Let's Get Physical: Promoting Data Physicalization in Workshop Formats

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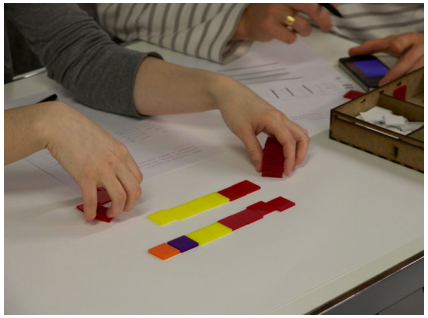
Abstract
In this pictorial, we present a method to facilitate hands-on physicalization processes during workshops. Data physicalization – encoding data in physical artefacts – allows for new ways to represent and communicate data and, as a process, can make the principles of data representation more "graspable". In order to (1) engage different research communities to discuss data physicalization from a social and technology point of view, (2) promote data-driven prototyping, and (3) teach physicalization as a creative process in educational settings we have run hands-on data physicalization workshops within Human Computer Interaction, Information visualization and Design communities. Based on these workshops, we identified three main pitfalls that can cause participants to get stuck in the data preparation, ideation and construction phases. To address these, we designed a workshop to facilitate a rapid engagement in physicalization activities. Testing this method as part of another physicalization workshop shows its potential for participant engagement, prototyping and design reflection.

Authors Keywords
Data Physicalisation; Information Visualization; Creative workshop.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

*INTRO***DUCTION**



Data physicalization – the representation of data through the geometric or physical properties of an artifact [16]– has recently received a lot of attention, visible in numerous publications [6,7,13,15,20,22] and projects within and outside academia [3]. Physicalization can be considered a thriving research area that raises new questions and opportunities to represent data in interactive and tangible ways to facilitate sense making and communication. However, it is also a practical process that enables people to actively think about data-related analytical problems, e.g. how to maintain an awareness of data changes over time [12] – all the while experiencing the principles of data representation and communication in a hands-on way.

In order to (1) **engage** different research communities to discuss the potential and challenges of data physicalization from a social and technology point of view, (2) **promote** data-driven prototyping among design practitioners, and (3) **teach** physicalization as a creative process of engaging with data in educational settings, we, together with other researchers and practitioners have organized a number of physicalization workshops , targeted at researchers [1,8,18], students [11,14,24], the general public [10,11], and local non-governmental organisations [4]. Our goal was to engage our participants that came from multiple backgrounds in hands-on physicalization activities first to provide them with an experience of this unique way of exploring and representing data which would then ground deeper discussions around (research) questions [19,21] and challenges in this area. However, we found that integrating such activities into a short, typically, one-day workshop to be a challenge as multiple steps and skills are required:

1. DATA PREPARATION *which includes finding a data set to work with, possibly collecting data or processing existing (digital) data into an adequate form.*

2. IDEATION of possible *ways to represent/physicalize the data, including the questions that the physicalization aim to answer or the intended usage scenarios.*

3. MATERIAL SELECTION *involves choosing the (physical) means to encode the data, including, e.g., analog material such as paper, wooden blocks, or plasticine, or digital tools such as 3D modeling software, laser cutters, or 3D printers (see images to the left).*

4. BUILDING THE PHYSICALIZATION as *the process of mapping the data to the chosen physical and material properties with the actual physicalization as a result.*

5. REFLECTING ON THE PHYSICALIZATION, *its intentions and the design process with other participants, leading into a discussion of general (technological, creative, and/or social) challenges in this area.*

To add to the complexity, ideally workshop participants would document their design process from beginning to end for themselves, to enhance reflection and further discussion with other participants, and for presentation beyond the workshop (e.g., on the web).

All of these steps require certain skills and expertises. With time being limited in a typical workshop setting, we learnt from early workshops we conducted that the few hours dedicated to such hands-on activities often left participants without a sense of a concrete outcome or accomplishment. We identified three potential pitfalls:

(1) Participants get stuck in the data preparation stage, because their data has to be processed, or because they spend a lot of time looking for data.

(2) Participants get stuck at the ideation phase, thinking too long about a concept for their physicalization.

(3) Participants get stuck at the construction phase with an ambitious idea that involves complex processes.

