DEVELOPMENT OF THE FORD CONCREATE

A Data Immersion Toolkit | Building data for better insights

Master graduation thesis

By Tiara Spalburg
Graduate student | MSc Integrated Product Design

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Delft University of Technology,
Faculty of Industrial Design Engineering
Landbergstraat 15, 2628 CE Delft, the Netherlands
+31 (0)15 27 89807

Dr. Milene Gonçalves | Chair
Dr. Senthil Chandrasegaran | Mentor

Ford Research and Innovation Center
Süsterfeldstraße 200, 52072 Aachen, Duitsland
+49 241 94210

Ir. Nicole Eikelenberg | Company supervisor

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PREFACE

Dear reader,

I am incredibly excited to share this thesis with you that results from 7 months of the hardest work I have probably ever done so far. Although no blood was involved, there was some sweat and a tear or two. Therefore, I would like to shortly describe the journey first and thank my incredible support system before I let you dive into this report.

I started this graduation project after working as a concept designer for 1.5 years, meaning I did no academic work whatsoever and hadn't been involved with the university in a while, which caused some nerves about finding a suitable project. However, when I came across the brief for this assignment, the topics creativity and data visualisation immediately sparked my interest and after googling the contact person, dr. Milene Gonçalves, I decided I wanted to do this project. After going through an application process tougher than the one I went through to be hired as a concept designer, I started the project full of energy. This energy dipped around the midterm when I realised that besides good work done, I had to step up my game to meet the academic standard that I slightly forgot about in the time off of studying. It reached an all-time low in the weeks after when, besides a broken laptop and other personal circumstances, I was mainly worried about the COVID-19 situation in Suriname, where my family lives. Luckily, through the support of my supervisory team, loved ones, and a healthy dose of performance pressure and persistence, I kept working and restored the connection with the project that got lost before. When all the research dots finally connected and I could do a little arts and crafts on the prototype, the excitement was back in full force, concluding with the highlight that was the final user test. After about 110 busy days, mostly spent at an almost empty faculty, I can present a concept that I am proud of.

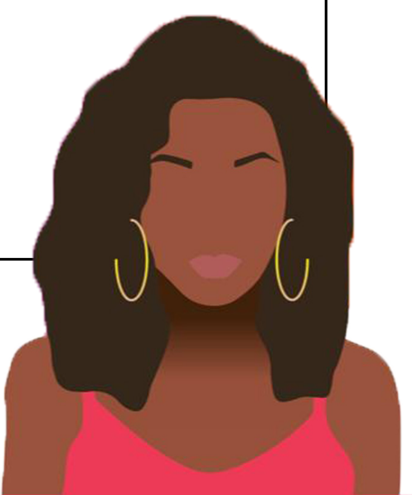
I could not have achieved this result without the support of my supervisory team that not only challenged me to strive for a higher academic level but also provided a safe environment for me to explore and grow in through warm, personal support. Therefore, I would like to thank Milene Gonçalves (chair), Senthil Chandrasegaran (mentor) and Nicole Eikelenberg (company mentor). A special thank you to Agnes Tan, the Ford design team, and my final user test participants.

I would also like to thank my family, friends and the Ford graduation community. As this is probably the last report of this extent that I will be writing in a while, if not forever, I want to mention the ones that had to listen to most of my nagging, ideas and all over the place explanations by first and last name: Pedro Barbosa Tinnemans, Vienna Spalburg, Jeanine Mooij, Xiao-Mei Huang, Maaike Weber, Siqi Hao and Deborah Mellado Cruz.

Now that you have made it through this preface, I hope you will also enjoy reading the following 100 pages.

Thank you,

Tiara Spalburg



EXECUTIVE SUMMARY

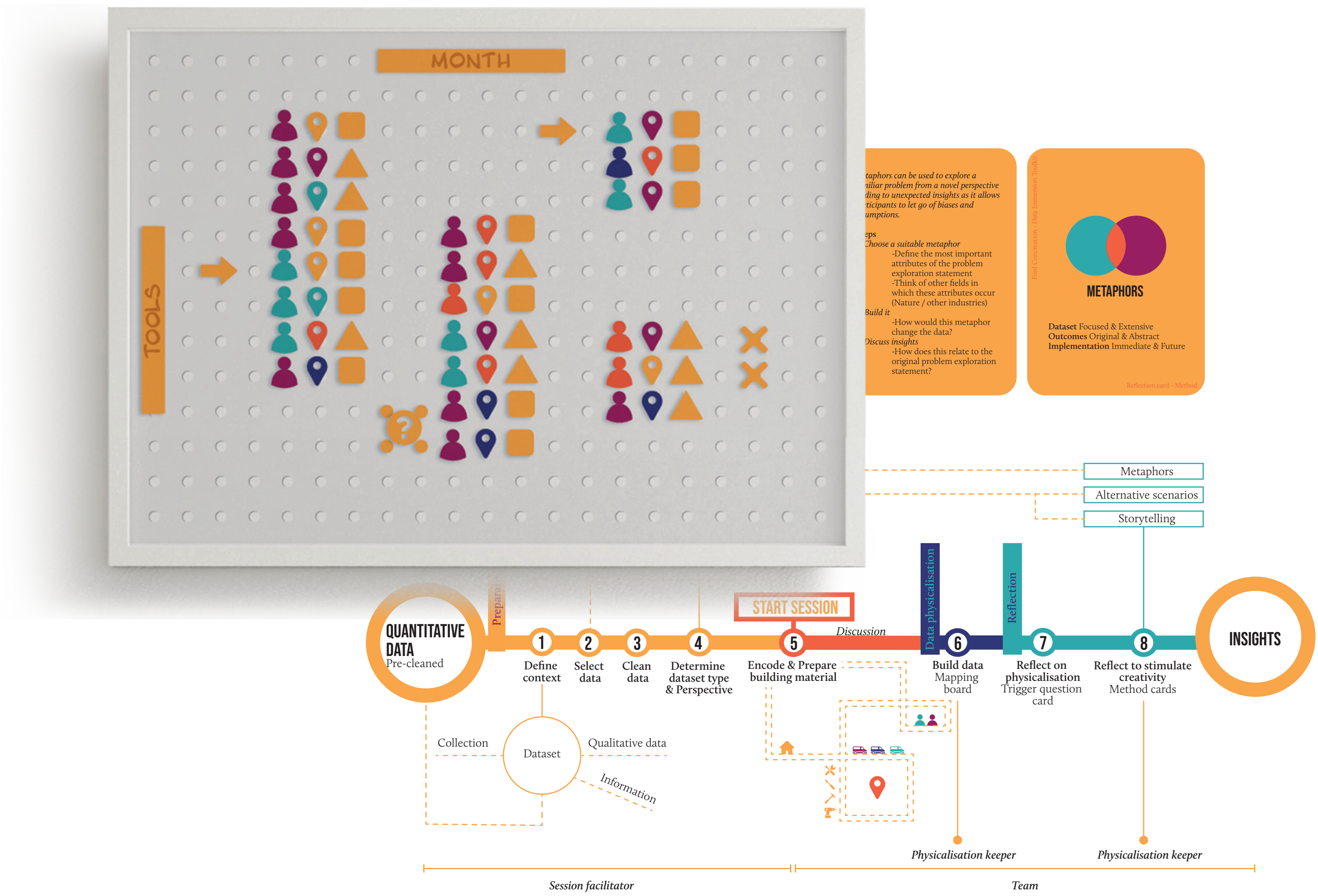


Figure 1. Final concept overview: The Ford Concreate

This report describes the development of the Ford Concreate (Figure 1), a data immersion toolkit designed for the Innovation Management for Smart Vehicle Concepts team (design team) of Ford's Research and Innovation Centre Aachen. The collaborative data physicalisation toolkit consists of three elements: an instruction process, the physicalisation tool and a set of reflection cards. Together, these elements lead the target group to collect inspiring insights from quantitative data by stimulating reflection and creative thinking through physical interaction with data. By consciously engaging with data while creating a physical representation of a dataset, users better understand the data and reveal patterns that lead to new insights. The toolkit is designed for use during creative sessions, led by a session facilitator.

With recent advances in data-based technologies like AI, machine learning and IoT, designing with data is becoming impossible to avoid. Within Ford, the amount of collected data is growing, forcing the design team to look for new ways to integrate its data to improve continuous product and service innovation. This led to the initial goal of 'using data as creative material', as quantitative data is currently solely being used for testing and validation rather than to inspire the entire design process. To specify and achieve this goal, the fields of creativity and data representation were identified and studied, focusing on answering the following research question: How can data be represented in a way that stimulated creativity during the design process at Ford? It was concluded that data physicalisation could stimulate creativity and lead to better insights as it encourages reflection and creates deepened understanding through active interaction with the data, which led to the development of the toolkit: the Ford Concreate.

GLOSSARY

This thesis contains field-specific terms that can be defined and interpreted in various ways. To increase understanding and avoid confusion, important terms, including their definition used in this thesis, are outlined below.

Quantiative data	In this type of data, the value of data is represented as counts or numbers with a unique numerical value.
Qualitative data	This type of data is defined as categorical, non-numerical data that can be observed and recorded.
Data-enabled design	'A situated design approach that uses data as creative material when designing for intelligent ecosystems' (van Kollenburg & Bogers, 2019).
Design Thinking	'A human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success' (Brown, 2018).
Design Method	Simple components of design including procedures, techniques, aids or tools used to aid the design process (Jones, 1980).
Design Methodology	'The broader study of method in design: the study of the principles, practices and procedures of designing' (Cross, 1984).
Tool	An instrument, for example, forms or cards, that can be used to perform a method (Freach, 2019).
Toolkit	A toolkit consists of a tool and the instruction or method explaining how to use the tool. They include either online resources, offline elements or both (Freach, 2019).
Metaphor	'A figure of speech in which a word or phrase is applied to an object or action to which it is not literally applicable.' (Oxford languages dictionary, 2021)
Analogy	'A comparison between one thing and another, typically for the purpose of explanation or clarification.' (Oxford languages dictionary, 2021)

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Define

Develop

Deliver

Implement

DISCOVER

1 INTRODUCTION

This chapter outlines the context of the project, including background information about the company and developments in the field of interest, the initially defined problem, the assignment, an overview of all involved stakeholders and lastly, how the project was approached.

1.1 Background

With recent advances in data-based technologies like AI, machine learning and IoT, designing with data will soon be impossible to avoid. Although most multinational companies are aware of this fact and are already using data to optimise their processes, many still have not reached the full potential of combining the use of data with design or 'data-enabled design'. The advantages of data-enabled design are highly noticeable, with companies that tightly interweave data and design capabilities to solve business problems experiencing a 10% to 30% performance improvement (Chhabra & Williams, 2019). An important characteristic of data-enabled design can be described as using data to inform and inspire the design process (Bogers & Van Kollenburg, 2020). This can not be achieved by having designers and data scientists work separately on their specific functions. Instead, stimulating both parties to work in symbiosis results in the most benefit for companies.
Ford Motor Company (Ford) recognised this need and started implementing a more data-driven approach throughout the whole enterprise in 2014. In 2015 the Ford Global Data Insights and Analytics (GDIA) unit was formed to centralise the use of data within the company, to allow different teams to share knowledge and make the most out of available data science expertise throughout all departments (Henschen, 2017).

Ford's data currently includes big and thick data from various sources, as shown in Figure 1 and offers the opportunity to be combined. Big data is the term used for complex data sets sourced from large samples. Data scientists often rely on machine learning to reveal patterns or insights from big data (Sagiroglu & Sinanc, 2013). This type of data is based on scale and is less suitable for clarifying details or understanding why specific patterns and insights exist (Bornakke & Due, 2018). Ford's big data sources include onboard computers from its vehicles, customer demographics, and online comments from customers on blogs, chat rooms, and auto sites (RP news wires, 2019).
Thick data is qualitative information generated by studying human behaviour collected from a small sample. Thick data relies on human learning, revealing connections between data, giving social context and understanding into patterns shown by big data, but loses scale (Bornakke et al, 2018). At Ford, this type of data is gathered by performing one-on-one interviews with clients, engaging in clinics or focus groups, questionnaires, and generally spending time with customers.

Like data and design, big and thick data should be used to supplement each other through data blending. Data blending is described as the process of combining data from multiple sources (big and thick), for example, onboard computers and interviews, into a single data sheet to reveal deeper insights (Reynolds, 2021).

With its data growing in quantity and new data analysis tools and technologies arising, Ford is looking for new ways to integrate its data to keep improving continuous product innovation. The team in charge of this process at Ford's Research and Innovation Center Aachen, the target group of this project, is the multi-disciplinary design team called 'Innovation management for smart vehicle concepts', which is shortened to 'Ford's design team' (unrelated to the Ford design department). This team consists of experts from different backgrounds and uses the Design Thinking approach to shift the design focus from vehicle- to user-based. Although The design team has implemented design Thinking for a longer time, the use of quantitative data in the design process is still new. Therefore, the full benefits of implementing data-enabled design can not be reaped yet. This project will focus on the use of both qualitative and quantitative data to not only inform the design process but also to inspire it by using data as creative material, meaning using data in a way that stimulates creative thinking.

1.2 Problem definition

Competitors are already using data-enabled design to optimise their products and services to the needs and wants of the client. Therefore, it is of high importance for Ford to be able to match this level of continuous innovation and potentially differentiate from the competition by also responding to customer's dreams and wishes for the future. In trying to achieve this goal, an overload of data is currently being gathered at Ford, consisting of big and thick data. Simultaneously, new data analysis tools pop up, and existing technologies are optimised to work more efficiently and handle bigger data. Ford is already utilising these developments by hiring more data specialists, solving problems and optimising processes in time and cost efficiency (Reese, 2016). However, the use of this data -especially quantitative data- has not reached its full potential within the product development department yet as it is currently solely being used to inform and evaluate ideas and solutions.

The next step for Ford's design team consists of exploring ways to use data as creative material during the design process, shifting from confirmatory to explorative and inspirational use of data to find more valuable insights from data. There are different ways to use data as creative material depending on the perspective you define 'creative material' from, for example, a data science or psychology perspective. However, as a design engineer creating for a design team, it is interesting to explore how data can be used as creative material through a design solution, taking 'A designerly approach to data analytics' as coined by Dennis Bücker (2019). This phrase is explained as being able to design with data rather than from or by data. Designing with data is defined by Speed and Oberlander (2016) as the following: 'When systems are designed by people, where they take into account the flows of data through systems, and the need to sustain and enhance human values', with the human value to sustain and enhance being creativity. A step in the data analysis process that may have an impact on creativity and can be influenced by designing with data is data representation.
When focusing on data representation to use data as creative material, the term can be defined as representing data in a way that triggers creativity during the design process. Although this definition might seem simple, the design team has experienced putting this theory into practice is not. Even though a large amount of quantitative and qualitative data can be collected and accessed either directly by Ford's design team, through the GDIA or other related units, the team has not yet figured out a way to use the quantitative data in their creative process.

Quantitative data is currently not being used to trigger creativity during the design process.

This problem formed the base of this thesis and was explored further to design a suitable solution. Specific knowledge gaps were determined first, leading to a research question from which a research phase was structured.

1.3 Assignment & Scope

This assignment aimed to design and test a solution that solves the identified problem after gaining a deeper understanding of the context and problem itself. Using data as creative material in the design process was interpreted within this project as representing data in a way that stimulates creativity. Therefore, a global understanding of the field of creativity needed to be obtained first. Secondly, it was essential to understand the various formats in which data can be represented, including functions, benefits and disadvantages.
Lastly, the design process at Ford was studied, focusing on the target group itself, relevant projects and creative sessions. From this gathered knowledge, a final concept was developed that can be integrated into the design process of Ford's design team and possibly by designers in other fields as well.

