for describing the data physicalizations' qualities and interactions.

The *primary perspective* that emerged from the analysis was the ability of the data physicalizations to **facilitate innovation.** This would also be the primary measure of success of these tools with the traffic authority. The other dimensions elicited from the analysis were then organized as indicative of the *context, conditions, process* and *consequences* of the activity, Table 1, as recommended by Kools et al. (1996). Our dimensional analysis led us to identify 'engagement' as a most salient precondition for the data physicalizations to 'work' as innovation facilitators.

MULTIMODAL INTERACTION ANALYSIS

We performed a second and more detailed analysis of the video recordings to identify patterns indicative of engagement, asking: How can we characterize what happens in participants' activity with the data physicalizations? We analysed the participants' interactions with the data physicalizations, with the facilitators, and with each other.

We observed patterns of engagement that might be explained by two theories in particular: **Flow State** (Csikszentmihalyi 1975) and **Play Moods** (Karoff 2013). Both theories describe an aroused feeling of euphoria in activities, but they are also distinctly different: Flow State originates in individual thinking, whereas Play Moods are inherently social. Flow State appears in (loosely) goal-directed activity, where Play Moods describe play as valuable in itself. Flow State is generalised to many activities in life (including work and play), whereas Play Moods relate to play as activity.

While reviewing the videos for patterns of engagement, we also began to see patterns of emerging innovation. We noticed 'a-ha!' and 'what-if…' moments when participants were engaged with the physicalizations, and we recorded these in the same way we had done for engagement. We found these patterns mirrored in Shaw's (2000) concept of **Small Beginnings**, so we used this as a theory for understanding these moments where something unexpected is about to happen.

We reviewed each video looking for patterns of engagement in participants actions, according to the principles of multimodal interaction analysis:

- "the participants' language and embodied actions (with all senses) in relation with the material surroundings
- the actions of the participants as meaningful in relation to surroundings and fellow participants
- participants' actions as situated, comprehensible and accountable." (Paasch & Raudaskoski, 2018:158)

We paid attention to how participants moved around and interacted with the materials, how they made sense of the data in relation to their own personal experiences and professional expertise, and how they responded to designers' facilitation of the activity. We recorded a list of our findings describing the (inter)actions we observed, and the qualities that characterized these actions (e.g., how participants puzzled to solve a collective task, as characterized by their contemplative silence). We organized our findings in the framework shown in Table 2 with the interactions in the left column and the videos in the top row. In the following three sections, we discuss the results of our analysis when employing Flow State, Play Moods, and Small Beginnings as analytical perspectives.