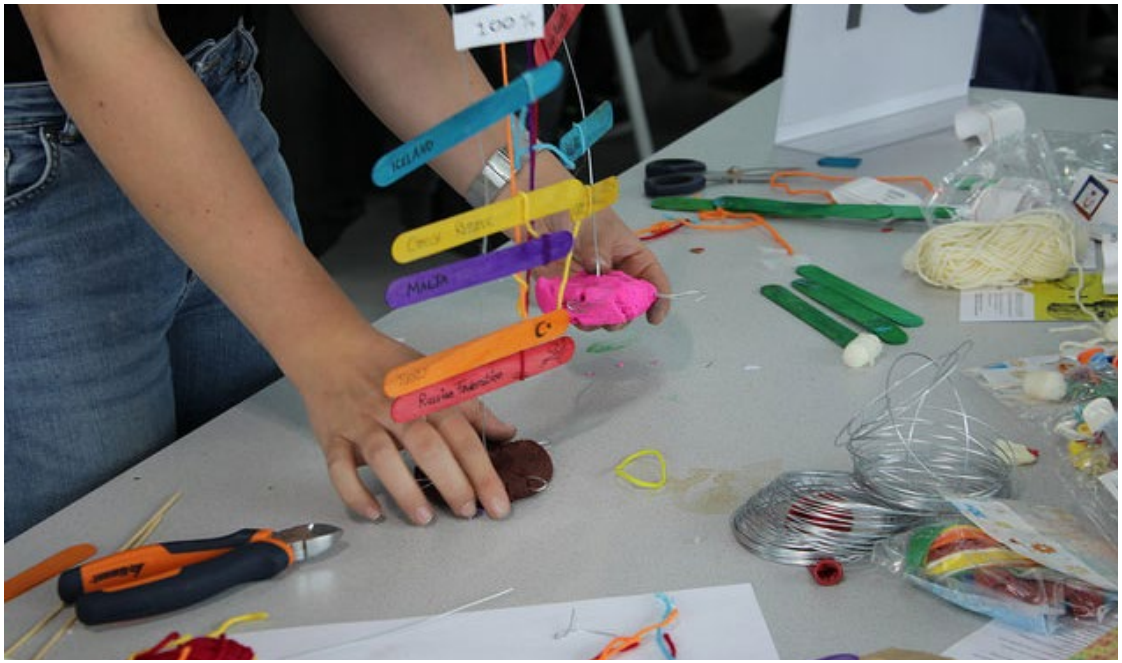
These pitfalls could be mitigated by introducing constraints. Indeed, in a study context where all but the ideation phase were determined by the experimental protocol [13], participants were able to go through the entire process in less than an hour. However, such constraints are not compatible with our workshop goal to promote the discussion of aspects such as materiality[23] or creative innovation through physicalization.

These observations led us to develop a more formalized workshop design method to facilitate a rapid, yet open-ended engagment in the physicalization process. The core of this method is a set of cards that invite participants to design a physicalization within given constraints (selected data and physical materials, and given usage scenarios). This reduces the problem space without overly constraining creative thinking. To facililitate documentation as an important component of prototype design, we introduced a system - Do.Doc [5] - to allow the easy creation of stop-motion animations, as included throughout this pictorial .

We tested this method at our most recent physicalization workshop held in conjunction with the Design Research Society conference (DRS, 2016 [17]), and found that, compared to our previous workshops, it led to more concrete outcomes in form of (a) physicalization prototypes and (b) active participant engagement which was also visible in participants' reflections on their prototypes and the potential of physicalization in general.

This pictorial contributes the introduction and discussion of a workshop design method applicable to academic, industrial, and educational settings to promote design-driven and hands-on discussions around tangible data-driven interfaces. In the following, we illustrate this method and its results, and discuss its application to physicalization workshops and beyond. All workshop materials are open source for others to reuse and modify to encourage an open discussion.

All figures presented in introduction come from precedent workshop editions of data physicalization workshops conducted by the authors (Futur en Seine 2014 & Twente 2016).