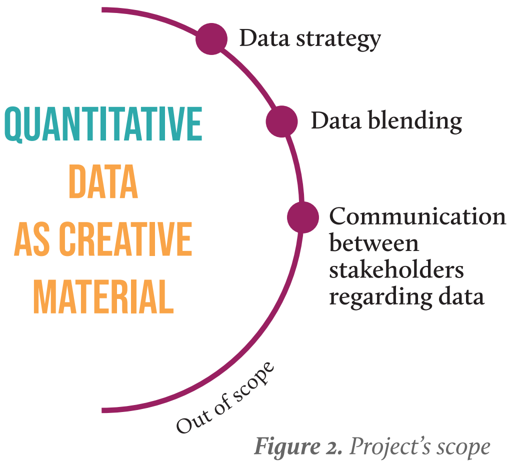


Figure 2. *Project's scope*

Scope
This graduation project is part of a larger collaboration between the Delft University of Technology and Ford Motor Company regarding Data-enabled design. Within the broad field of Data-enabled design, multiple directions have been established, including Data strategy, Data as creative material and Data visualisation. This assignment focuses solely on Data as creative material. Other connecting topics have been excluded from the scope as pictured in Figure 2.

1.4 Stakeholders

Figure 3 and the accompanying text describe the role and relationship of each stakeholder within the project. All stakeholders involved in this project are either part of the client company, Ford Motor Company (Ford) or connected to the Delft University of Technology (TU Delft).

Ford | Company
Ford's primary goal is improving the company's continuous product innovation process by taking data-enabled design to the next level. As the project was executed on behalf of the company, they hold the right to develop relevant outcomes and provided approved data.

Design team: Innovation management for Smart vehicle concepts | Target group
The design team aims to generate innovative results as the outcome of their design processes and hopes to ensure this by using data as creative material during their creative sessions. As the target group of this project, the solution should match the team's design approach and be desirable to use.

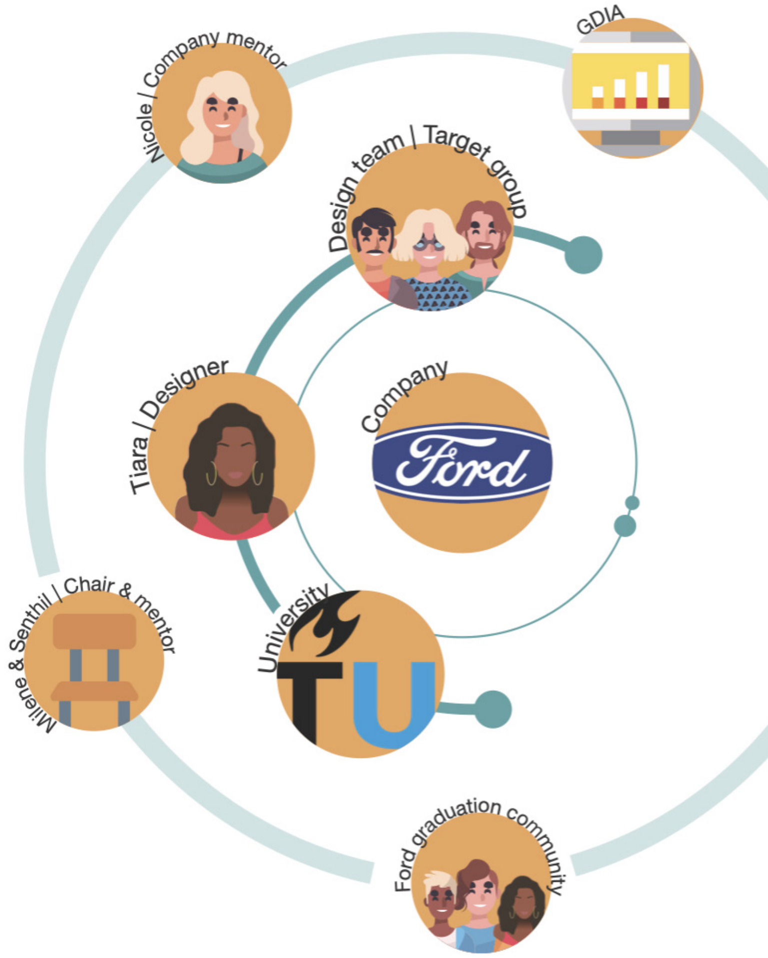


Figure 3. *Stakeholder overview*

Craftsmen | Target group Design team
The 'Craftsmen' are a target group the design team has been focusing on and can be interesting to consider while designing a potential solution.

Nicole Eikelenberg | Company coach
The company coach is also part of the design team and shares its objective. In addition, the company coach provided relevant information and supported the project from the company's perspective, making sure the solution can be of value to the design team.

Data team: GDIA | Support
The GDIA is not directly involved within the scope of this project, and direct contact will be minimal. However, they provided relevant data when necessary and supported the design team with their data analysis expertise.

Tiara Spalburg | Concept designer
As a concept designer performing my graduation internship at Ford for the TU Delft, I functioned as the lead of the project and bridge between all stakeholders, ensuring all objectives were met and a valuable outcome was guaranteed.

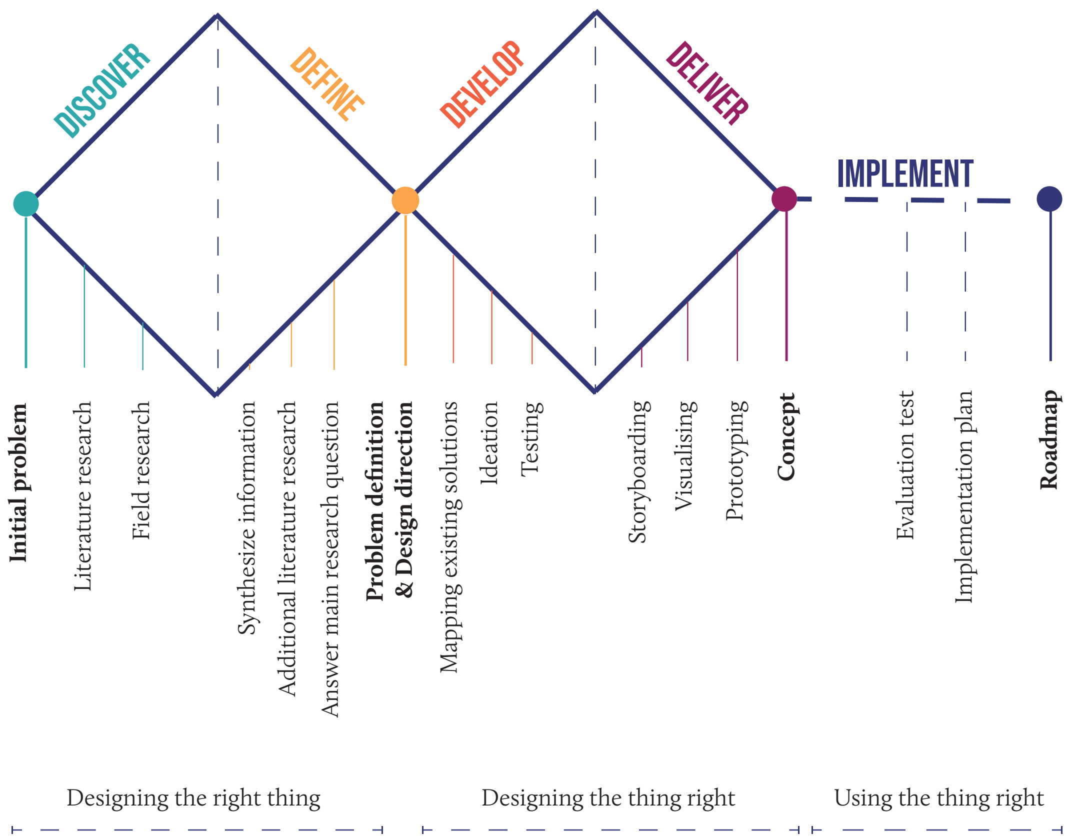
Milene Gonçalves & Senthil Chandrasegaran | Chair & Mentor
Both chair and mentor supported this project from an academic perspective, recommending relevant literature and ideas based on their expertise and providing guidance through planning and approach during the design process.

Ford graduation community & TU Delft
As this project is part of a larger collaboration between TU Delft and Ford, more students are currently graduating at Ford, creating a 'Ford graduation community'. Besides sharing information about the company and official biweekly meetings, casual meetings were used to exchange ideas, inspire and support each other. Outcomes from Ford graduation community alumni have been shared to serve as a base for current projects, just like the projects currently being developed will do for future graduate students at Ford.

1.5 Approach

This subsection describes the approach for the design process of the entire graduation project and each phase within this process. As Design Thinking plays a crucial role in the design process for the target group, this same way of thinking was leading in this thesis to align the user-centred focus.

Thinking like a designer offers the possibility to creatively answer complex questions by creating choices (diverging) and making choices (converging)(Brown, 2018). This way of thinking recurs in the Double Diamond Model; the approach used to structure the complete graduation project. The main activities performed in each phase to move on to the next phase are summarised in Figure 4, including the goals, partial outcomes and deliverables. This linear process merely functions as an outline, as in reality, moving back and forth between phases is quite common. An adjustment was made to the original Double Diamond Model in the form of an additional phase called 'Implement', which includes optimisation and future implementation of the solution.



Discover | Chapter 1 - 3
Gain a better understanding of the context by defining a main research question and answering sub questions.

Define | Chapter 4
Redefine the initial problem and create design direction.

Develop | Chapter 5
Explore and develop elements of a solution.

Deliver | Chapter 6
Defining and creating all elements of the final concept, including an evaluation plan.

Implement | Chapter 7
Optimise the concept for implementation at Ford.

Figure 4. *Double Diamond Model*

1.5.1 Research questions

To reach the goal of the Discover phase, a research question had to be drafted, which formed the base of the entire project. Both a literature and field research phase was needed to answer the research question. The literature research mainly functioned as a knowledge base for the main part of the research phase, field research with Ford's design team members. The problem statement as defined in Chapter 1.2 read: Data is currently not being used to trigger creativity during the design process. This statement has revealed a set of relevant fields that needed to be studied: data representation, creativity, and Ford's design process. Within these fields, subtopics and sub research questions were defined. All relevant research and subfields are summarised in Figure 5, with the fields studied by literature research in turquoise and the areas explored through field research in dark blue. The figure also shows areas of interest in orange discovered as a result of the performed literature research and often overlapped between two main research fields.

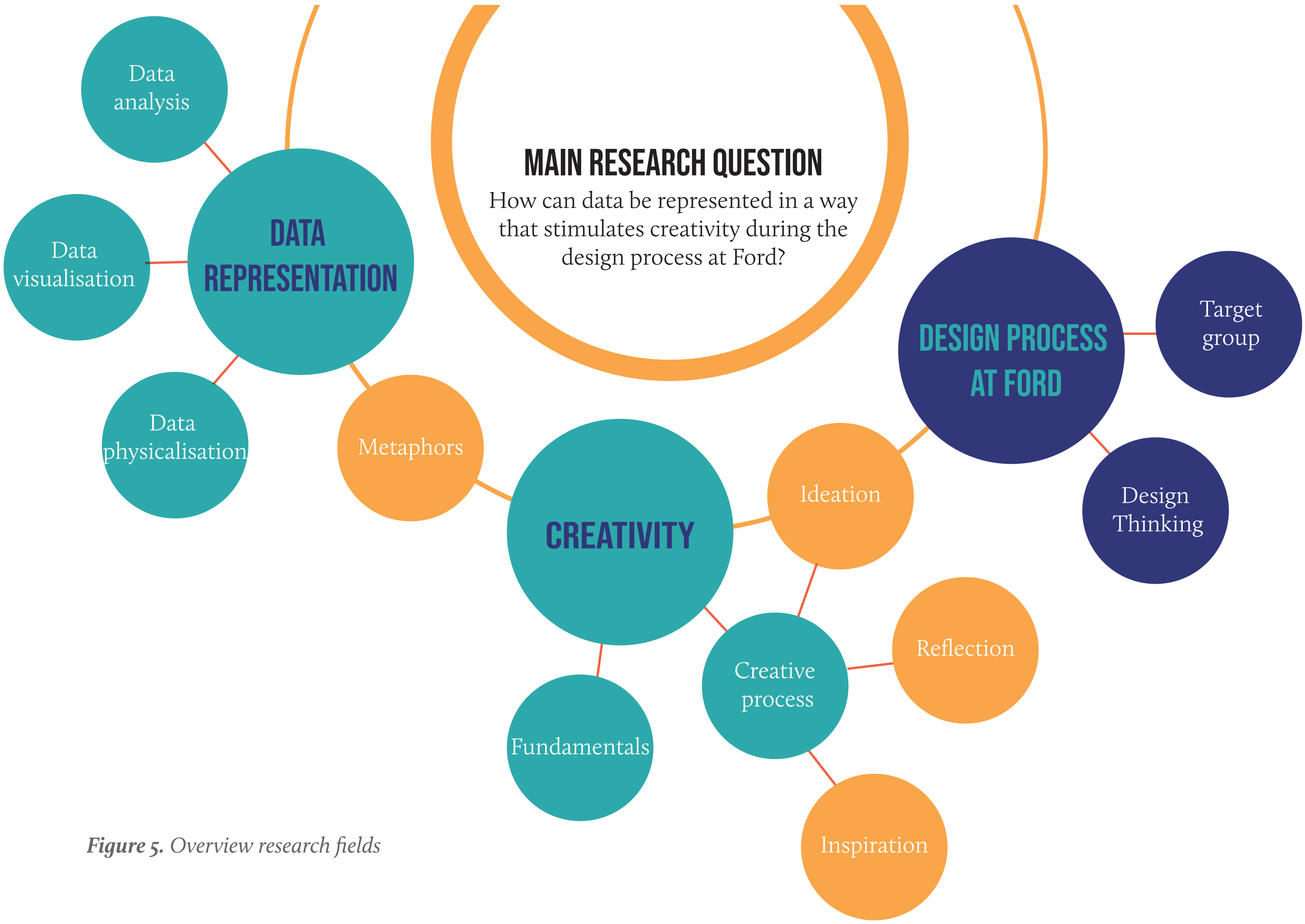


Figure 5. *Overview research fields*

For raw data to become meaningful to its user, it needs to be represented somehow as it has no meaning in and of itself (Segal, 2020). The term 'representation' is defined in Google's English dictionary Oxford Languages (2021) in the following terms: 'The description or portrayal of someone or something in a particular way'. By creating data representations, raw data is transformed into an external stimulus, causing a reaction in the brain of which the impact on creativity was studied. With the professional field becoming more and more data-driven, the demand for data visualisation has increased exponentially, making it the most common way of representing data (Blackwood, 2021). Another way of representing data less common than data visualisation that has been gaining popularity over the past few years, as can be seen from a chronological list of projects maintained by Dragicevic and Jansen (2021), is data physicalisation. The fundamentals of both fields were studied to determine their influence on creativity. The broad field of creativity was studied as well, focusing on a variety of aspects. The focus on creativity within this project's scope was how design could stimulate creativity, specifically by data representation. Lastly, as the solution was designed to be used as part of the design process at Ford, a global understanding of the target group, design process structure and current use of data within the design team at Ford was gathered through field research.

Based on this overview and the identified problem, the question that should be answered to design a valuable solution for the target group can be formulated by the following:

RQ: How can data be represented in a way that stimulates creativity during the design process at Ford?

The main research question (RQ) can be divided into two sub research questions (SQ), as shown in Figure 6. A complete list of sub research questions and questions (Q) used to guide both research phases can be found in Appendix 1. The sub-questions are answered in the corresponding Chapter 2.3.1 and Chapter 3.2.1.

Creativity & Data representation | Literature research

SQ1: How can creativity be triggered in the design process through data representation?

The design process at Ford | Field research

SQ2: How can quantitative data be used in the design process of the design team at Ford?