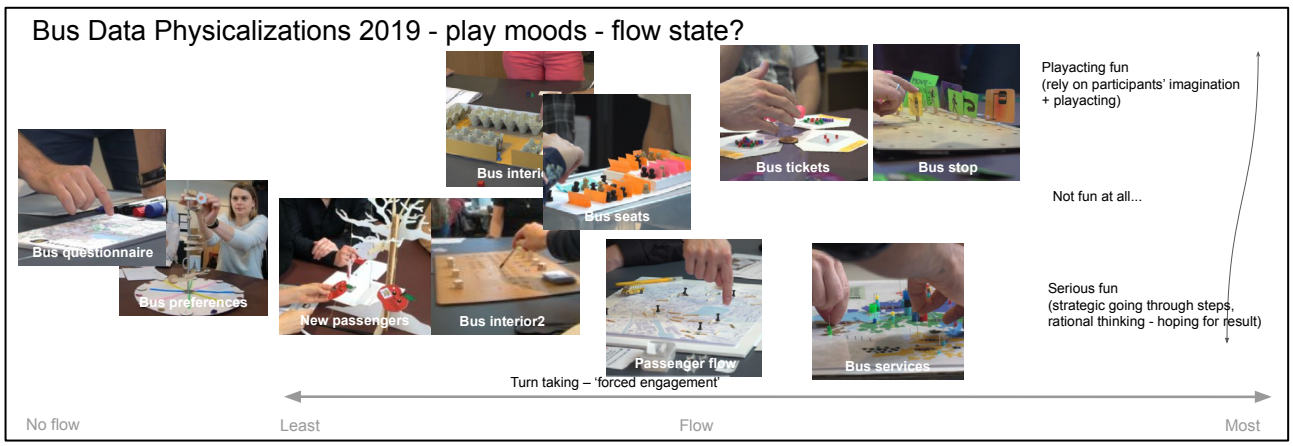

Figure 2. Example of one of the scaled dimensions scrutinized with Dimensional Analysis. Data physicalizations shown as photos.

ENGAGEMENT AS FLOW STATE

Csikszentmihalyi (1975) defines Flow State as a state of mind in which competence and concentration converge, and the subjective sense of time is altered. The experience of a heightened level of awareness of the activity in which one is engaged, and a lack of critical self-reflection or "internal mental chatter" in the moment. The essence of flow is the removal of the interference of the thinking mind. Flow arises from engagement with activities that are precisely mentally or physically challenging enough to require concentration, but not so challenging that they exceed competence. And: *"The second you realize that you are in a state of flow - you cease to be in a state of flow."*

"Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person's skills, it usually begins to be intrinsically rewarding." (Csikszentmihaly 1975:68)

Flow States can be experienced through both solitary and collaborative activities, and usually through engagement with an activity in which the goal or "meaning" with the activity is clear.

When observing participant interactions from a Flow State perspective, several patterns in the video documentation indicate that the participants may indeed approach flow:

Primary	**Facilitating innovation.** To which extent do the physicalization help facilitate innovative ideas? This is ultimately the meassure of success of these tools with the traffic authority. The data physicalizations were categorized on a scale from *no innovation* to *much innovation*.
Context	**Type of data.** How is data included? Scaled from *qualitative* to *quantitative*, with sub-categorizations (e.g., as stories, as background data). **Data processing**: How interesting is this data to the Traffic Authority: "How much have you done with our data?" From *unchanged* to *transformed*. **Contextual representation**. How do the designs represent the bus context? Each design was scaled from *abstractly* to *concretely* for how the data context was materialized (e.g., passengers as beads or sticks, routes as yarn, model of bus interior).
Conditions > Material expression	**Data affordance**. What does data encourage? The physicalizations were scaled from *observable* (a visualization) to *manipulable* (encouraging hands-on engagement). This dimension centered on the role of the data (as presented) in eliciting particular types of engagement. **Aesthetics**. How visually appealing does the data physicalization appear? From *very* to *not so much*. **Scale of prototype**. What is the scale of the data physicalization? From *big* to *small*. **Completion**. How 'finished' is the design as a prototype? From *hi fidelity* to *low fidelity*. **Complexity**. How complex does the physicalization look? How many 'parts'? From *complex* to *simple*. **Experiential complexity**. How easy to use is the design? The physicalizations were scaled from *self-explanatory* to *facilitated*. This dimension took into account how much explanation was needed to make a physicalization work.
Process > Participant interaction	**Engaging with data**. How effectively is data used to engage participants? This dimension was scaled from *least* to *most* engaging, focused on the primacy of the data in the tangible tool, and how it shaped the participants' experiences. **Experience flow**. What kind of Play Moods or Flow States are instigated? This dimension measured the level of participant engagement from *least* to *most*, and cross-characterized from *playful* to *serious*, with playacting on the playful end, and problem-solving or decision-making on the serious end. **Gamification.** How is a game experience used to encourage engagement? From *game* to *lecture*. On the one hand, the characterization *game* included participatory elements, like roles, turn-taking, and objective/problem-solving; on the other hand, *lecture* included explanations and static data. **Participant roles**. Which role do participants need to take to engage with the tool? The dimension explored a scale where participant roles ranged from maintaining their own perspectives, being *oneself* (in a decision-making process, e.g.) to embodying a *character* (in a role-playing scenario, e.g.).
Conse-quences	**Role as a tool**. Which role does the tool play in innovation? Scaled from *research tool* to *practical tool*, this dimension investigated the tools' utility in data collection and in decision-making, respectively.