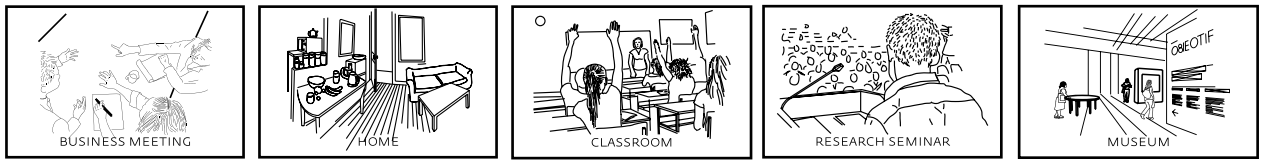
WORKSHOP **COMPONENTS**

ACTIVITY CARDS

Each activity card contains a single descriptive word to evoke a high-level task. These tasks are "convince", "discover", "collect", "enjoy", "stimulate" and "collaborate".

These cards are designed to inspire. We want to avoid being too prescriptive. The tasks are deliberately high-level and can be interpreted in many ways.

SCENARIO CARDS



Each scenario card contains a figure and word describing the scenario. The scenarios are "the street", "business meeting", "home", "classroom" and "museum".

Some scenarios focus on a range of different contexts: personal, research, or industry. By offering this range of contexts, we provide different constraints, evoking different ideas and inspirations.

DATA CARDS

DISTRIBUTION OF CONSUMED ALCOHOLS

	Average (g)	% Beer	% Wine	% Spirits	% Others
Ethiopia	57.1	49.7	0.6	8.2	41.4
Brazil	33.1	59.6	4	36.3	0.1
USA	28.7	50	17.3	32.7	0
France	27.9	18.8	56.4	23.1	1.7
Germany	31.7	53.6	27.8	18.6	0
Ireland	31.7	48.1	18.7	18.7	7.7
UK	29.8	36.9	33.8	21.8	7.5
Russia	48.3	37.6	11.4	51	0
Australia	31.3	44	36.7	12.5	6.8

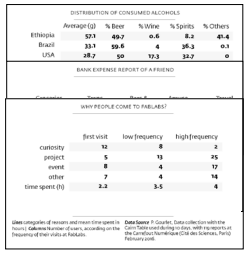
Lines countries | ***Columns*** average amount of daily alcohol consumption in grams & how (percentage of specific bevarages) ***Data Source*** World Health Organization

ASYLUM APPLICANTS TO E.U. COUNTRIES (2011-2015)

	Male	Female
<14 years old	333380	290375
14-17 years old	198670	55190
18-34 years old	1306925	395150
35-64 years old	395665	199790
65 + years old	9845	12020

Lines Age | ***Columns*** Number of Males/Females asylum applicants to the E.U. from 2011-2015 ***Data Source*** EuroStat http://appsso.eurostat.ec.europa.eu/nui/show.do?data-set=migr_asyappctzm&lang=en

Download card set: https://tinyurl.com/hjcgsud



Each dataset card contains a title, a label for each dimension, a table with the data values and the data source. Data sets focus on topics such as: "Distribution of consumed alcohols", "Asylum applicants to EU countries (2011-2015)", "Why people come to FabLabs?", "Tarantino movies (profits, death, swear words)" and "Appropriateness ratings of behaviors in certain social situations".

Our selection of datasets was driven by the following criterias: easy to read and understandable; diversity of topics, e.g., ranging from highly political to more personal, or fun; inclusion of different data types such as temporal and geo-spatial data, as well as more abstract data.

MATERIALS & TOOLS

MATERIALS (SEVERAL UNITS)
- wooden blocks
- small colored tokens
- pastas
- Lego characters
- wool
- tooth-picks
- colorful plastic tiles
- food coloring
- elastic bands
- plastic cups
- cloth-pins
- popsicle
- marshmallows
- play-doh (+ accessories)

TOOLS (SEVERAL UNITS)
- rulers
- knifes
- knife mat
- tapes
- pencils
- markers
- glue
- paper
- post-it
- scissors

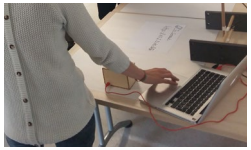
When choosing these materials, it was important to us that they would cover a range of different material properties such as being bendable, pourable, and malleable. Furthermore, we chose materials that participants could easily engage with, without needing instructions or practice.