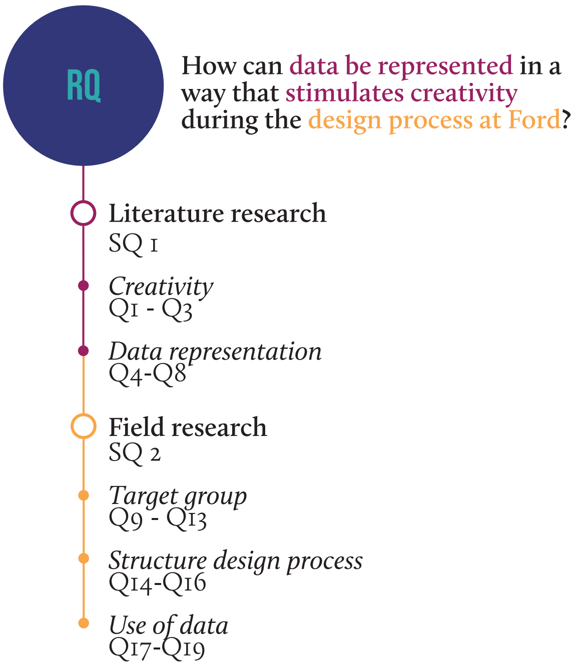


Figure 6. *Overview of research questions*

LITERATURE RESEARCH

Through literature research, the following sub research question was answered:
How can creativity be triggered in the design process through data representation?

By studying the field of creativity, it was discovered that creativity could be triggered in multiple phases of the creative process. Studying data representation has revealed two promising ways to create these triggers for creativity using data: data visualisation and data physicalisation. This chapter describes creativity and data representation's relevance to find common factors that connect both fields. Figure 7 shows which questions were used to guide the field research.

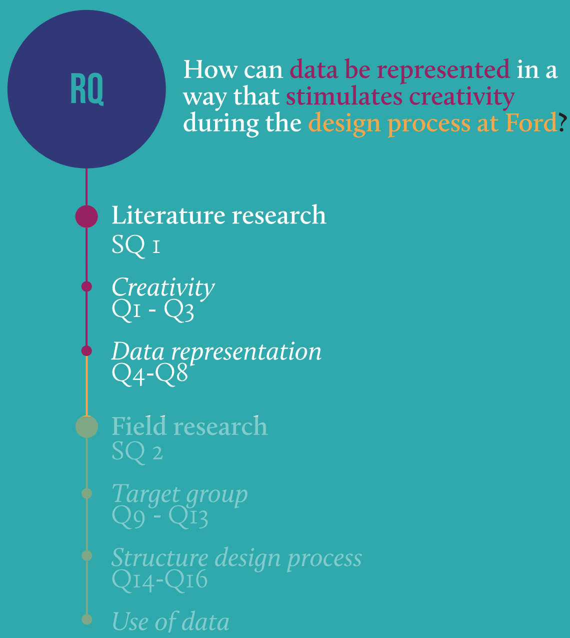


Figure 7. *Questions answered through literature research*

2

2.1 Creativity

The field of creativity was studied to discover how creativity can be stimulated by design. After understanding the basic definition, the creative process was dissected as elements from this process could then be linked to the target group's design process, revealing ways to stimulate creativity. Creativity can be defined as the production of novel, original, and valuable ideas in response to an open-ended task (Boden, 2007). Although the idea should be novel to be considered creative, it should still be appropriate within the task's context to be solved (Amabile, 1983).

2.1.1 The creative process

The design process at Ford is a creative process, specialised in the goals and context of Ford. Therefore, it is valuable first to understand the structure of the general creative process, so similarities and differences can be linked to Ford's design process.

The cognitive steps taken consciously or unconsciously to produce creative ideas can be summarised in the creative process. The creative process includes transforming previously obtained knowledge, skills and inspiration into creative ideas and consists of various stages that can be influenced by different components (Amabile, 2008). Although these stages have been studied extensively, disagreement among researchers exists regarding the number and exact nature of the stages involved in the creative process (Botella et al., 2018). One of the oldest known models still used most commonly today, introduced in 1926 by Wallas, consists of four stages: Preparation, Incubation, Illumination, and Verification (Sadler-Smith, 2015). However, Figure 8, created as part of a study into the different stages of the creative process by Botella et al. (2018), shows an overview of all other named stages of the creative process extracted from models created by different researchers up till 2016. In this study, Botella et al. compared stages of existing creative process models to stages identified by students in the present day. The first two stages that were studied in this project in more detail are the stages that most models have in common: Preparation (also called Immersion, Conception etc.) and Ideation (also called Idea production, Generation, Development etc.).

Author(s)								Stages							
Wallas, 1926			Preparation					Incubation			Insight				
Guilford, 1956	Sensitivity to problems														
Osborn, 1953/1963		Orientation	Preparation	Analysis				Incubation		Ideation				Synthesis	Evaluation
Busse and Mansfield, 1980		Selection			Efforts	Constraints				Transformation		Verification			
Shaw, 1989, 1994			Immersion					Incubation			Insight	Explanation		Creative synthesis	Validation
Mumford et al., 1994	Problem discovery	Problem definition										Problem construction			
Treffinger, 1995		Understanding								Idea production			Planning		
Amabile, 1988, 1996	Problem presentation		Preparation							Answer generation		Answer validation		Outcome	
Runco, 1997			Information					Incubation			Insight	Verification		Communication	Validation
Doyle, 1998	Incident									Navigation					
Carson, 1999			Preparation		Concentration			Incubation		Ideation	Insight	Verification	Elaboration	Production	
Runco and Dow, 1999	Problem finding							Incubation							Evaluation
Mace and Ward, 2002			Conception							Development				Realization	Finalization
Basadur and Gelade, 2005										Generation		Conceptualization	Optimization	Implementation	
Kilgour, 2006			Definition				Combination			Idea generation					
Howard et al., 2008				Analysis						Generation				Communication/ Implementation	Evaluation
Botella et al., 2011			Preparation		Concentration			Incubation		Ideation	Insight	Verification	Planification	Production	Validation
Cropley and Cropley, 2012			Preparation						Activation	Generation	Insight	Verification			
Botella et al., 2013	Idea or "vision"		Documentation and reflection							First sketches		Testing		Provisional objects	
Sadler-Smith, 2016			Preparation					Incubation	Intimation		Insight	Verification			

Figure 8. *Creative process stages, adapted from Botella et al. (2018)*

Stages retained in the present study	Correspondence with existing stages
Reflection	*Preparation* (Wallas, 1926; Osborn, 1953/1963; Blunt, 1966; Amabile, 1988; Nemiro, 1997, 1999; Carson, 1999; Botella et al., 2011) *Analysis* (Osborn, 1953/1963; Howard et al., 2008) *Efforts* (Busse and Mansfield, 1980) *Problem definition* (Mumford et al., 1994) *Conception* (Mace and Ward, 2002) *Generation* (Basadur and Gelade, 2005; Howard et al., 2008) *Goal of creation* (Fürst et al., 2012) *Documentation and reflection* (Botella et al., 2013)

Figure 9. *Reflection stage (Botella et al., 2018)*

The third stage that was explored further is Reflection. The study conducted by Botella et al. (2018) showed Reflection coming back in many of the other stages throughout the entire creative process, which can be seen in Figure 9 and was, therefore, determined to play an essential role in the process.

Preparation
In the models compared in the study of Botella et al.(2018), the preparation phase includes defining the problem and gathering information to assist the formation of creative solutions to solve it, including inspiration (Treffinger, 1995). This phase can be linked to the 'Empathise' phase of the Design Thinking approach used by the target group, which includes similar actions like 'Gathering research and inspiration'. Other terms to describe the preparation phase include inspiration, information and immersion (Botella et al., 2018). As inspiration is an integral part of the preparation phase, the phenomenon of inspiration is zoomed in on.

Inspiration
Inspiration is described as being mentally stimulated to do or feel something, particularly something creative (Gonçalves, 2016) and can arise from different categories of either internal or external stimuli, which often consist of physical or mental visual material (Vasconcelos et al., 2017). Sarkar and Chakrabarti (2008) define stimulus as: 'An agent that activates exploration and search in design'. Although both internal and external stimuli can achieve this, the focus is on how data can be used as external stimuli.

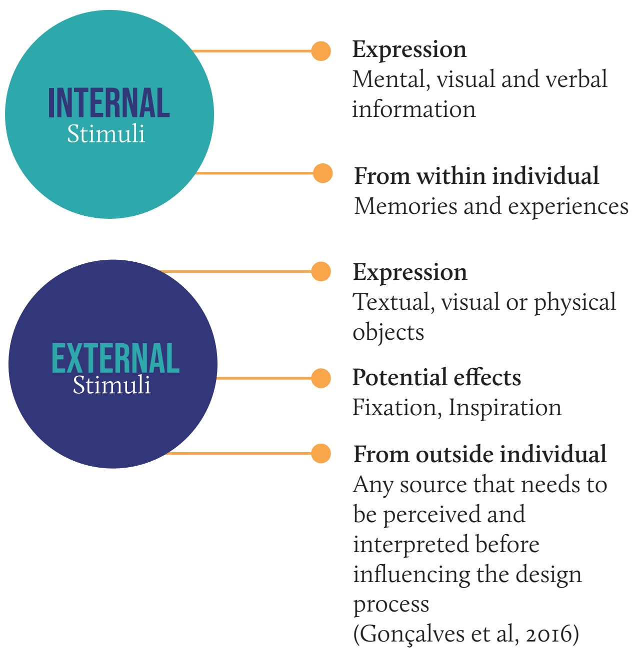


Figure 10. *Internal and external stimuli*

These external stimuli can come in different formats as summarised in Figure 10 and potentially trigger creativity through activating the imagination and enhancing idea generation (Vasconcelos et al., 2017). A potential negative effect on design caused by external stimuli is fixation (Vasconcelos et al., 2017). Fixation in design can be described as the blind tendency to get stuck to a limited set of ideas in the design process (Jansson & Smith, 1991) and therefore dismissing the consideration of different approaches to define and solve a design problem, limiting creativity (Condoor & LaVoie, 2007). Different ways to overcome fixation have been researched. Methods include presenting external stimuli less directly related to the design field and focusing on reformulating the design problem and solution space through creative techniques like metaphorical or analogical thinking (Goldschmidt & Smolkov, 2006).

Ideation
Like the 'Ideate' phase performed by the target group, ideation is an essential stage of the creative process during which new ideas are generated. However, these ideas are essentially not evaluated yet (Botella et al., 2018). Although ideation usually starts from an individual level fuelled by any stimuli that can be accessed during the inspiration stage, the act of ideating can also be done as a group activity (Heijne & van der Meer, 2019). Ideally, this group should consist of 5 to 8 people led by one facilitator to function most efficiently (Heijne & van der Meer, 2019). The ideation process can then be advanced by collaboration between team members and ideation methods, tools and techniques, as summarised in Figure 11. Ideation methods were explored to discover elements within these methods that could positively affect creativity and can be adapted to the to-be-designed solution.

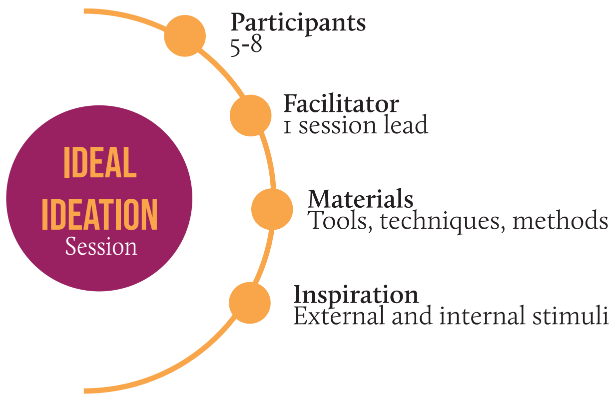


Figure 11. *Components of an ideal ideation session*

Ideation methods
The most popular ideation method among students and professionals are brainstorming, potentially because of its high amount of creative freedom and the feeling of progress caused by the rapid generation and flow of ideas (Gonçalves, 2014). Like many other intuitive ideation methods, brainstorming is based on divergent thinking opening up the mind to produce a wide range of ideas or insights (Gonçalves, 2016). The critical elements of this type of thinking defined by Heijne & van der Meer are 'postponing judgement' and 'quantity breeds quality'. Research has shown that using a range of ideation methods results in more creative ideas, which can be encouraged by reflecting on the ideation process (Gonçalves et al., 2014).

Reflection
In a design process, reflection is often referred to as an effort to decipher and understand the field of interest. Some distance from the topic is taken to examine existing relationships between concepts or ideas (Botella et al., 2018). Reflecting also offers an alternative method for gathering knowledge in the traditional sense, learning from actions taken (Schön, 1983). Schön's (1983) theory on reflection outlines two types of reflection: reflection-in-action, which takes place while designing, and reflection-on-action, which happens by taking a step back from the design process, usually after the specific design project is finished.

Reflection-on-action and reflection-in-action
Reflection-on-action is often a consciously planned step performed after the completion of the process and is also referred to as evaluation of the process. Reflecting on the design process as a whole may help designers adapt their process to reach desired outcomes. Reflecting on specific stages within the design process might encourage more beneficial selecting of external stimuli (Gonçalves et al., 2016) or encourage exploring different ideation techniques, resulting in a positive effect on creativity (Gonçalves, 2016).
Reflection-in-action requires designers to consciously reflect while designing, which could lead to gaining new perspectives, reframing problems, or adding new actions into the design process (Gonçalves, 2016). Adding a reflection-in-action task, a moment of evaluating generated ideas, into the ideation process has been found to generate ideas higher in originality (Hao et al., 2016).

2.1.2 Metaphors

Metaphorical and analogical thinking have previously been mentioned to overcome fixation (Goldschmidt & Smolkov, 2006). This effect is achieved by eliminating constraints the initial problem might have and establishing unexpected associations, leaving room for exploring more innovative ideas (Casakin, 2007). This can be achieved by making a new concept familiar or a familiar concept novel (Eklund, 2014). In the first case, identifying similarities can help give meaning to a design problem or situation we are not familiar with. Examining a familiar problem from a novel perspective could reveal unexpected solutions or insights. It allows designers to think more freely about the situation, letting go of biases and assumptions regarding the original problem (Eklund, 2014). However, metaphorical thinking plays a much more significant role in creativity than only helping to overcome fixation as metaphors are used to express creativity and creativity is also boosted by metaphors. Using metaphors in the design process encourages reflection-in-action, forcing the designer to think about the problem's relevant characteristics to find a suitable metaphor (Casakin, 2007).

The creative process is understood mainly by metaphors because many of its elements like problems, ideas and solutions are abstract, making metaphors our natural way of communicating (Hey et al., 2008). Metaphors can be used in the creative process to stimulate creative thinking to gain new insights or ideas, reframe problems or simply find inspiration. The process of finding a suitable metaphor can be started by extracting the most relevant characteristics of a specific problem or situation (van Boeijen, 2014). A different concept is then sought that roughly contains similar attributes but is unrelated to the initial problem (Dam & Siang, 2017). Then, the metaphor can be applied by abstracting the similarities found and transforming them to fit the problem at hand, force-fitting (van Boeijen, 2014). A good metaphor fits the characteristics that need to be highlighted, has a sense of novelty while still making sense, and should be abstract while still recognisable (Cila, 2019).

2.1.3 Key takeaways

The questions (Q1-Q3) that were used to guide this part of the literature research can be found answered in Appendix 2. Answering these questions led to a set of key takeaways summarising all relevant information from Chapter 2.1 and are presented in Figure 12.

THE CREATIVE PROCESS

The creative process consists of multiple stages which have been identified differently by various researchers. However, it could be concluded that three important phases are preparation, ideation and reflection.

Preparation
Creativity can be stimulated by design in the preparation phase by utilising external stimuli in the form of textual, visual, physical or combined material. They should be used cautiously as they could cause fixation when (partial) solutions are presented. This effect can be overcome by using stimuli less directly related to the field or applying creative techniques like metaphorical thinking.

Ideation
An ideal ideation session includes 5-8 participants and a session lead and is stimulated by the use of tools, techniques, methods and stimuli. Combining different ideation techniques has the most efficial effect on creativity.

Reflection
Reflection-in-action has shown to produce ideas higher in originality. Adding a reflection-on-action task in order to optimise the design process could lead to increased creativity as well. Therefore, it can be concluded that reflection is valuable throughout the entire design process.