Table 1. Framework for designing data physicalizations: 15 scaled dimensions developed in the dimensional analysis.

	Data physicalization	Bus Route Map		Travel Worms			Bus Stop Crowd			Corona Touch	
	Participant team	S-team	H-team	A-team	B-team	D-team	A-team	B-team	C-team	A-team	B-team
FLOW STATE	1. Ask questions about data		III	I	I	I					
	2. Solve a challenging problem	I	I				I	I	I		
	3. Take initiative	I								I	
PLAY MOODS	4. Make data personal			I		I					
	5. Share stories	I			I	I	IIIII	I			
	6. Play roles	III	II							II	I
SMALL BEGIN-NINGS	7. Use professional expertise	III									
	8. Compare to 'what I do'									II	
	9. Suggest design ideas	I	II			I	I	I	I		
	10. Initiate the unexpected	I									

Table 2. Framework for developing facilitation of co-analysis with data physicalization: 10 observed interaction patterns and in which videos they appear

1. ASK QUESTIONS ABOUT DATA

In many instances, the physical shape of data triggers participants to pose questions. With the Travel Worms, for instance, the facilitator asks the participants to pick four 'worms' (strings of coloured beads representing a passenger's travel time and modes of transport) and explain why they find them interesting. Two particular 'worms' trigger repeated questions about the passenger data:
A very short 'worm' with a few minutes of walking at each end of a 1-min bus ride: *"I picked a very short one, because I wondered why anybody would bother to take the bus that short?"*
"Why take a bus – walk, take a bus for 1 minute and then get off? It's a waste of resources!"
"I was wondering: Why did you want to take a bus if you are not disabled for just 5 minutes?"

And a 'worm' that combines walking, bus-ride and biking, Figure 3: *"I think this one is interesting: Biking in the end. It's a nice phenomenon if it is these commuter bikes?"*

Also, some of the very long 'worms' elicit questions: *"Why do they remain on public transport, when it takes so long?* Handling the data physically seems to stir curiosity.

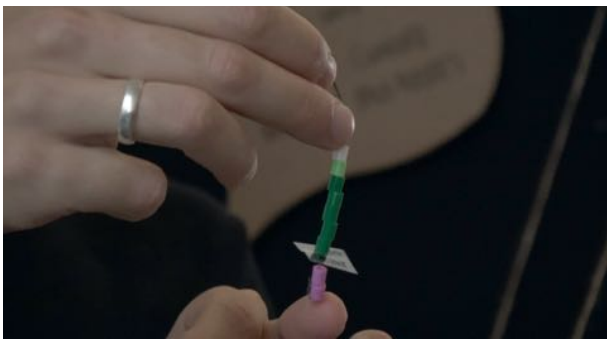

Figure 3.A short 'Travel Worm' triggers a participant to ask questions about the bike ride (pink beads) at the end of the travel.

2. SOLVE A CHALLENGING PROBLEM

The Flow State perspective helps identify situations when the participants get deeply absorbed in solving a challenging problem – rather than just look at the physicalization, or perform tasks as asked by the facilitators. In the Bus Route Map, the participants are challenged to buy the minimum of bus routes required to move a given number of passengers (coloured beads) to their respective neighbourhoods (coloured areas) in the map. This triggers intense discussion and experimentation with different bus route configurations. When the facilitators make suggestions, it seems to interfere with the flow rather than scaffold it.

Similarly, in the Bus Stop Crowd physicalization, participants are encouraged to find a physical arrangement at busy bus stops that prevents passengers from flocking to the door, when the bus arrives. With all participant teams we observe inspired shifting around of the materials at their disposal.

We observe that hectic activity sometimes is interspersed with moments of silence. From context it is quite easy to sense, even in the video recordings, if such moments are awkward silence, waiting for facilitators to push on, or rather quiet contemplation, where facilitation will appear interruptive.