DOCUMENTATION TOOLS

We provided Do.doc to document the design process, which is a system specifically designed to document design and learning activities.

https://github.com/l-atelier-des-chercheurs/dodoc

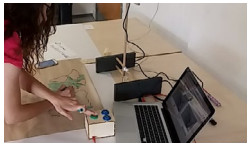
THE *WORKSHOP* PROCESS











PRESENTATION
30 minutes

GROUPING & PICKING CARDS
30 minutes

MATERIALS & TOOLS
20 minutes

BUIDLING & DOCUMENTING
2 hours

PRESENTING TO OTHERS
2 hours

REFLECTION
1 hour

01
After a short introduction round, we present the physicalization process, including the design cards described above, physicalization materials, and the Do.Doc documentation tool. Participants are asked to document their design process while creating the physicalization.

02
Participants are assigned to groups based on affinity and random selection. Each group picks one design activity card of each type (an activity, a scenario and a data set). After picking the cards participants get 10 minutes to read them and asked questions to make sure they understand the activity, scenario, and data.

Groups should consist of 2-4 people. Mixing workshop participants randomly can be a good way to bring together diverse perspectives.

03
Participants are asked to select a maximum of 3 different materials from a wide range (see previous page). Additional tools such as measurement tape, scissors, and glue are provided to manipulate the materials.

Groups are allowed to change materials throughout their design process, if necessary.

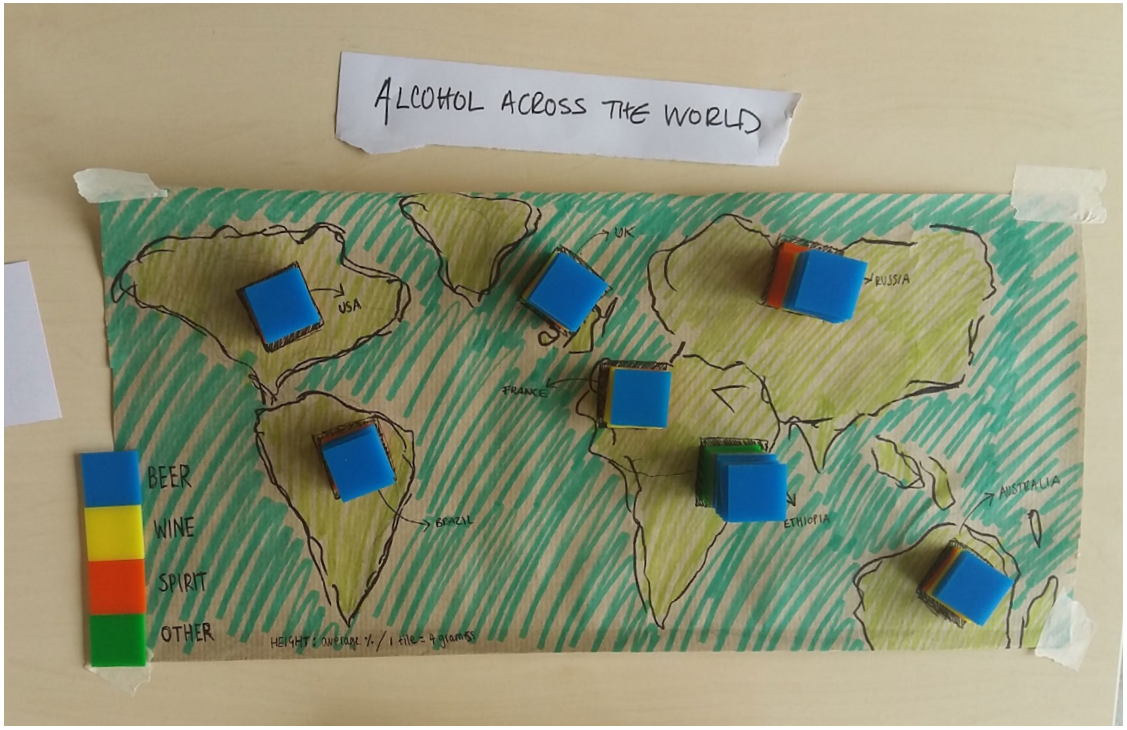
04
Participant are coming up with an idea for their physicalization and create it. They are asked to document their design process, by taking pictures or videos of sketches, prototypes and the assemblance of their phsyicalization. The Do.Doc station facilitates this by providing a stationary camera and an online environment to upload, annotate and share pictures and videos.