METAPHORS

Metaphors are a key component of creativity as can they are used to express and boost creativity, stimulate reflection and can help overcome fixation. Good metaphors are fitting yet novel and abstract yet recognisable.

Figure 12. *Key takeaways creativity*

2.2 Data representation

This chapter studies two forms of quantitative data representation, data visualisation and data physicalisation. It was determined that design could stimulate creativity by using data representation to transform data into creative material. Data visualisation was selected to be studied in more detail. It is currently the most used form of data representation, as the large number of existing and arising data visualisation tools have shown (King, 2021). However, data physicalisation is currently gaining popularity. These forms of data representation could then be compared to one another to determine the most optimal for this specific goal. The definition and the data analysis process are presented here to understand the place of data representation in the complete data analysis process.

Segal (2020) divides the process of representation into three elements as represented in Figure 13 : the object, which is the symbol that is being represented, the manner describing in which way the symbol is represented and the means, explaining what materials are used to represent the object. In the most common data representation process, the object is represented by a data set. The manner usually includes coding with specific software on a computer. The means are the pixels on a computer screen, resulting in a 2D visualisation that can be printed or studied online (Segal, 2020).

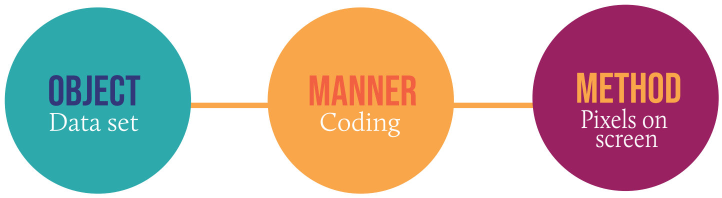


Figure 13. *Elements of the representation process*

Data analysis process
To effectively gather quantitative data and represent it to discover valuable insights and be used as design material, the data analysis steps from the Exploratory Data Inquiry framework (Ruiz, 2020), portrayed in Figure 14, have been described. This helped to determine how the to-be-designed solution would fit in the more extensive data analysis process and what other steps would influence or be influenced by the addition of this solution.

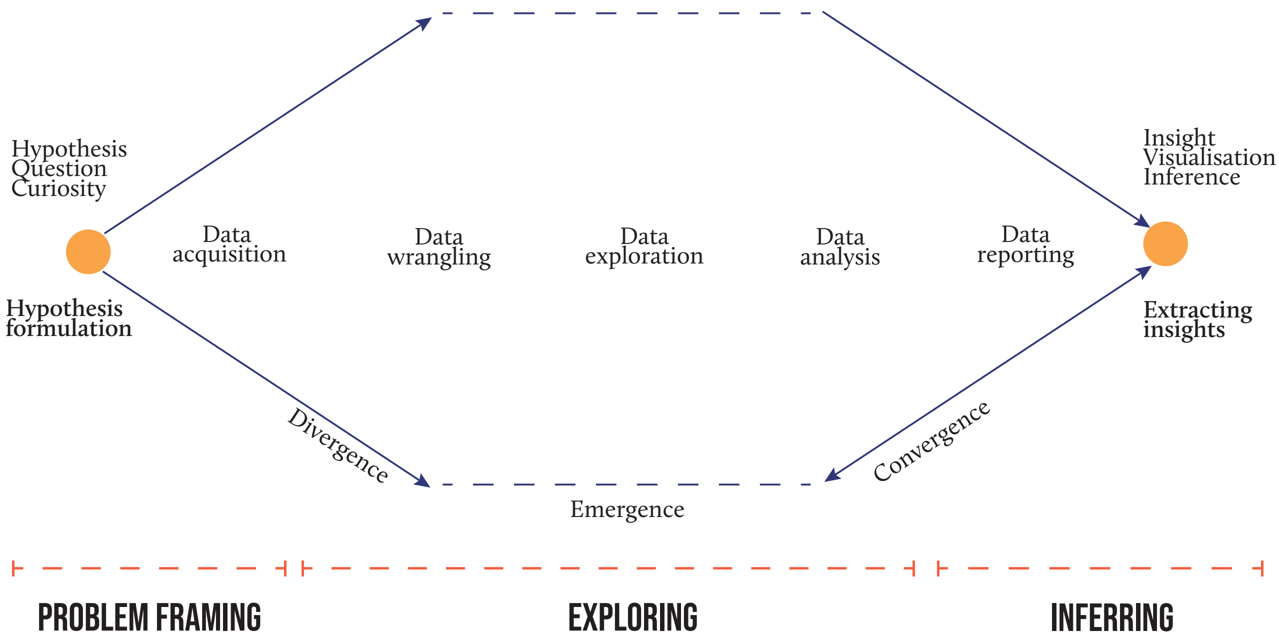


Figure 14. *Exploratory Data Inquiry Framework, adapted from Ruiz (2020)*

1. Hypothesis formulation
Although the primary goal of the data analysis process for Ford's design team is to explore the problem and develop new insights. It can still be valuable to formulate a hypothesis so overwhelming amounts of irrelevant data can be avoided later. Formulating a hypothesis helps frame the problem and provide direction on where to start looking for interesting insights.

2. Data acquisition
In this stage, data of interest is collected from varying sources defined in the previous stage.
Data wrangling (preparation and cleaning)
To prepare and clean the data, different software tools can be used.
3. Data exploration
In this stage the data set is explored by playing around with it in a suitable program, to reveal preliminary areas of interest. In this stage could again be decided to leave some attributes or part of the data set out that is deemed irrelevant.

4. Data analysis
Data is analysed using determined methods.

5. Data reporting
Another term used for data representation. Found insights are summarised in a format that can be shared and discussed with others.

6. Extracting insights
New insights can be revealed from the data report or representation.

According to Ford, an extra step in the data analysis process that is not included in this framework but is highly relevant is a step called 'Data selection', which follows after data acquisition. In this step, relevant data to explore is selected and made accessible to appropriate parties. The team member in charge of data selection determines what data can be insightful and dismisses irrelevant data to provide structure and decrease the chance of getting overwhelmed by a large amount of data.

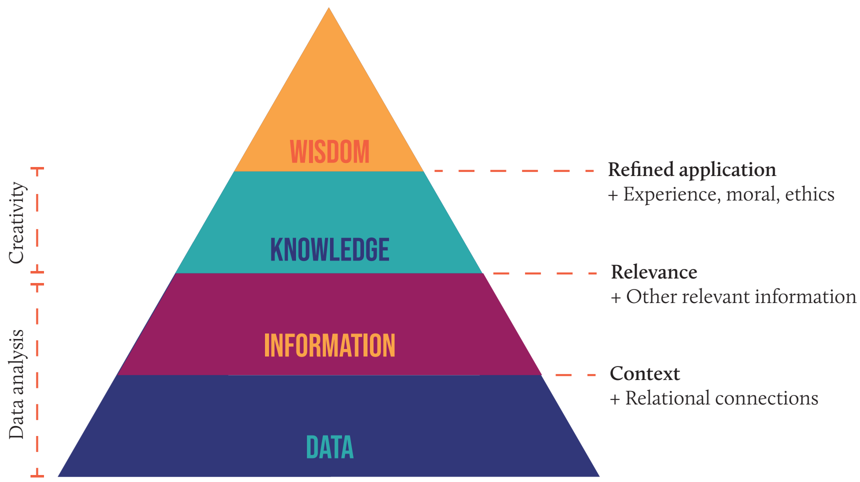


Figure 15. *DIKW-hierarchy, adapted from Jifa & Linling (2014)*

DIKW-Hierarchy
Segal (2020) and Jifa & Linling (2014)argue that raw data itself does not have meaning to the user and should be transformed and represented into a different form to do so. The transformative process that turns raw data into a format carrying meaning to its user is studied and explained through the DIKW-hierarchy, an abbreviation for Data, Information, Knowledge and Wisdom, first introduced by Ackoff (1989). This process was studied to understand how both types of data representation described in this chapter can stimulate creativity in data. Understanding how data gets transformed from raw data into knowledge could help evaluate the two types of data representation.

Figure 15 displays the DIKW-hierarchy in the shape of a pyramid. Each layer adds more elements to the layer underneath. Raw data is transformed into information through the addition of context created by finding relational connections. This first transformation requires multiple data analysis steps, including data representation. However, even after analysing data and representing it, found information might still be irrelevant and unusable. The information can tell the user something new but does not tell the user how to use it. To find valuable, new insights, it needs to be translated to knowledge. New knowledge is synthesised by adding other relevant information to the represented data, such as blending big and thick data (Bornakke et al., 2018). Lastly, wisdom guides the user in when and why to use specific data by relating human characteristics like experience, morals and ethics. However, this layer has been excluded from the scope as the to-be-designed solution will not influence it.

Data categories
As mentioned in Chapter 1.1, Ford currently collects two types of data, big data and thick data. However, as both of these categories also have an opposite, more data categories exist. Where thick data consists of qualitative data, thin data consists of quantitative data. Big data includes huge samples, while small data involves smaller amounts of more structured data (Clark, 2020). When using small data, the data set is limited to fewer sources or focused on fewer types of data, increasing the speed at which it can be processed. Therefore, selecting the collected big-thin data resulting in a small-thin data set could lead to insights more quickly. Ford currently collects big-thin data and small-thick data as visualised in Figure 16.

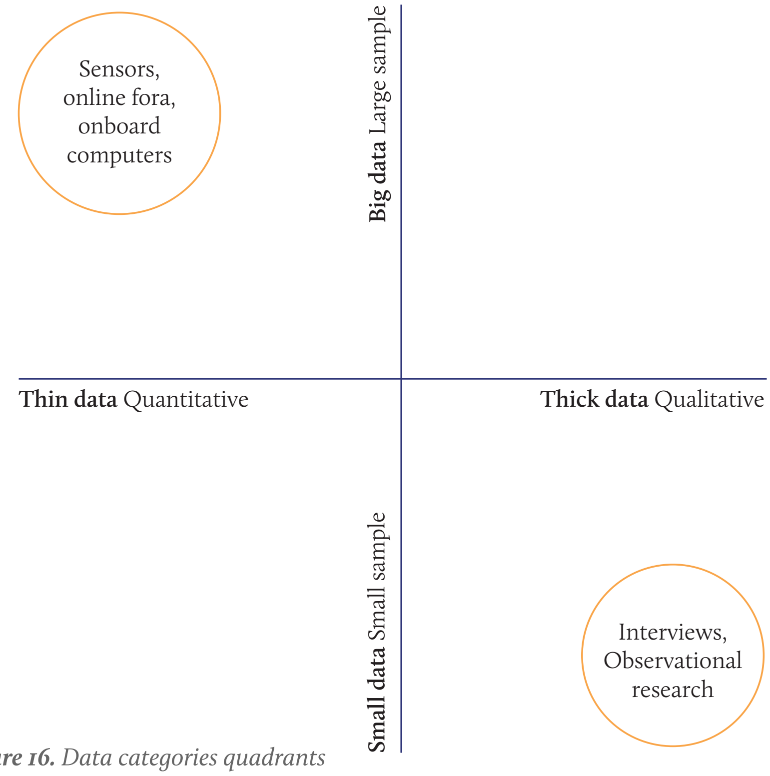


__Figure 16.__ Data categories quadrants

2.2.1 Data visualisation

Data visualisation transforms different types of abstract data into interactive, often computer-supported representations that are easy to interpret and understand (Beutler & Karn, 2015). Data visualisation facilitates identifying trends, patterns, and outliers to effectively make data-driven decisions and integrate data-enabled design based on knowledge. They are currently mainly created and interacted with digitally using an array of available tools. Using computer screens allows for quick adjustments, high-resolution representations and the ability to process large amounts of data (Van de Moere, 2021).

Designing data visualisations
Knowing the fundamental elements of building data visualisations is essential to create data visualisations that are considered successful. The main aspects of data visualisation are studied based on the book Visualization analysis & Design by Tamara Munzner (2015). Figure 17 shows an overview of the data types, attribute types and different types of marks, and geometric elements used to depict items or links. The marks depict either a single item or a link between items. Channels control the appearance of these marks and should be well matched to the encoded attributes in order to create effective visuals. A channel can say something about the magnitude of an attribute or the identity of an attribute, giving 'what' or 'where' information. Figure 18 displays an overview of the magnitude and identity channels used to build data visualisations ordered by effectiveness.

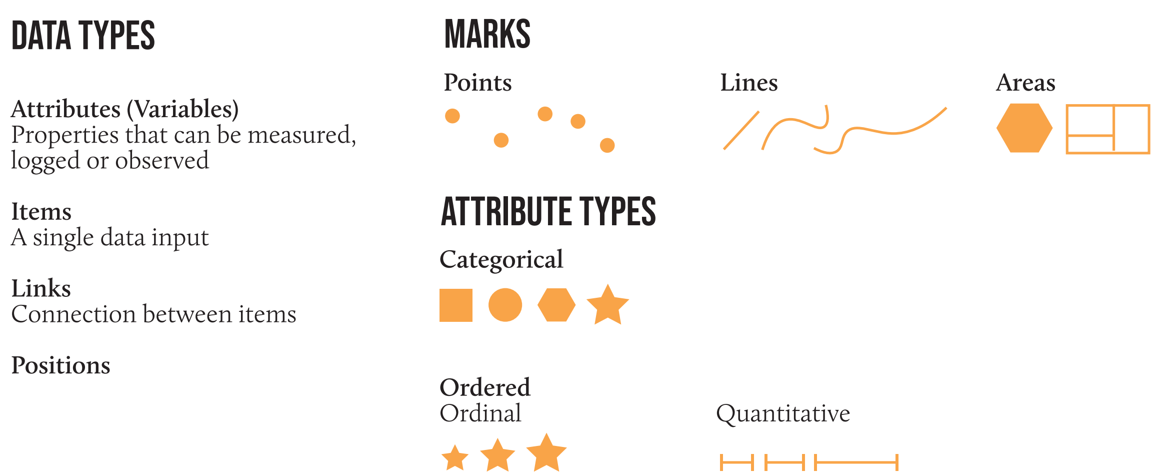


__Figure 17.__ Fundamentals of data visualisation, adapted from Munzner (2015)

Figure 18. *Magnitude and identity channels, adapted from Munzner (2015)*

All marks and channels are metaphorical elements used to represent data, as they only convey meaning after encoding and not by themselves. Therefore it is important to follow two principles when using channels for encoding data: expressiveness and effectiveness. Expressiveness is about matching attributes to suitable channels that contribute to the message to be conveyed (Munzner, 2015). From the broader perspective of data representation, expressiveness determines whether the desired information can be expressed (Mackinlay, 1986). Ordered attributes should be expressed through magnitude channels, whereas categorical attributes should be depicted using identity channels. Effectiveness is about matching attributes and channels according to their prominence, which helps differentiate primary elements from less important elements or additional information (Munzner, 2015). Mackinlay (1986) describes effectiveness as: 'whether a graphical language exploits the capabilities of the output medium and the human visual system'.

2.2.2 Data physicalisation

A proposed definition of data physicalisation by Jansen et a.l (2016) is the following: 'Data physicalisation is a physical artefact whose geometry or material properties encode data', meaning data items are represented by physical, tangible displays or elements (Jansen et al., 2016). Although the principle of data physicalisation isn't new, with presumed examples going back to 5500BC (Dragicevic, 2018), the field is much less researched than data visualisation. However, the interest in data physicalisation has been on the rise. This increase might be explained by the growing emergence of fast prototyping techniques and virtual fatigue (also Zoom fatigue or screen fatigue), which leads to the rediscovery of the physical world (Lee, 2020). With the design team at Ford working entirely from home for over a year due to the pandemic, they may be experiencing a similar feeling as well. This lack of physical interaction, combined with the design team being part of Ford's Research and Innovation Centre, feels the need to keep innovating internally and makes data physicalisation an interesting direction to pay more attention to.