Figure 4.Participants solve the challenging problem of nudging passenger to keep a distance with the Bus Stop Crowd data physicalization.

3. TAKE INITIATIVE

Once participants emerge into an activity, they may be inspired to take their own initiatives, to take control of the process. In the Bus Stop Crowd activity, the designers have prepared situation cards, which participants can draw at any time to challenge their bus stop designs, e.g. 'THE BUS NEEDS TO LEAVE IN 60 SECONDS'. While at the beginning the facilitators challenges participants to pick a card, later participants pick cards themselves to move the activity on. They even challenge themselves with 'red' (the most difficult) cards rather than 'green' ones. We see that as an indication that the activity 'flows', facilitation is no longer required.

In our analysis, we recognise Csikszentmihalyi's eight components of "The phenomenology of enjoyment":

"working with a clear goal in an activity, a balance between challenges and skills, receiving immediate feedback from the activity, the merging of action and awareness, intense concentration on a task, a sense of heightened control, forgetting one's self, forgetting time, and an activity that becomes autotelic or an end in and of itself." (Mainemelis and Dionysiou 2015, 131)

These dimensions seem useful not only as analytic lens but also as a guiding star for designers aiming to design inspiring data physicalizations.

ENGAGEMENT AS PLAY MOODS

Karoff (2013) suggests a framework and vocabulary for understanding play as practice (doing) and sensing (being). She draws on Bateson, Schmidt and Heidegger to conceptualise *Play Moods* as a way of describing the aim of the playing activity, the commonness of play as practice. Play Moods is a theory of engagement with the present moment, in contrast to theories of human play that suggest play as a vehicle for learning. Play Moods recognise play as a phenomenon and experience that is valuable in and of itself.

Karoff suggests that several Play Moods appear simultaneously and describes four in detail (Karoff, 2013:10):

DEVOTION - letting go of "doing" and seeing where being leads
INTENSITY - the unpredictable feeling of something exciting is going to happen
TENSION - readiness to "show oneself"
EUPHORIA - intense expectation of silliness

"In play, the production of meaning takes place through our activities together." (Skovbjerg & Bekker, 2018:8). Through the Play Moods perspective on engagement, we observe several patterns of playful interactions:

4. MAKE DATA PERSONAL

There are instances, when participants relate their personal experiences to the data. Quite clearly in the Travel Worms case: When asked to explain which 'worms' they picked, several participants talk about personal experiences: "*I chose this very long one, because that reminds me of me in public transport. I live far out in the countryside."* and *"They look like my travel. When I do I do short distances."*

In Play Mood terms, personalising data seems to align well with 'Tension', the readiness to show oneself to other participants.

5. SHARE STORIES

Some participants find opportunities to relate stories from their own life. For instance, when pondering about the short, 1-min bus Travel Worm, a participant tells this narrative: "*The short trip is really interesting, because it reminds me of back in the days, when I lived in Lithuania. There were these one-way streets and trolley busses always going the same way. If I was really late and I could see the trolley bus coming, I would jump in and ride for 2 minutes, just to save 5 minutes!"*

We feel the excitement of participants being engaged also on a personal level. More generally, the data physicalizations tend to trigger associations to things the participants have heard or seen, for instance, when discussing the Travel Worms: *"There is a lot of walking [before and after the bus ride]. Some years ago, there were commercials that you should leave the bus one stop before you normally would to get more exercise."*

Similarly, in the Bus Stop Crowd activity, participants make several associations to other places with similar crowding challenges:

"Like at concerts, the barriers"
"Like in the airport, you make a channel"
"In the supermarket it works with drawings on the floor"
"In theme parks they have winding barriers. Like a maze."
"Like Orange Stage on Roskilde Festival"

While associations like these are less personal, participants in a sense work hard to make the data real for themselves.

6. PLAY ROLES

The most playful moments in the activities happen when participants start playacting roles – what Karoff would term Euphoria, an intense expectation of silliness. In the Corona Touch activity, participants draw situation cards, describing a situation in direct language, e.g.