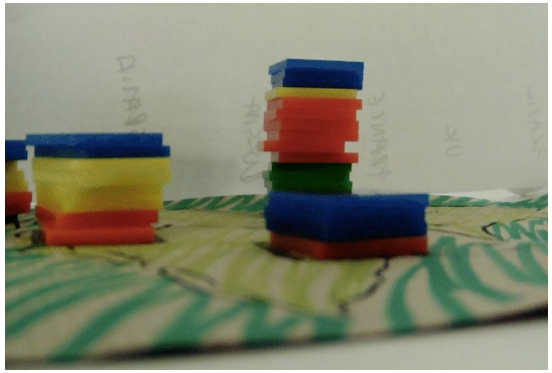
05
During the presentation phase, participants share their physicalization outcomes, along with their general ideas and intentions (“show”). Presentations include a period where other participants can explore the physicalization themselves (“explore”), asked questions and provide feedback (“discuss & reflect”).

The presentation phase can be left for participants to shape as they see fit. However, it should always include the three aspects of “show”, “explore” and “discuss & reflect”.

06
Participants and facilitators discuss their experiences with the process of physicalization, its benefits and challenges (as experienced as part of the workshop as well as in general) and any questions that came up during the workshop. Discussions also include on the workshop outcomes and potential improvements on the workshop design.

GROUP
PHYSICALIZATION
PROJECTS





GROUP 1
Consumption of Alcohol in Different Countries

ENJOY MUSEUM CONSUMED ALCOHOLS

MARKERS
SCISSORS
TAPE

CRAFT PAPER
PLASTIC TILES

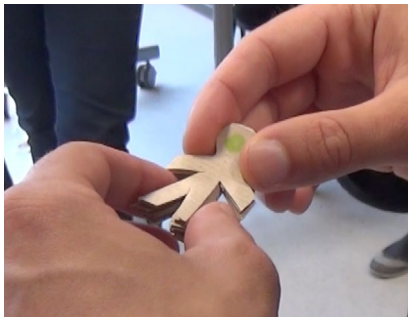
Group 1 was instructed through the activity cards they picked to create a representation of the types of alcohol consumptions in selected countries (dataset) that would be suitable to be presented in a museum setting (scenario) for visitors' enjoyment (activity). The group sketched and colored a world map where the countries included in the data set were visible. Each type of alcohol was then represented by a square token with different colors representing the type of alcohol (beer, wine, spirits and others). One token represented 4 grams of alcohol consumed (in average per year and per person). Piles of tokens were positioned on the map according to the alcohol consumption in each country. The group produced short animations using the DoDoc to document their process and give the physicalization an animated touch.

Below is a top-down view of the final data representation. While this representation worked out great for the participants present in the room, it was difficult to document as the 3D stacks of tokens hide the different colors included from a top-down view, while a side view makes it difficult to see countries that belong to the token stacks.

GROUP 2

Asylum Seekers Represented by Paper People Chains

"Take this, you are responsible for it"



COLLABORATE

CLASSROOM

ASYLUM APPLICANTS TO E.U

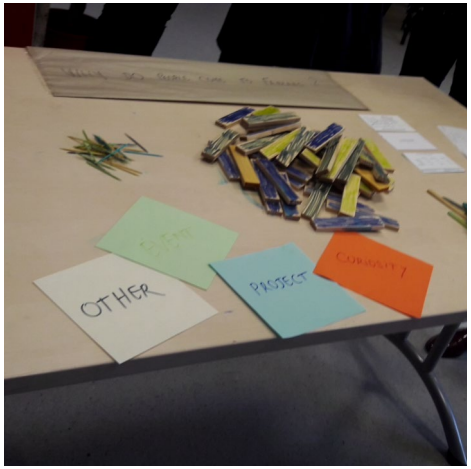
PEN
SCISSORS

CRAFT PAPER

The activity cards instructed Group 2 to create a representation of the number of asylum seekers to the European Union (data) suitable for a classroom setting (scenario) to stimulate (activity) discussion. The group cut out paper chains shaped as little figurines holding hands. This group decided to present their physicalization through a performance. The designers first handed each of the paper chains to other workshop participants with the words "They are your responsibility now". The fragility and intricateness of the paper chains created a urge to hold them carefully.