Data physicalisation essentially shares the same goal as data visualisation, aiming to increase the human understanding of data (Sosa et al., 2018). However, an essential difference is that data physicalisation is not solely focused on the visual sense but offers room to tap into other perceptual exploration skills (Dragicevic et al., 2019). A second difference provides the opportunity to interact with digital information using our natural ability to understand the world around us through perceiving and manipulating tangible objects and materials (Dragicevic et al., 2019). Some early research has shown that abstract physicalisations of data that are both playful and enjoyable can benefit task performance and reflection while engaging users and stimulating active perception by providing a multi-sensory experience (Sosa et al., 2018).

2.2.3 Comparing data visualisation and data physicalisation

The two studied forms of data representation each have unique characteristics that can be beneficial depending on the goal. To better understand the application of both forms, they were compared in terms of how they represent data and their effect on creativity.

Representing data

When looking at how data is represented and can be interacted with, the advantages of data visualisation are undeniable. The large array of available tools offer the user to transform large amounts of raw data into visualisations quickly, accurately and with the possibility to easily change and interact afterwards as well. However, a large part of this transformation process happens using a computer screen that we are already exposed to daily and can therefore be experienced negatively (Van de Moere, 2021). Data physicalisation allows the user to explore data using our natural abilities to understand the world around us by perceiving and manipulating tangible objects and materials off-screen (Dragicevic et al., 2019). Transforming data into a physical artefact can be slower than into data visualisations, more tedious and less suitable for big data and fast adjustments of a data set (Jansen et al., 2015). Therefore, when looking at the transformation of raw data into a meaningful representation, data visualisation might be more efficient, and the time between data collection and analysis of the visualisation is relatively short. In contrast, data physicalisation might offer a calmer medium that encourages reflection and analysis through the process of transforming data itself already.

As described in Chapter 2.2, raw data should first be translated into information to be then able to extract insights and become knowledge. Data visualisation tools are highly effective in translating raw data to information because of their computer-based tools and other characteristics mentioned above. To better understand the transformation from information to knowledge, the definition of knowledge is studied first and states: 'A familiarity, awareness, or understanding acquired through experience or education by perceiving, discovering or learning' (Cambridge dictionary, 2020).

Both forms of data representation can offer education through perception, discovery and learning. However, data physicalisation can also be experienced as it allows for physical interaction using not only the sense of sight but also touch. Segal (2020) thinks that interacting with data in a physical format enables the user to gain knowledge by triggering their own intuitive experience instead of telling them exactly what to see.

Stimulating creativity

From literature research, it was concluded that creativity could be stimulated through exposure to external stimuli and the implementation of reflection moments. Data visualisation can quickly transform data into external stimuli by creating graphs and figures that can be a source of inspiration. Data visualisation allows for easy exploration as changes in the data set and outcomes can easily be made, possibly offering moments for reflection-on-action, which have been proven to positively impact creativity. However, as the transformation from raw data to visualisations partly happens automatically performed by written algorithms, data visualisation has less effect on reflection-in-action.

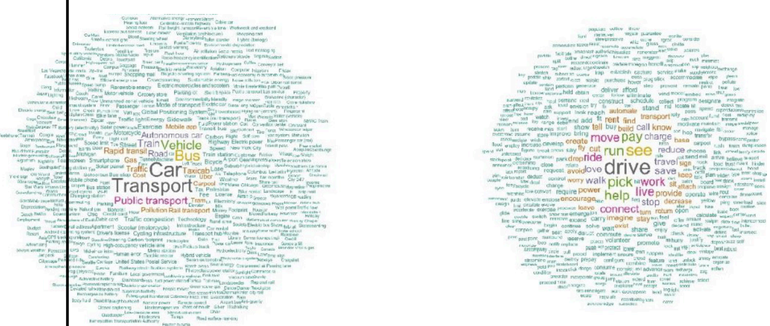
Data physicalisation also offers moments for reflection-on-action, but as the process of constructing a physicalisation happens mostly manually, requiring more time and awareness it encourages a lot more reflection-in-action (Thudt et al, 2018). In Chapter 2.2.1, the highly positive effect of reflection-in-action on creativity has been explained. Jose Duarte (2021), designer and developer of the Handmade Visualisation Toolkit, stresses that the experience is maximised by materialising data, creating a dynamic relationship between the user and data, which increases understanding and critical reflection on data.

2.2.4 Mapping existing solutions

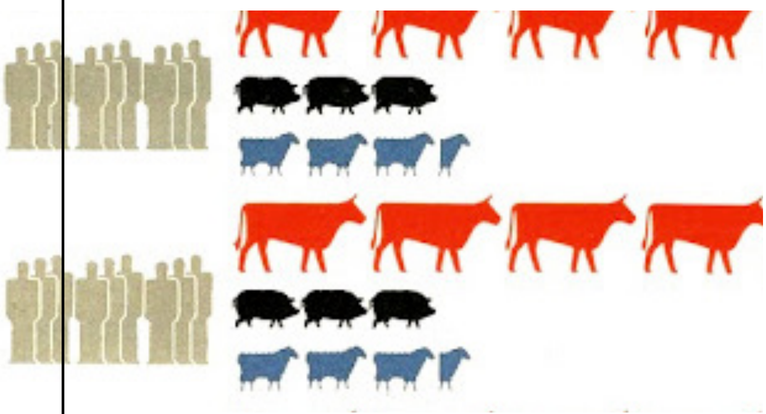
To get a better understanding of what data representation looks like in practical solutions that are being used by designers, researchers, companies and other professionals, existing solutions have been mapped on the matrix in Figure 20. These solutions mainly functioned as a source of inspiration for the design process but solutions in bold have been implemented more directly in the concept, as is explained in Chapter 5. A short explanation of each mapped solution, including a picture in Figure 19.

1. Lego Serious Play (Lego, 2021)
The Lego Serious Play methodology is an innovative process created to boost innovation and business performance. It is designed to deepen reflection and support effective communication. Research has shown that hands-on, minds-on learning stimulates a more meaningful understanding of the world and its possibilities. The methodology consists of a set of selected Lego elements and a problem-solving process that leads participants through a series of questions. They need to build 3D models in response, utilising visual, auditory and kinesthetic skills.

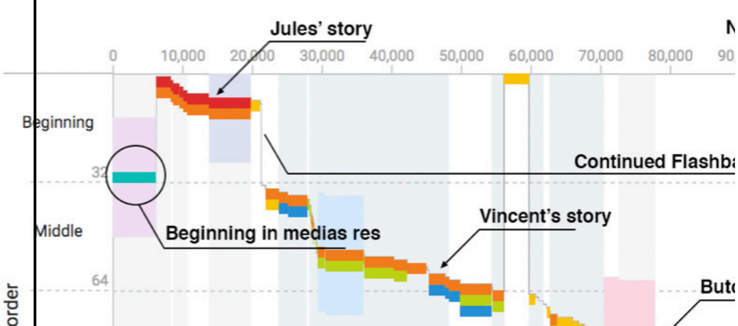
2. Handmade Visualisation Toolkit (Duarte, 2021)
The original Handmade Visualisation Toolkit was developed by designer Jose Duarte and included simple materials like tape, balloons and ropes that can quickly represent information through all kinds of graphs and other physicalisations. Duarte wanted to shift the focus from making complicated, online visualisations to simply making information visible and clarifying ideas with nothing more than your hands and readily available materials by creating this toolkit.


(C) Adjective (D) Adverb

3. Visual sensemaking through a word cloud ideation method (He et al., 2019)
In the study performed by Yuejun et al., a method to expand the ideation space was developed. The method uses textual idea data collected from online crowdsourcing to stimulate the generation of new ideas. By using a natural language processing method, the textual data is summarised and represented as word clouds. Recombining words from these generated word clouds are then used as ideation aids to stimulate new ideas that score higher in terms of novelty, usefulness and feasibility.



4. Isotype visualisation (Haroz et al, 2015)
Isotype visualisation is developed by The International System of TYpographic Picture Education (ISOTYPE) and uses various pictographs to express different kinds of information, such as numerical data. It is designed to create a universally understandable language for communicating quantities of different kinds of information like the number of children born per year or automobile production. The study suggests that pictographic elements can improve the effectiveness of data visualisation communication when pictographs are integrated as a part of data mapping. They can stimulate memory during tasks and engage users more.



5. Story curves (Kim et al, 2018)
Story curves are a visualisation technique designed to explore and communicate nonlinear narratives in movies. Although a nonlinear narrative can be complex to portray as events of a story happen out of chronological order, story curves can visualise this by displaying the order in which events unfold in the movie versus the events in actual chronological order. The story curves are included as inspiration as they might provide insight into visualising historical and time-relevant data.

6. VizKit (Huron et al, 2016)
The VizKit is a toolkit designed to teach information visualisation to a broad audience in a constructive visualisation workshop and was also developed as the result of a series of workshops introducing the basics of authoring and interpreting data visualisations to lay audiences. To be accessible and reflexive to a broad target group, the workshop is designed to avoid technological restrictions, focus on cognitive processes and utilises peer learning. The toolkit consists of printed material, including instructions, a dataset, evaluation questions, and an assessment grid. The authoring toolkit consists of 72 tangible plastic tiles of 25x25x5mm in 8 different colours. The participants are asked to physicalise a data set using the toolkit and reflect on their construction on an individual level, followed by a peer to peer reflection.

7. PhysiKit (Houben et al, 2016)
The PhysiKit is a system that offers non-expert users the opportunity to create, share, explore and engage with environmental data through ambient physicalisations, using a human-data design approach. The toolkit consists of a number of PhysiCubes, each providing the physicalisation of one environmental attribute like movement, light, air or vibration. A web-based end-user configuration tool provides a user-friendly connection point between data sources and the PhysiCubes through a touch-enabled interface. Houben et al. (2016) state the following: 'It aims at providing a hybrid expressive representation of data by providing physical ambient cues, signals and alerts that present socially meaningful events in the data as changes in the physical environment.'

8. InForm (Follmer et al., 2013)
The inFORM is a so-called Dynamic Shape Displays, a type of 2.5D shape display that allows users to interact with digital data in a physical form by rendering 3D content on a physical display. The actuated bars of the display move up and down, offering the ability to move objects laying on its surface and even giving remote users the chance to interact with the display and objects from a distance.

9. Self-reflection physicalisation (Thudt et al., 2018)
In the study by Thudt et al. (2018), multiple participants were asked to map self-chosen personal data for 2-4 weeks by creating a data physicalisation, using various materials including beads, clay and pins. It was found that this process of collecting, encoding and finally constructing the data led to data-driven self-reflection.

10. Reorderable matrices by Bertin
The reorderable matrices by Jacques Bertin, developed in the 1960s, are a physical device designed to explore and represent tabular data, meaning data presented in columns or tables (Perin et al., 2014). The rod mechanism on which the design is based allows for unlocking and restructuring of both rows and columns, which could then reveal patterns.

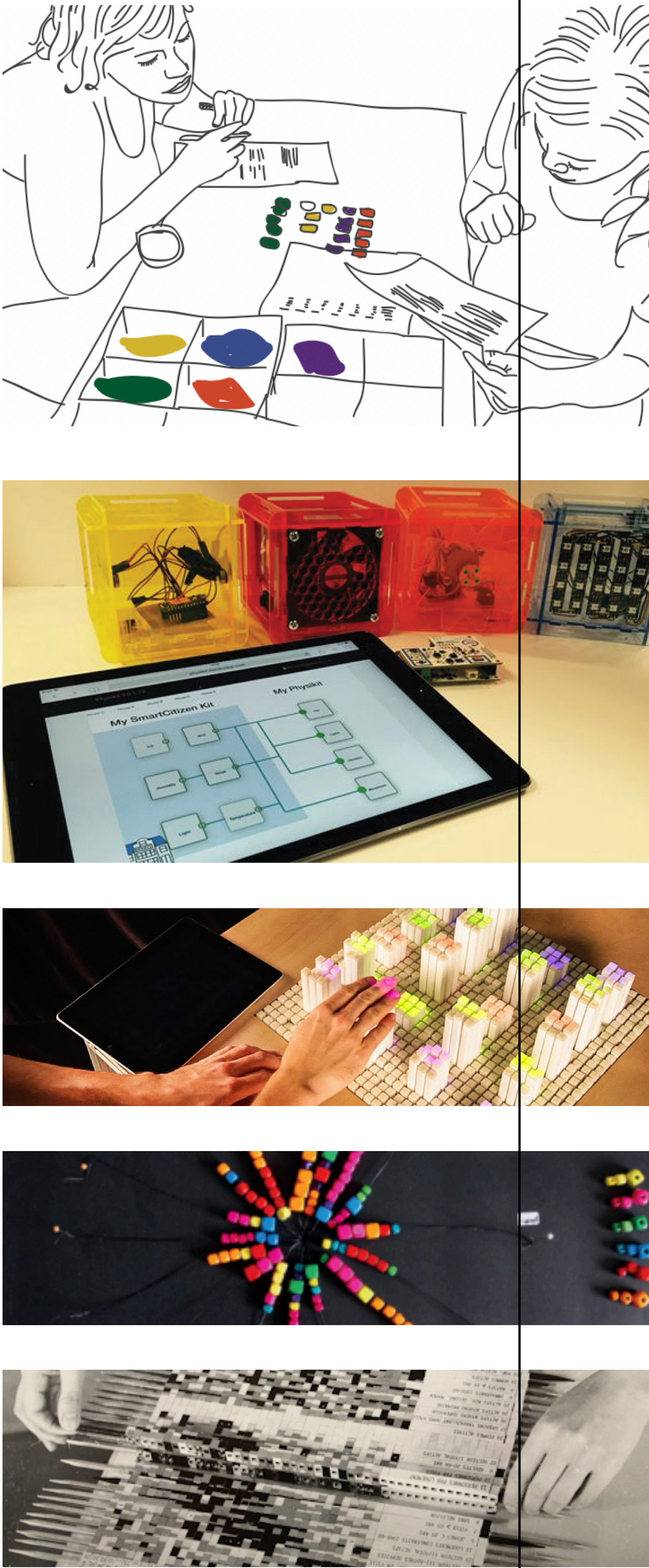


Figure 19. *Overview existing solutions*

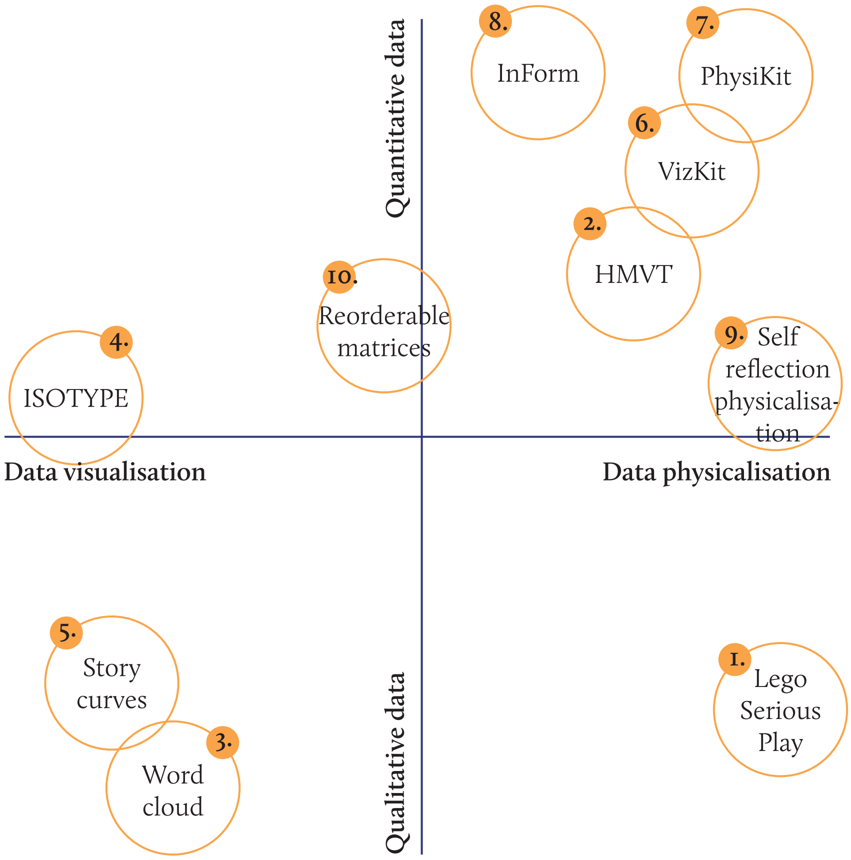


Figure 20. *Existing solutions matrix*

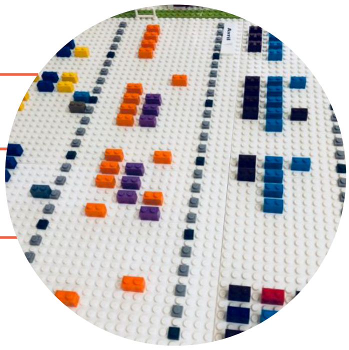
The mapped solutions ranged from products and models to tools and included a wide range of different solutions. A heavier focus was placed on data physicalisation applications for quantitative data as these include many newer solutions with high variations, whereas data visualisation tools can be more similar to one another. The solutions are mapped according to the type of data representation and their suitability for either quantitative or qualitative data.