YOU ENTER THE BUS AND START TO LOOK FOR A SEAT. SUDDENLY THE BUS STARTS DRIVING AWAY FROM THE STATION. YOU FEEL OUT OF BALANCE AND MIGHT FALL OVER. HOW MANY BARS WILL YOU TOUCH ON THE WAY TO YOUR SEAT?

In response one participant acts the movements of a monkey to show how she might tackle the situation – to the amusement of her teammates, Figure 5: *"And probably on my way to the seat, I would at least touch the vertical bar once, but probably twice, usually just kind of going monkey-bars, like…[miming monkey bars]."*

In the Bus Route Map activity, facilitators prompt the participants to imagine they are politicians discussing bus service levels vs. cost for citizens in the city. This leads to spontaneous acting: *"There are lots of voters here, how do we move them? Good voters, they are rich in this area!" "Because they are rich, they are complaining a lot! – That's how they get their own bus route."* Upon completing the map: *"I'm not sure we'll be elected next time!"*

In some of the data physicalizations not shown here, the roleplay elements are even more pronounced: In one activity, participants act out how they will react to a ticket controller, if they have no ticket. In another, they roleplay how they will catch a bus if the routes have been temporally shifted. These physicalizations, however, are richer on qualitative data (passenger stories), but make less use of the quantitative data.

"Play moods are essential to play, and they are always in plural, depending on how players engage with the world and the people they are with. (…) When highlighting mood in play it becomes possible to go beyond a functional approach to play, and instead to focus on play as a common way of living" (Karoff, 2013:10)

Play Moods is a convincing perspective for characterising playful activities when observed, and there is likely potential for drawing on the theory proactively in design.

Figure 5.A participant demonstrate how she migh go 'monkey-bars' through a shaking bus to to keep balance.

INNOVATION – SMALL BEGINNINGS?

Our overall perspective on the data physicalizations was to investigate, if they are able to facilitate innovation. In the video analysis, we looked for indications of 'innovation'. We particularly observed the reactions of the traffic authority and municipality participants – if there were any indications of 'innovation' emerging in the trial sessions. If, according to Buur & Larsen (2010), the emergence of novelty comes about in local interactions between people with different intentions, a vocabulary around the phenomena of "emerging novelty in local interactions" is useful. The traditional business definition of innovation – *"any new policy that an entrepreneur undertakes to reduce the overall cost of production or increase the demand for his products"* (Schumpeter 1943) – is not useful for this kind of micro-analysis. Instead, we look for *Small Beginnings*, a term introduced by Shaw (2000) to denote "low key" but meaningful practices. Shaw suggests conversational inquiry as an approach to organizational development. Larsen (2005) uses the related term "openings" similarly as minor differences that might be amplified.

The present moment becomes extremely important here, as does the understanding of time. Based on Mead (1934), Stacey (2001) understands time as a circular relation between the past, the present and the future, always perceived as present. As interaction takes place in the present as continuous iteration, the past is reproduced, but not necessarily in the same way; thus, it is "transformed as the process of its expression" (Larsen, 2005:41). Small differences might be amplified, resulting in the ideas of the future being changed along with the forming nature of the past. Following an ethnomethodological understanding of human interaction, we can only know the significance of a particular Small Beginning when viewed in sequence, but it is possible to notice that something is taking place that is slightly different from the usual. We observe four patterns that indicate Small Beginnings:

7. USE PROFESSIONAL EXPERTISE

The traffic authority and municipality participants often find opportunities to air their professional expertise on busses, bus traffic, bus planning. For instance, in the Bus Route Map case, the designers' activity only allows the 'politicians' to buy passenger services in one direction, Figure 6. A traffic authority member challenges the designers: *"But going the one way there are 50 and going the other way we have 50. That's how we plan routes."* The designers compromise.

While not necessarily showing the emergence of Small Beginnings, it does show that the participants work to make the data physicalizations relevant to their practice. In some cases, this may lead to rethinking of terms or perspectives.