This feeling of responsibility was enhanced when the designers started to explain the meaning of the chains: Each chain represents a particular age group and gender (male or female) of asylum seekers. Each human shape in a chain represents 1000 humans, the ones with skirts women, the others men. Each chain was marked with a color so that two chains representing asylum seekers of the same age group but different genders would match up. Workshop participants holding different chains immediately started to find their "gender match", holding chains side-by-side to discuss differences in numbers. The discussion quickly started to focus on the topic of responsibility and vulnerability, moving away from the quantitative data toward a rich discussion of its implications.

GROUP 3
Why Do People Come to FabLabs?



DISCOVER

SEMINAR

FABLABS VISITS

MARKERS

WOOD BLOCKS, TOOTH PICKS, FOOD COLORING PAPER

Group 3 drew activity cards that invited the creation of a representation of people's motivations to visit a fab lab (data) that would allow people in a research seminar (scenario) to discover insights (activity).

The group colored differently shaped wooden blocks to represent different motivations; block size showed how frequently people visited a fab lab (first-time, ocassionally or frequent).

During the presentation these blocks were placed in piles on a table to encourage active exploration by all workshop participants. As the task was to "discover", the group invited the other workshop participants to engage with the wooden blocks which led to sorting by color and size and active discussions.

GROUP 4
The Piñata Movies

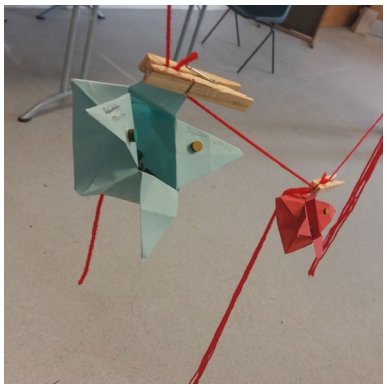
COMMUNICATE

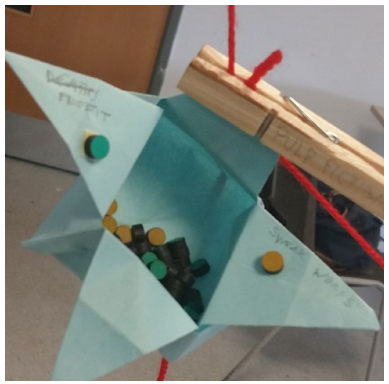
HOME

TARANTINO MOVIES

TAPE
MARKERS

WOOL
CLOTH PINS
SMALL TOKENS
PLASTIC CUPS
MASHMALLOWS





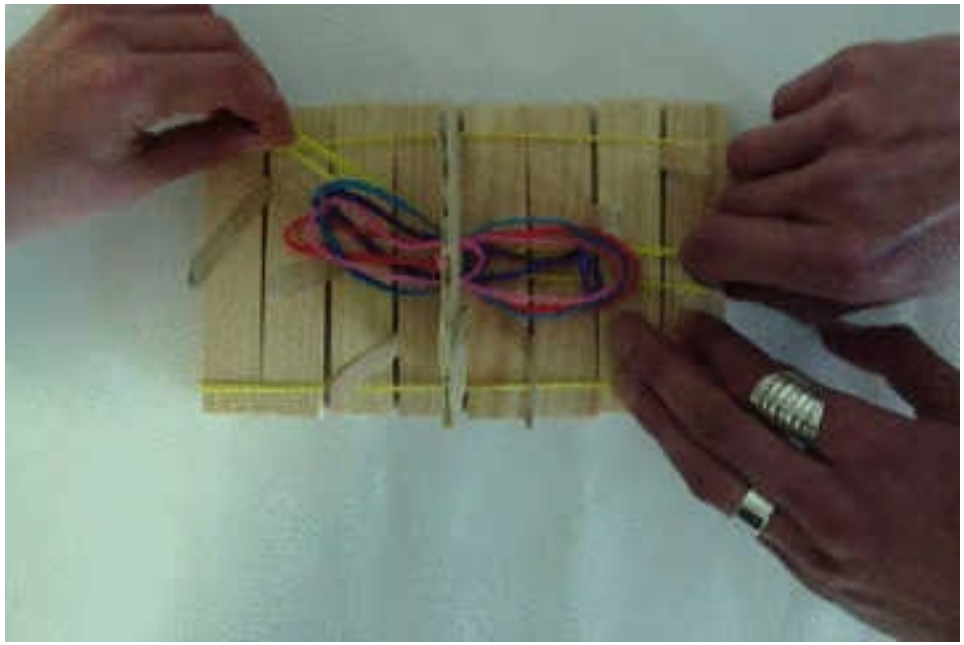
The activity cards asked Group 4 to communicate (activity) data about Quentin Tarantino movies (data) in a home setting (scenario).