Data physicalisation materials
As data physicalisation solutions need materials to be functional, the materials that were used in the mapped solutions have been studied in more detail to extract attributes of these materials that could be useful in a later stage of this design process. These attributes and some additional information about the materials are listed in Figure 21.

HOUSEHOLD MATERIALS

With the development of the Handmade Visualisation Toolkit, designer Jose Duarte (2021) showed that simple household materials like tape, balloons, labels and ropes can be utilised to represent information through all kinds of tangible graphs and other physicalisations built within the personal environment of the user. He believes that using these materials helps make data representation accessible to not only data scientists but to anyone who simply wants to express an idea.

TILES & BRICKS

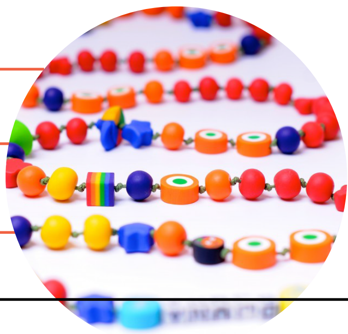


One of the most simple physicalisation elements to express data are tiles or similarly structured components like Lego bricks. Tiles and bricks are a popular physicalisation element as they are easy to manipulate, can be stacked and composed together to create a large variety of shapes and structures. A small set of primitive elements stimulates the user to actively compare different possibilities for encoding while staying close to the meaning of the encoded data (Huron et al, 2016). For these reasons, tiles and bricks are seen as a highly suitable construction element for data physicalisation for non-data scientists.

MODELLING CLAY

Willet and Huron (2017) discovered that a possible disadvantage of using tiles and bricks, is the fact that the square edges mostly encourage the building of rectangular shapes, alignment and stacking, limiting creative freedom. To counter this effect they also studied the use of a highly manipulatable material like clay, as it could support a whole new variety of use. Clay can still be used to create 3D shapes, while offering more freedom of shape, the opportunity to blend colours and isn't bound to units. Although clay offers more freedom and produces more creative designs, it can be harder to manipulate and build with for users not experienced with the material, taking away from the actual encoding of data (Willett & Huron, 2017).

TOKENS



Examples of chosen tokens in the study about self-reflection physicalisation (Thudt et al, 2018) are plasticine (formed into balls or other shapes), beads and pins. Another example of data physicalisation built with tokens is the 'Kanjerketting' (Kanjerketting, 2021). This necklace built by children with cancer consists of beads that each represent a specific treatment that they received.

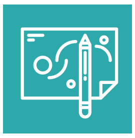
Figure 21. *Common data physicalisation materials*

2.2.5 Key takeaways

The questions (Q4-Q8) that were used to guide this part of the literature research, can be found answered in Appendix 3. Answering these questions led to a set of key takeaways summarising all relevant information from Chapter 2.2 and are presented in Figure 22.

DATA ANALYSIS PROCESS

Data representation is a way to transform raw data so it has meaning to the user. This can be achieved through the data analysis process, of which data represenation could be the last step before extracting insights. Following the DIKW-hierarchy data is first transformed into information, afterwhich it can become knowledge.



DATA VISUALISATION

Data visualisation is a highly accurate and flexible way to represent data, with many available tools. Graphs and other figures can be created through marks and channels, the fundamental elements that need to be used following the principles of effectiveness and expressiveness. These figures can function as sources of inspiration.

DATA PHYSICALISATION

Data physicalisation represents data by encoding it in 3D using physical artefacts that can be interacted with. This physical interaction could stimulate reflection and task performance as it uses multiple senses. It is therefore a slower form of data representation, less suitable for large data sets, but could have a larger impact on creativity.

EXISTING SOLUTIONS

There are many existing data representation studies, tools and methods, suitable for different types of data, from which inspiration could be drawn. Some common materials that are used for data physicalisation are household materials, tiles and bricks, clay and tokens.

Figure 22. *Key takeaways data representation*

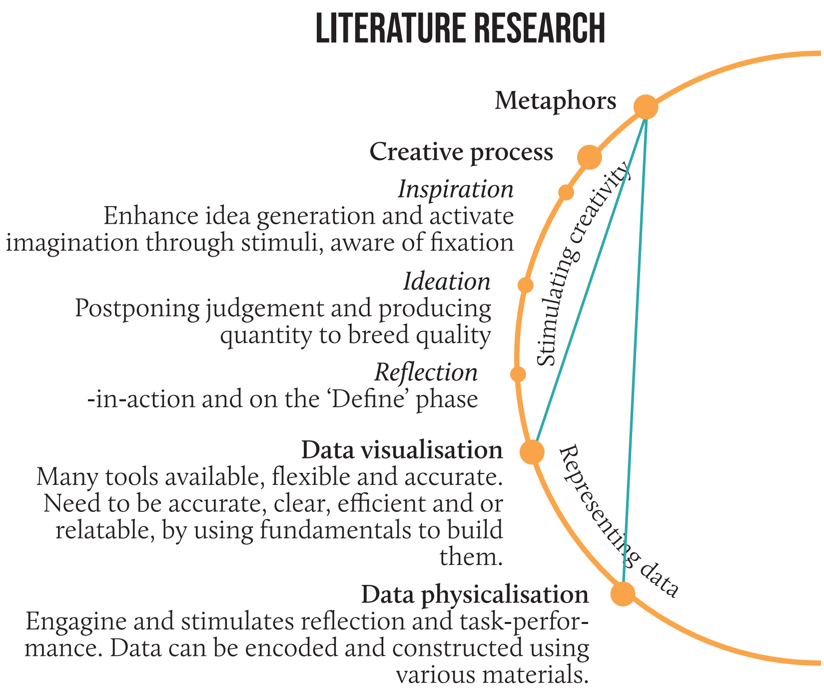


Figure 23. *Conclusion figure part 1 - literature research*

2.3 Conclusion

Figure 23 displays an overview of the conclusions gained from literature research, summarised by combining the key takeaways. Links have been established between metaphors, which, as we have discovered, are an essential component of creativity and data visualisation and physicalisation, as both forms of data representation rely on metaphors to express themselves.

2.3.1 Answering sub research question 1

After studying the research fields creativity and data representation, the first sub research question can be answered.

SQ1: How can creativity be triggered in the design process through data representation?

Chapter 2 made it clear that creativity can be triggered in different stages of the design process, including the use of external stimuli in the inspiration stage, using multiple ideation methods and stimulating reflection-on-action and -in-action. Both studied forms of data representation, data visualisation and physicalisation, can create external stimuli or be part of different ideation methods. However, as data physicalisation requires users to interact with tangible objects consciously, it might have a more significant impact on the stimulation of reflection, triggering creativity.

FIELD RESEARCH

Through field research, the following sub research question was answered: **How can quantitative data be used in the design process of the design team at Ford?**

By gaining a better understanding of the different attitudes of members of this team regarding Design Thinking and what the current design process and use of data look like, opportunities for design could be formulated. The found insights were combined with the generated insights from literature research, forming a base for the 'Define' and 'Ideation' phases.

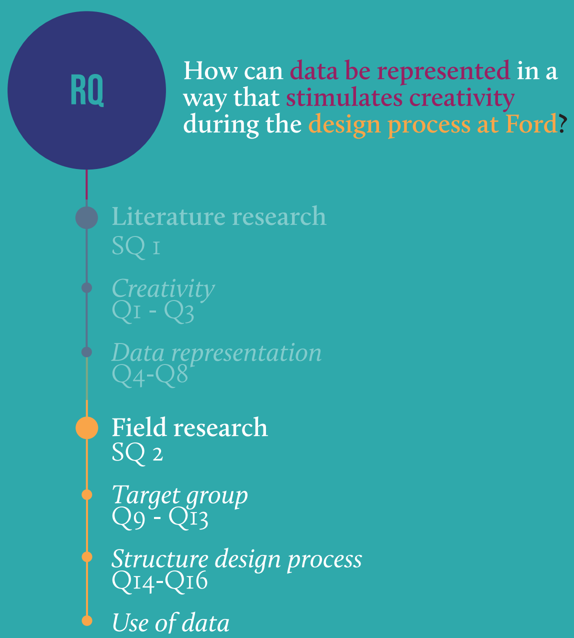


Figure 24. *Questions answered through field research*

3

A series of semi-structured sessions with experts from various departments within Ford have been conducted to complete the field research. These sessions consisted of a presentation by the user research expert at Ford, four interviews, two interactive sessions and many more informal yet insightful conversations with the company mentor. The sessions were prepared and conducted in collaboration with other Ford graduation students and planned with assistance from the company mentor. Figure 25 presents an overview of the different sessions, including their goal and the experts involved.

INTERVIEWS

01. **General process design team**
18 February 2021
Participant 1

02. **Design teams' perspective on the use of quantitative data**
1 April 2021
Participant 2

03. **GDIA's perspective on the use and analysis of quantitative data**
April 2021
Participant 5

04. **Function and working process of SyncAnalytics**
15 April 2021
Participant 6

INTERACTIVE SESSIONS

05. **Design process target group**
19 March 2021
Participant 3

06. **Creative session**
25 March 2021
Participants 1, 3, 4

PRESENTATION BY FORD

07. **Craftsmen**
11 March 2021
Participant 3

INFORMAL CONVERSATIONS

08. **Weekly meetings regarding various topics and questions**
Participant 1, 2

Figure 25. Overview expert sessions

Participant 1

Design / Research engineer
Design team

Focused on the implementation of Design Thinking and innovation.

Participant 2

Research engineer
Design team

Focused on the implementation of data from a design perspective.

Participant 3

User experience expert
Design team

Leading the user research on the target group.

Participant 4

Design / research engineer
Design team

Facilitating creative sessions.

Participant 5

Data analysis expert
GDIA

Data analysis and assisting the design team regarding data visualisation.

Participant 6

Data analysis expert

Leading the optimisation of SyncAnalytics, Ford's onboard infotainment system.

Figure 26. Participants field research

Participants

The six involved experts are employees at Ford from various departments, chosen upon expertise, availability and interest by the company mentor.
Figure 26 gives an overview of these participants, including their function, role and department.

Procedure

All sessions were conducted online either via Webex (Ford) or Zoom and were scheduled to take around 60 minutes, using the screen sharing option to share material or allow for interactivity. In some cases, the roles were divided between graduation students, with one student leading the interview or conversation and the others taking notes. Additionally, most sessions were recorded to be transcribed during analysis. For most of the sessions, a set of questions had been prepared beforehand, which can be found in Appendix 4.

Additional material

To create a more engaging and fun interview style that assisted the expert with answering the sometimes complicated questions, hand-drawn slides were created to be filled in during the session. The filled-in slides can be found in Appendix 5. Having one researcher lead the conversation while the other fills in the slide in real-time based on the expert's answers helped the expert trigger more detailed explanations. The templates also immediately provided a visual summary of the session. During the second interactive session, a Bluescape board from an earlier creative session conducted between members of Ford was shared. Bluescape is an online collaboration tool that allows users to work on different boards or canvases. The prepared questions were used as a guideline while answers were being demonstrated and elaborated on by the participants with the used Bluescape boards.

3.1 Design process at Ford

Relevant data from the performed sessions have been collected in quotes, extracted from the sessions listed in the method. Quotes from various sessions and participants have been combined, analysed and interpreted, resulting in the following subsections. Session 4 was deemed irrelevant for the project's scope and functions solely as background information but has not been integrated into this analysis. Insights gained by combining the conclusions from the field research and literature research are presented in Chapter 4.

3.1.1 Target group

The project's target group, the team called Innovation management for smart vehicle concepts, which has been shortened to 'design' team, focuses on finding opportunities for innovation and optimising services and processes by performing user research and delivering concepts. These concepts are then developed by a different suitable department within Ford or further tested and developed by the design team itself if possible. The design team can be seen as the predecessor of the Product Development department, which focuses primarily on the improvement of physical features in vehicles. Although the design team sometimes works on assignments derived from this department, projects are started mainly by the team based on a discovered opportunity for innovation that will help Ford distinguish itself from the competition. These opportunities are found by looking into customer's needs and wants, as they form the heart of the design process.

Attitudes towards Design thinking

The multidisciplinary design team consists of experts with backgrounds ranging from industrial design and mechanical engineering to electrotechnical, business, marketing and more. This broad range of backgrounds results in diverse skills and expertise, but also in different attitudes towards implementing the Design Thinking approach. The team started implementing the Design Thinking approach in 2016 to switch from a highly technical vehicle focus to a more human-centric approach, placing their customer's needs and wants first.

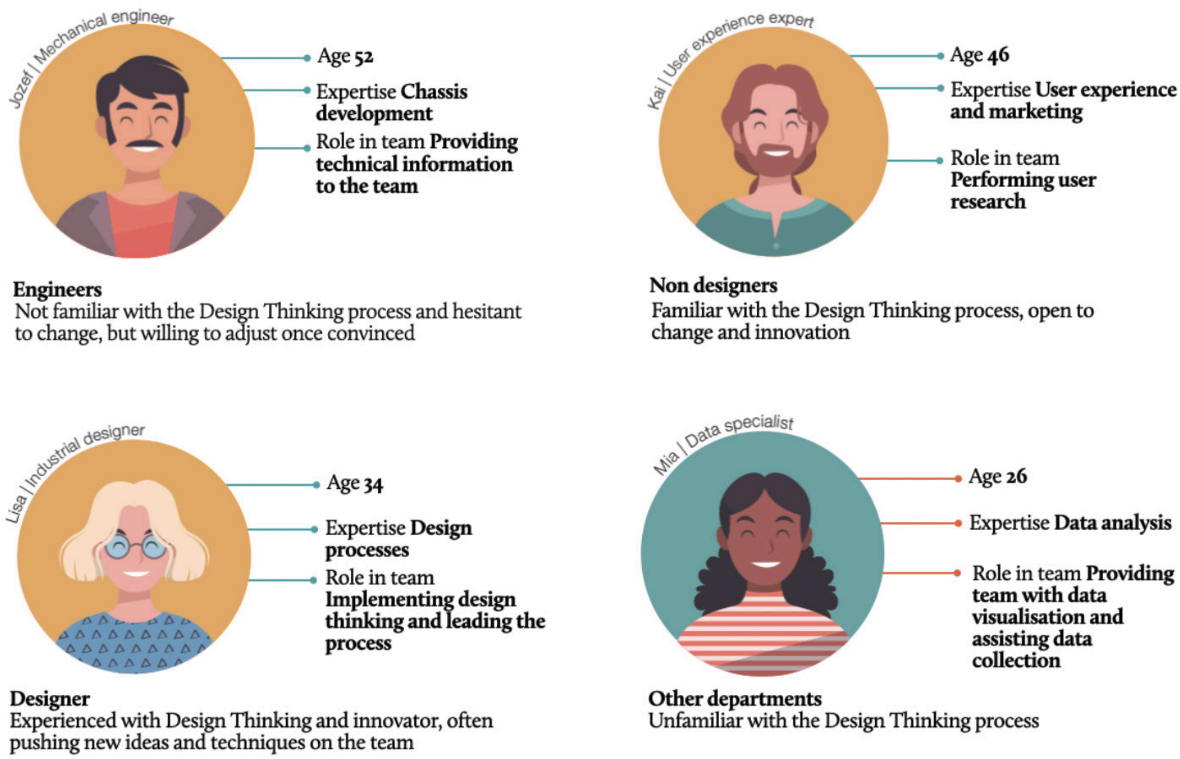


Figure 27. Target group persona

The team persona depicted in Figure 27 shows a general overview of the types of team members based on their attitude towards implementing Design Thinking. The persona is simply a generalisation tool that helps to create a more nuanced understanding of the target group and does not represent specific team members. Understanding different behaviours and attitudes might help create a solution that suits all team members and adds to the potential value of the whole team.