8. COMPARE TO 'WHAT I DO'

Several participants find ways of relating the data they experience to 'what I do'. They compare what data tells about other peoples' actions to their own. In the Corona Touch physicalization, participants are challenged to guess how many times bus passengers touch the bars, handles, stop button, their face mask, their cell phone in these times of pandemic restrictions. (While the designers had the totals of bus passengers in any bus from the quantitative data, the number of touch contacts they had to register themselves in field observations). The participants make their guesses by counting out small laser cut "virus tokens": *"I always touch the chair for some reason when I enter... I'm not that tall, I don't think I'd touch [the horizontal bars]." "I'm hanging on for dear life."* Confronted with what other people do, such an activity may lead to Small Beginnings of what you yourself might do differently in your daily commute – but they would likely only show in retrospect.

9. SUGGEST DESIGN IDEAS

The data physicalizations that were presented along with a problem-solving scenario (e.g. planning new bus routes on the Bus Route Map and designing a bus stop configuration in the Bus Stop Crowd), elicit lots of suggestive questions, and when participants themselves come up with design solutions there is a potential for Small Beginnings of innovation. In our events, participants for instance together develop the ideas of:

- A projector on the bus that illuminates distance markings on the pavement in front of the doors (to remind passengers to keep safe distance when boarding)

- An indication in each bus seat telling how many have sat here recently (to reduce contamination risk)

While we do not know if such ideas develop into innovations, the traffic authority may actually have opportunities to bring the ideas forward, whereas regular bus passengers seldom have such an option. Larsen (2005:40) argues for attention to *"a heightened awareness"* of a sense of opportunity that might have emerged in the actual moment. It is fragmentary and might change again very quickly as the spontaneous action continues. It may turn out to be insignificant, or it might lead on to something important.

Figure 6. Traffic planners engage their professional expertise to develop a plan in the Bus Route Map data physicalization.

10. INITIATE THE UNEXPECTED

Something that tends to really push an activity forward, is when participants take unexpected initiatives. For instance, when participants 'break the rules' set by the facilitators, or start using the data physicalizations in unexpected ways. For instance, one participant in the Bus Route Map activity tries to stretch the otherwise fixed-length threads that represent a bus line at a fixed cost. Larsen refers to a kind of difference in the conversation *"perhaps something surprising, or a kind of 'presence' and engagement that emerges between the people talking"* (Larsen, 2005:40). It may be a change in a participant's tonality, gestures and responses, a lingering pause or a rapid/overlapping exchange of turns in the conversation between participants.

CONCLUSIONS

We have explored how particular qualities in the design of data physicalizations invite interaction. When balanced with facilitation to support engagement around these big-data physicalizations, participants begin to make Small Beginnings toward innovation. The dimensional analysis of 15 data physicalizations open a space of material aspects that influence the engagement that may be achieved with well-designed data physicalizations, and ultimately the innovative potential that they open with participants. As analytical perspectives, the theories of Flow State, Play Moods and Small Beginnings further allowed us to identify ten patterns in the video documentations of how people employ the data physicalizations as data analysis method for scaling big data to something meaningful, of value to them.

We observed, for example, that fixed constructs invite observation, while loose parts invite manipulation. The passenger Travel Worms, hanging from hooks, invited users to hang them from the bus frame below. Facilitators asked participants to reflect on travel worms, which led them to make the data personal and share stories. The fixed vira-token display, on the other hand, which was presented after participants had placed their own vira-tokens in an interactive activity, invited participants to compare the data to their own imagined experiences ('what I do'). We observed also that facilitation can scaffold participants in asking questions to the data, personify with them, and engage their professional expertise. In some instances, we observed how (interruptive) facilitation served to break rather than support flow. We believe that the dimensions and scales presented in Table 1 as a framework can inspire the design of data physicalizations. The set of interaction patterns summarized in Table 2, grounded in Flow State, Play Moods and Small Beginnings theories, may serve as a framework for developing facilitation of analysis with data physicalization.

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