The group designed a two-part physicalization to help people decide which movie to watch in two different ways: First, little boxes made out of folded paper represented each movie. Each box was filled with little colored plastic pieces, represening profit (green) and swear words (yellow). Red strings attached at the bottom of each box represent the number of deaths occuring in the corresponding movie.
A second representation was meant to be more persuasive: the data for each movie was converted into differently colored marshmallows and filled into a transparent cup. People could choose their movie based on the attractiveness of the corresponding marshmallows.

GROUP 5
Elastic Appropriateness

In contrast to the other groups, Group 5 was asked to build a physicalization that would facilitate "collecting" data (activity) about behavior appropriateness ratings (data) in a business meeting context (scenario). The group addressed this challenge by designing a physicalization tool to collect feedback on appropriateness questions during a job interview.

The interviewee sits on one side of the device; the interviewer on the other side.
Both pull an elastic of a certain color to declare the level of appropriateness of a certain behavior. The more they pull the less they consider a behavior appropriate in a certain situation. A small wall in between the interviewee and the interviewer obscures their actions for each other. A grid on the device allows to measure the position of the elastic and, hence, the level of appropriateness. But if interviewee or interviewer pull the elastic too hard it breaks the device!



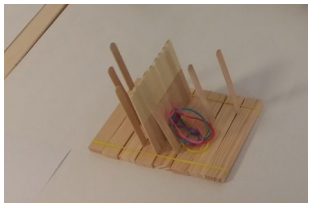
COLLECT

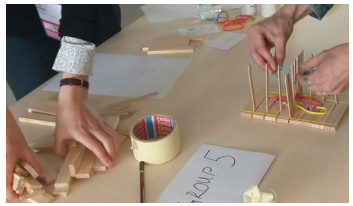
BUSINESS MEETING

APPROPRIATNESS RATINGS

MARKERS

ELASTIC BANDS
WOOD BLOCKS
POPSICLES





*DIS*CUSSION

Reflecting on our workshop design, the diversity of prototypes and participants' reflections show that the introduced design constraints enabled a focused engagement with physicalization while leaving sufficient room for creativity. Groups created maps with physical tokens (G1), paper sculptures (G2), arranged wooden blocks (G3), assembled hanging sculptures from folded paper boxes (G4), and interactives using popsicles and elastics (G5).

In contrast to our previous workshops, all groups finished a complete physicalization prototype within the given time constraints, and their presentation of these diverse prototypes directly led into vivid discussions around the impact of the chosen material, potential for interactivity, and potential real-world application scenarios. The documentation activity served as an additional prototyping and reflection mechanism for participants. For example, Group 1 explored how to communicate 3D structures in a 2D medium. Their documentation videos were an instrumental part of their prototype presentation and subsequent discussions. The documentation material also helped to make participants' activities during the workshop more persistent, promoting a feeling of accomplishment.

We find that our workshop method successfully mitigated the pitfalls we identified at our previous workshops:

1. *The data set cards provided a quick entry point into the physicalization activity without having to deal with finding and preparing data. Working with sample data gave participants an idea of how to prepare and structure their own data for future physicalization projects.*
2. *The scenario and activity cards gave sufficient context and focus to help participants reduce the problem space of possible physicalizations for their assigned data. It also highlighted the importance of considering the intended context as a major element of the physicalization process, visible in enactments performed by participants while presenting their prototypes and in subsequent discussions.*
3. *Constraining participants to three physical materials promoted a playful and exploratory mindset to come up with creative ideas achievable in a short time.*

Compared to more open-ended [1,8,18] and more constrained [10,11,24] workshop formats, we found this card-based workshop to represent a fruitful middle ground to promote thinking of materials, data types, supported activities and intended usage scenarios crucial for physicalizing data in general. Exposing researchers, design practitioners, or students to such activities can lead the way into critical discussions as well as innovative data-driven design projects using digital technology such as 3D printing, laser cutting and Arduino.