Current projects
The team has been working on various long term projects, currently focussing most of their efforts on one specific target group: the Craftsmen. This group of different types of handymen, including plumbers, electricians and more, is interesting to Ford as the Ford van plays a crucial role in the work lives of the Craftsmen, functioning as their transportation, office, lunch break room and storage space. The team has been performing extensive, ongoing user research on the target group for the past three years, identifying relevant problems to solve and creating a community Ford can rely on for research and testing concepts.

> *"It was so much work to build this community up to collect all this data, put this into presentation, and also to keep them engaged."*
> ***- Participant 3***

However, the handymen involved are not only treated as research participants and potential clients but are also invited to co-create with the design team during different types of workshops and creative sessions. This makes it interesting to include some basic background information about this group, as the to-be-designed solution might also benefit these co-creation sessions. Solutions designed for this target group take into account the current situation of the Craftsmen and past experiences and their future dreams regarding their work.

Information and characteristics of this group have been generalised and presented in Figure 28. The persona does not represent a specific craftsman but was created to summarise relevant information that should be taken into account while designing a solution. The information is based on a presentation given by participant 3, the main researcher of this target group.

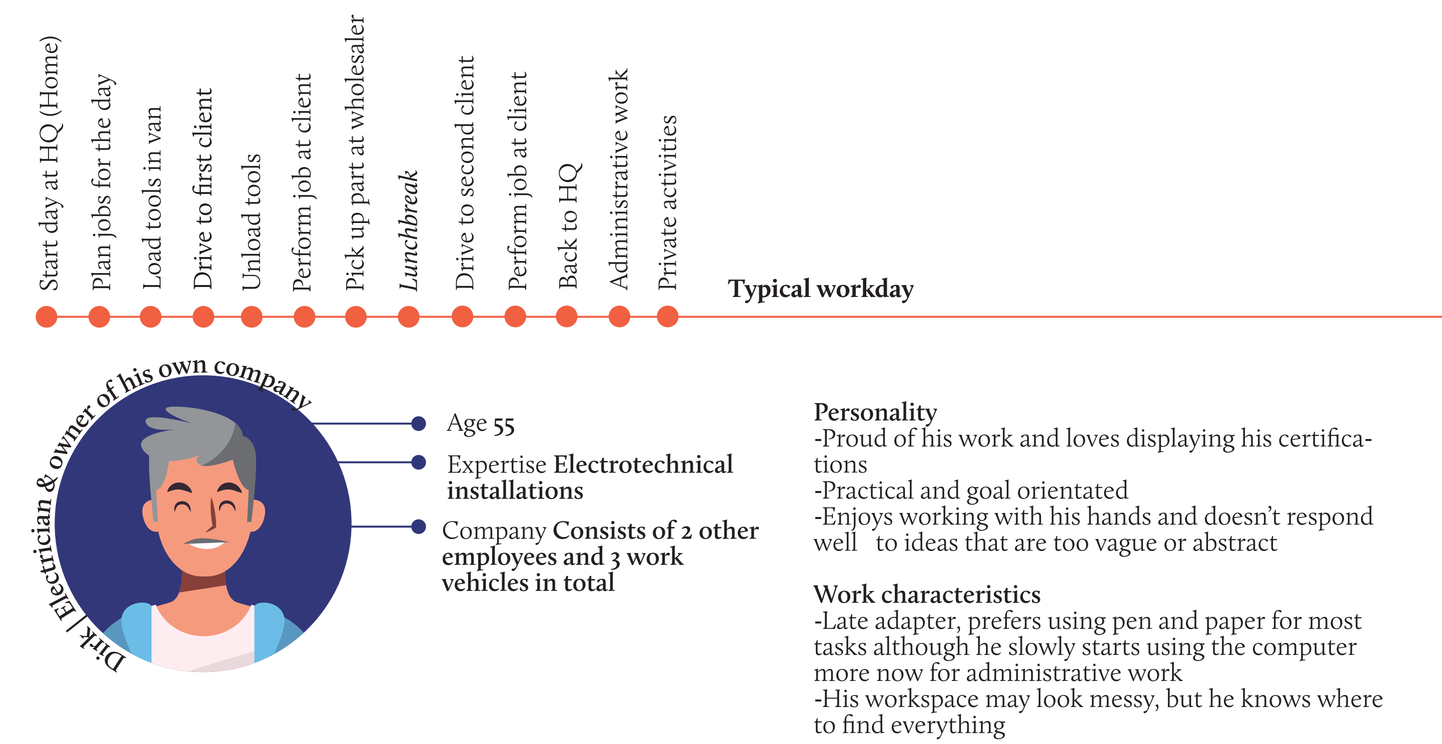


Figure 28. *Craftsman persona*

3.1.2 Creative sessions

As Design Thinking is a dynamic approach that can be adjusted to what suits the specific project best, there is no fully standardised design process. The team learns and grows by doing and gaining more experience over time. As flexibility is important to the design team, the iterative steps of the Design Thinking process are generally followed, but are not fixed. Figure 29 is an adapted image of Ford's design process.

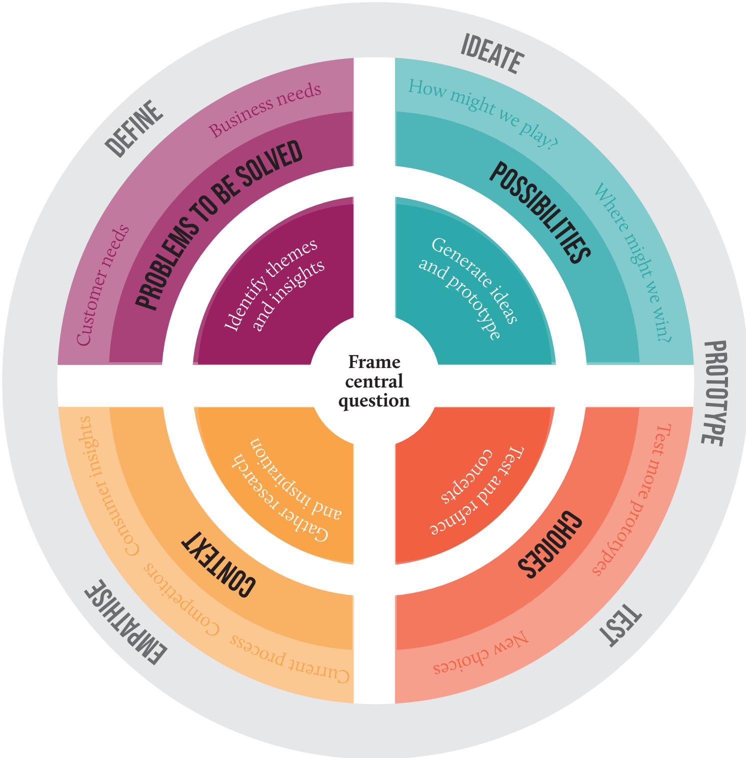


Figure 29. *Ford's design process, adapted from Ford*

The image has been combined with the stages as defined in the Design Thinking approach to describe the different steps in the process. The design process is generally started in the 'Empathise' phase where research and inspiration are gathered, which leads to the 'Define' phase. During this stage, themes and insights are identified through multiple creative sessions that function as the starting point or problem definition for a potential concept. In the 'Ideate' phase, creative sessions lead to the generation of ideas and prototypes as a solution to the identified problem. Finally, the concept can be evaluated and refined in the 'Test' phase, after which the process can be restarted. In reality, this process looks far more iterative, and multiple switches between phases will take place.

Creative sessions play an essential role throughout the process as these sessions ensure the project's progression and are therefore studied in more detail. They are the heart of the creative process as this is where the design team of Ford comes together, possibly with members from outside the team, and the outcomes of these sessions determine how a project evolves. Creative sessions are held throughout the entire design process but are most common in the Define and Ideate phase. Sessions in the Define phase are usually focused on gaining insights from gathered qualitative data, whereas these sessions in the Ideate phase aim to generate ideas or solutions. Both phases can have different goals and setups, ranging from ideation and exploration to deep diving into a subject or developing ideas regarding a specific topic. Figure 30 shows an overview of the general structure of a creative session, including identified problems in each stage of the session. Below, all elements that are relevant during the creative sessions are described.

PROBLEMS

Before session

Ideation lead
Prepares & facilitates session

Team
Consists of 5-10 people

		Problems
Preparation	Creating a presentation with all relevant information and visual material (in Bluescape), a structure and time schedule	-Very time-consuming -No quantitative data presented -Often running out of time

During session: 09:00 - 16:00

Breaks
Include enough breaks to prevent information overload

Background music to stimulate creativity

Examples
Brainstorming, -drawing, force fit, mind mapping, trigger questions

Outliers
Identify outliers and determine if useful

		Problems
Warm up game	Short, fun game that forces people to think differently and get into a creative mindset	-Can be hard to get people into a creative / innovative mindset -Not all participants familiar with Design Thinking, making them question the steps or tasks
Information sharing	Present all relevant information to the them using video and photo material	-Audio or textual information does not hold people's attention
How Might We question	Come up with problem framing and interpreting related words or introduce central question if deter-mined beforehand	
Individual brainstorm	Take a short time to come up with ideas indivually and present them to the team	-Interaction changed by ideation online, not all techniques are suitable -Obvious ideas and solutions, need for more innovative thinking -Lot of time spent discussing
Problem exploration	Perform different ideation techniques to answer central question	
Clustering	Grouping ideas to discover patterns and main themes	
Rate and analyse	Rate ideas to discover and select directions with most potential	
Concepting	Create preliminary concepts using idea boards in break out rooms	-New members afraid to be critical, enjoy the setup of the session so don't give feedback on the content -Hard to determine concrete conclu-sions and next steps

After session

		Problems
Reflection	Take 15minutes with the team to reflect on the process and outcomes	
Outcomes	Outcomes are used as input for future sessions or lead to other research questions or topics to investigate	

Figure 30. *Structure creative sessions including identified problems*

Team

Ideation sessions usually take place with around 5 to 10 people involved in the specific project. However, this number depends on the goal and set-up of the session. However, as we have seen in Chapter 2.1.1 it would be ideal to limit this number to maximally 8 people. Smaller groups could be suitable for sessions more focused on deep diving into specific topics. In contrast, larger groups are helpful when many perspectives or opinions are needed, such as exploration and ideation. Among this group are members from Ford's design team, and if required, other departments are invited as well.

One of the biggest challenges while working with the design team at Ford is dealing with different attitudes towards Design Thinking. Some participants with more traditional engineering backgrounds tend to be hesitant to changes in the design process, taking time away from the actual problem the team is trying to solve.

> *"The audience of the participants tends to question all the steps you propose. So it's not a team that you can set up a schedule, and they will follow, you know, they will question every step. And if they think it's not a useful step, you will have a hard time convincing them."*
> ***- Participant 1***

The team strives to find the balance between pushing to implement Design Thinking and more innovative methods while still leaving room for participant's backgrounds and thinking structures by being flexible in the setup of the sessions and consciously leaving some room for discussion. By experiencing the benefits of this new way of working and implementing changes step by step, participants can slowly be convinced and start feeling more comfortable with the approach. This could lead to more efficient ideation and reflection phases, which has been shown to have a positive effect on creativity (Gonçalves, 2016)

Preparation & Timing

The sessions are led by a facilitator, who prepares for the sessions by creating a presentation with all needed information and material, possibly using Bluescape boards and providing a schedule and structure. These boards are used to structure the process and collect insights during the session as well. Working online decreases flexibility while working significantly as there is less space for dynamic conversation, which makes having well-prepared material and a time management schedule more critical than ever.

> *"In my experience, it's really helpful to be really precisely prepared, because what I experienced was that there was a lot of discussion on the task itself. And then we haven't had time for doing the task, as all the team was discussing, is that really valuable? Or does it bring us to the next step? Or shouldn't we focus on something else?"*
> *- Participant 4*

It regularly occurs that the blocked time isn't enough to go through all the prepared material or activities, as many unplanned discussions happen while performing tasks. As these discussions can still hold valuable outcomes, they are partly taken into account while setting up a plan. Therefore, the facilitator should aim at striking a balance between pushing to go through as many of the planned activities as possible while still being flexible enough to allow for unplanned activities or conversations to happen.

> *"But my experience with this kind of workshop is that there are always elements that go differently than you anticipated when you set up the session. You can, of course, build in some extra time. But on the other side, you also want to keep it a little bit ambitious." - Participant 1*

It can be concluded that well-prepared material positively affects creative sessions, leading to more creativity, higher quality results by keeping participants focused and excited and allowing the facilitator to steer the group towards valuable discussions while still staying on schedule. This preparation offers the session facilitator the opportunity to include external stimuli (Sarkar & Chakrabarti, 2008) to increase the generation of valuable outcomes (see Chapter 2.1.1).

Prepared material

The material currently being shown to the participants of the creative sessions mainly aims to provide them with relevant information in the form of qualitative data about the context to get all members on the same level of knowledge. Prepared material may include video, photo or audio material of user problems, self-made solutions or user explanations about relevant topics. During previous sessions, it was discovered that participants respond best to qualitative data represented in video or photo format, and audio or written material is most likely to be dismissed.

> *"Yeah, it's always visual material that works best. So videos if you have them are the best. And secondly, pictures. Audio files or only written information is almost useless in a session."*
> *- Participant 4*

From the format in which the material is currently presented, it is clear that it is mostly focused on informing the team rather than inspiring them. This not only carries the risk of causing fixation (Vasconcelos et al., 2017) as described in Chapter 2.1.1 but also wastes the opportunity to present quantitative data as external stimuli to trigger inspiration and enhance creative thinking.

Desired outcomes
For one-time participants or people who were invited from outside of the design team, it is important that they enjoyed the session and felt they could bring valuable contributions, so they won't hesitate to participate again in the future. The number one priority of the design team is the collection of new, valuable insights that will move the project along.

> *"It's good for me to see that people enjoyed the session because then I know that they would participate another time again. But then more importantly, if I have the impression that we collected good insights, not necessarily fine ideas or concepts, but insights we hadn't collected before, then that's the most important thing for me."*
> ***- Participant 3***

The to-be-designed solution should ensure the generation of valuable insights for the design team from their quantitative data, which could be enhanced by incorporating reflection. Research showed that this could lead to more original ideas (Hao et al., 2016) more valuable insights. As it is important for the design team to involve members from other departments, it would be valuable to create a solution that is accessible and enjoyable for these participants as well.

Warmup games
Warm-up games are included at the start of the sessions to get people into a creative mindset, hoping to generate more innovative outcomes. To achieve this goal, the game should stimulate people to think differently, without making them feel ashamed or hesitant.

> *"But the thing is that quite often if you're doing ideations, then most of the results, they are obvious. And I think it would be beneficial, if possible, to get people on a higher Design Thinking level. This means that they are more thinking out of the box and are triggered to come up with more innovative ideas that are not that obvious."*
> ***- Participant 3***

Differences between members of Ford's design team in backgrounds and attitudes towards a more progressive design process are noticeable in this part of the creative session.