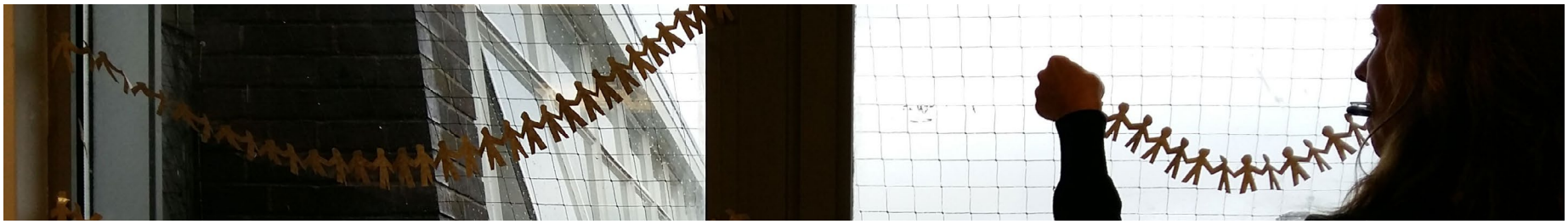
OPEN QUESTIONS

This pictorial presents initial practical experiences with this constraint-based workshop design method - its application in future workshop settings will show how participants' background and the workshop context in combination with our cards influences the workshop dynamics and outcomes. For example, at our DRS workshop, participants were trained designers which may have influenced deeply the workshop outcomes. Through varying the pre-selected materials and potentially introducing different forms of technology, we will further investigate the impact of such choices on design outcomes and discursive reflections.

PRACTICAL CHALLENGES

With their focus on data, activities and scenarios, our set of cards provide a useful structure that can scaffold design activities in other workshop settings within academic, industrial, and educational contexts. The particular data sets, activities, and scenarios we provide here are mere examples that can easily be changed or expanded. However, workshop organizers should watch out for

challenging combinations of different card types. For example, Group 5's cards included "collect" as an activity (participatory data collections through physical devices is an area of interest for data physicalizations) and "business meeting" as a scenario - a somewhat unrealistic combination. While the participants found a creative solution within their constraints, such challenging combinations might become counterproductive. We generally encourage the addition of more scenarios, activities, and, of course, data sets to our card set to cater for a range of physicalization workshops and beyond, and we hope to initiate a discussion among workshop designers and participants to develop this approach further.



*CON*CLUSION

In this pictorial we have presented a workshop design method to promote data physicalization activities and initiate reflections and discussions within the time constraints of a one-day workshop. By introducing design constraints on data, scenarios and activities in form of cards and pre-selected physical materials, our method promotes rapid engagement in data-driven prototyping with physical materials, without participants getting lost in the data preparation, ideation, or construction phases. Our illustrations of this method based on a workshop we ran at DRS 2016 show a vivid diversity of physicalization outcomes that participants were able to create, document, present and discuss in a brief period of time.

While we tested our methodology in the context of data physicalization, we believe that it can apply to other forms of data visualization as well as in other design exercises such as early-stage prototyping. The set of constraints provided by our cards is in line with initial questions a designer needs to ask when designing interactive systems (Who are your users? What do they intend to do with your system and in which context?). In fact, our approach relates to previous work on tangible interfaces [9] and designing interactive technology for children where activity cards have been designed to guide design processes [2].

This pictorial provides a blueprint to apply, adapt, deploy and further study this method in different contexts (see Page 4 for a checklist of workshop components, and Page 5 for an example workshop schedule). All workshop materials are available online (http://dataphys.org/workshops/materials/) for everyone to use and modify and share their experiences to start a discussion about designing physicalisation workshops.

Acknowledgements
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