> *"It's not really useful, or it's not necessary to do that. Let's directly start focusing on the content."*
> ***- Participant 3, quoting one of the members of the design team***

Already weaving topic related content, like data visualisations or physicalisations as described in Chapter 2.2, into these games could be a way to convince more hesitant participants to engage in these games actively and possibly recognise the value in them. The warmup games could then be seen as external stimuli, triggering inspiration and reaching their goal of getting people into a more creative mindset without causing fixation.

Reflection
To keep improving the process, the team always reflects for at least 15 minutes after the sessions.

> *"So I always want to have 15 minutes to reflect on the sessions. So we're always learning. Small changes are always possible and it's always, always necessary to adjust the process."*
> ***- Participant 3***

The team still struggles with defining how the session should be summarised and how outcomes can be transformed into a format that can be used in the next stage of the process. In this stage, it could be helpful to combine found insights with earlier acquired qualitative and quantitative data.

> *"Maybe it's an idea also for the next session, to create a kind of a summary board, where after each step, you move the most important elements from the previous step to that summary board."*
> ***- Participant 1***

Building this board during the session itself would require a reflection-in-action task, of which the effects on creativity became clear in Chapter 2. Besides reflecting on the process to optimise it, reflecting on the session's outcomes could be valuable to the team. It could help determine the next steps and reveal insights that were not yet found during the session.

3.1.3 Use of data

As mentioned in the introduction, the Ford Global Data Insights and Analytics (GDIA) unit was formed in 2015 with the main goal of centralising data use and making better data-driven decisions (Henschen, 2017). The GDIA department located in Aachen works together with Ford's design team to achieve this goal and fully integrate data-enabled design at Ford. The GDIA's role in this collaboration is mainly to collect and analyse data, after which it can be used by the team and assist Ford's design team where needed. Although the current design team doesn't have a software engineer yet, most members have some programming experience and can develop small datasets to a certain extent. These relatively small data sets are often collected and analysed by the design team at Ford themselves without involving the GDIA. For larger data sets, the assistance of the GDIA is used, with members of Ford's design team asking the GDIA to provide specific plots or visualisations from collected data. However, there is no seamless communication strategy between Ford's design team and the GDIA yet, resulting in ineffective results sharing. As the teams are often unaware of each other's goals regarding requested data, miscommunication and ineffective collaboration occur. The communication between both teams will be researched in more detail in the Ford community by Yen-Heng Chang and will not be taken into account within this project's scope.
What is interesting within the scope of this project is the fact that quantitative data is currently only used to inform the design process, as opposed to inspiring the full design process. Ford's design team is experienced with the use of qualitative data throughout the full design process, but the use of quantitative data is still in its early stages and is currently only part of the test phase where data is collected and the empathise phase where the collected data is analysed, as portrayed in Figure 31.

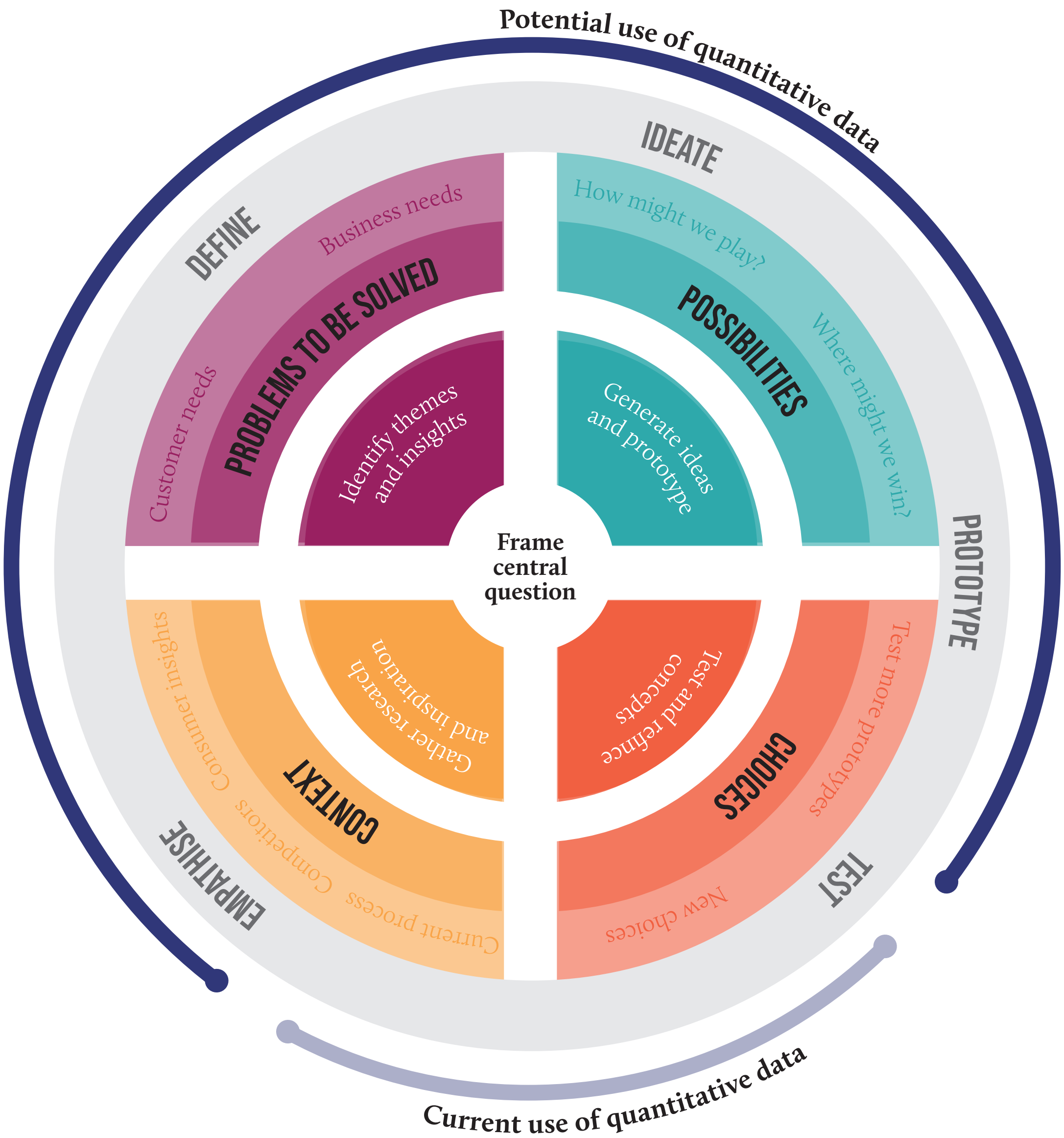


Figure 31. Potential use of quantitative data in Ford's design process

On the question if there is already a structured data analysis process in place within the design team to achieve this, participant 2 answered the following:

> *"No, it's learning by doing. We get the data and then look at it. That's mainly why I'm looking into it now, to see how we can get that to a state where perhaps we can do it automatically."*
> *- Participant 2*

The next step for the design team of Ford would be to combine the familiar small-thick data collected from multiple interviews and observational research with quantitative data, which can be big-thin or small-thin data. However, one of the problems experienced by the design team is not knowing how to implement big data, as the enormous amount can be overwhelming. Using more bite-sized, structured small-thin data by selecting big data could help solve this problem and find new insights more quickly. By combining small-thin data with small-thick, patterns found in quantitative data can be explained by more in-depth insights derived from Ford's qualitative data without getting overloaded by too much data.

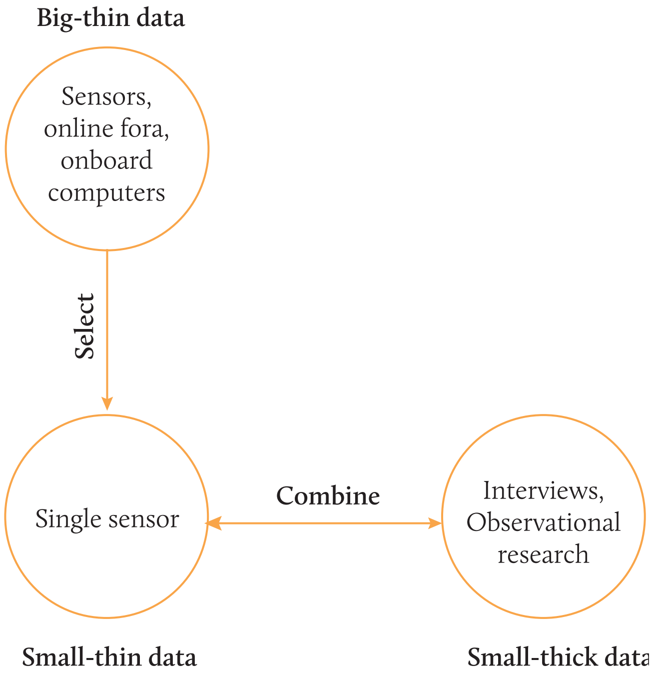


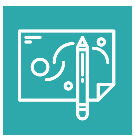
Figure 32. *Implementation of data at Ford*

3.1.4 Key takeaways

The sub questions were used to structure the field research which led to a set of key takeaways that are presented in Figure 33. The key takeaways were drafted by linking the conclusions from field research to the key takeaways from field research in order to better understand the context of the design team at Ford, mostly focusing on the current design process. The answers to the sub questions can be found in Appendix 6.

DESIGN TEAM AT FORD | TARGET GROUP

The team consists of members with different backgrounds, which results in different attitudes towards Design Thinking. As some members have more innovative mindsets where others are more hesitant to change, it is important to find a balance between pushing for innovation while leaving room for personal strengths. The target group the design team is focusing on are the Craftsmen, which the team co-creates with.



DESIGN PROCESS AT FORD

Ford uses the Design Thinking approach to structure the design process. The creative sessions that are part of this process play a crucial role. They should be well prepared, to eliminate the chance of getting lost in pointless discussions. External stimuli currently consists of mostly photo and video material presented to inform, which coud lead to fixation. Warm-up games are often used to get people into more creative mindsets, but could be improved for members doubting their value by involving topic related ceontent. Sessions are always concluded with a reflection moment, but as the team struggles with defining concrete solutions and next steps, implementing more reflection-on and -in-action steps could help stimulating creativity. This then leads to valuable insights which are the desired outcome of the creative sessions.

USE OF DATA

The use of data in the current design process is limited to mostly qualitative data for testing and validating, rather than including and combining quantitative data to inspire the entire process. This can largely be explained by the fact that there is no set structure in place for data analysis, resulting in a large amounts of data with no specified purpose.

Figure 33. *Key takeaways field research*

3.2 Conclusion

Figure 34 displays an overview of the conclusions gained from field and literature research. By combining these conclusions, the solution space could be formed in which the future concept had to fit. This is represented by the circle. Connections between insights from literature and field research are represented by the straight lines, connecting multiple points. Each colour line represents one of the main insights that are elaborated upon in Chapter 4. From these insights, requirements and guidelines were drafted.

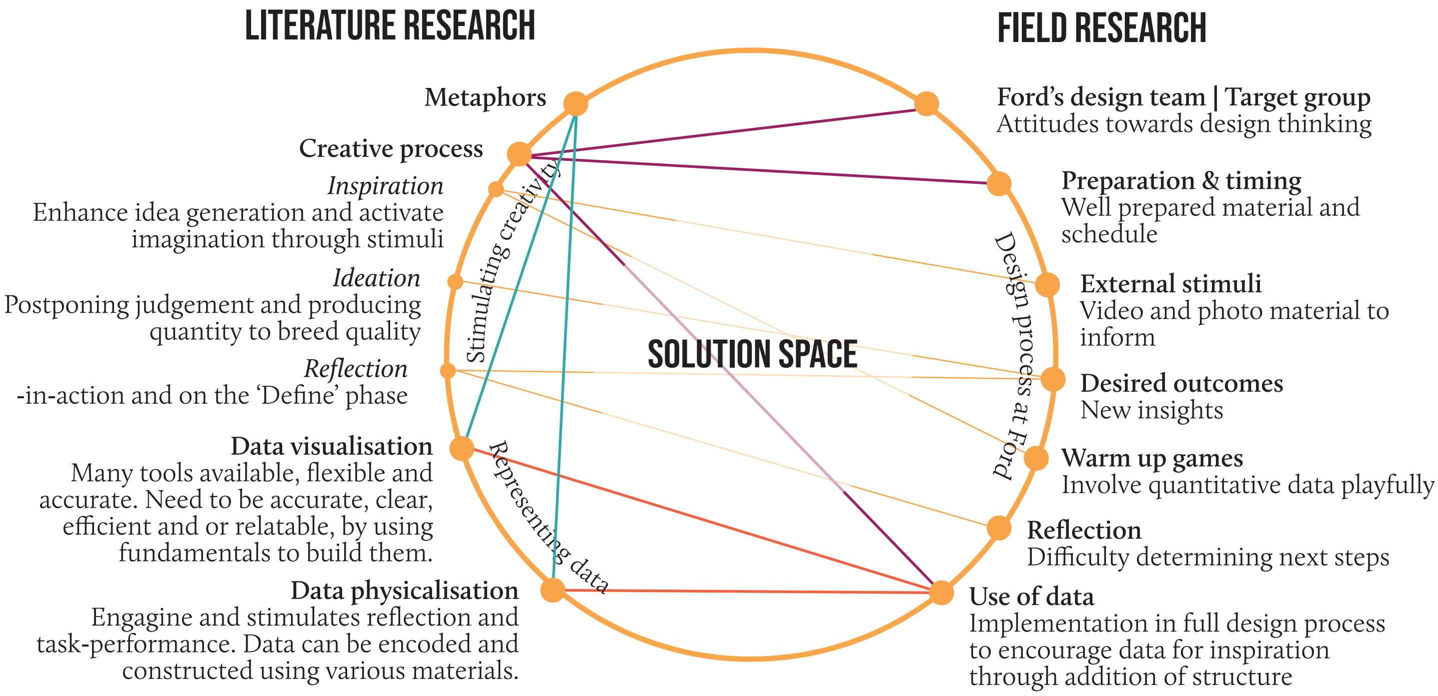


Figure 33. Conclusion figure part 2 - field research

3.2.1 Answering sub research question 2

SQ2: How can quantitative data be used in the design process of the design team at Ford?

As the design team is experiencing difficulty implementing quantitative data because of the large, overwhelming volume, it could be beneficial to transform big-thin data into small-thin, creating a more bit-size selection. This smaller quantitative data set can then be converted through data representation to implement it earlier in the design process. It can serve as a source of inspiration rather than just information to validate choices.

3.2.2 Redefined problem definition

The initially defined problem statement was: *Quantitative data is currently not being used to trigger creativity during the design process.* However, based on the conclusions from research, this statement could be specified and redefined to the following:

Quantitative data is currently not being used as creative material during the design process as there is no structured method in place to represent data in a way that can trigger creativity during creative sessions.

Quantitative data - Data is currently only used to inform the design process, testing prototypes and concepts. The design team has yet to figure out how the recently collected quantitative data can be used in the design process to find new insights (see Chapter 3.1.3).

No structured method - There is no set process for data analysis in place at the moment, meaning there is also no set way to represent data that can be valuable during the design process, see Chapter 3.1.3.

Trigger creativity - Creativity can be triggered in various ways, including presenting external stimuli, utilising techniques and tools that help overcome fixation and stimulating reflection, see Chapter 2.1.

Creative sessions - The creative sessions during the Define phase are a crucial part of the design process. It brings together the design team of Ford and colleagues from other departments, and outcomes of these sessions determine the project's progress, see Chapter 3.1.2. Backgrounds and attitudes of attending participants during these sessions are essential to consider to design a successful solution.

DEFINE

DISCUSSION

This chapter combines literature and field research conclusions, resulting in three main insights that reveal how to represent quantitative data best to enhance creativity in Ford's design team's design process and answer the research question. These insights also lead to formulating the design goal and design direction, and requirements the solution will have to meet, which are all presented in this chapter.

4

4.1 Insights from combining research

Figure 34 summarises the found insights and portrays how the different key takeaways from the performed literature and field research were linked to derive three main insights. Although all field research elements could be connected to literature research, the most critical connections were highlighted and coloured according to the matching insight. These insights were studied in more detail in the upcoming subsections.

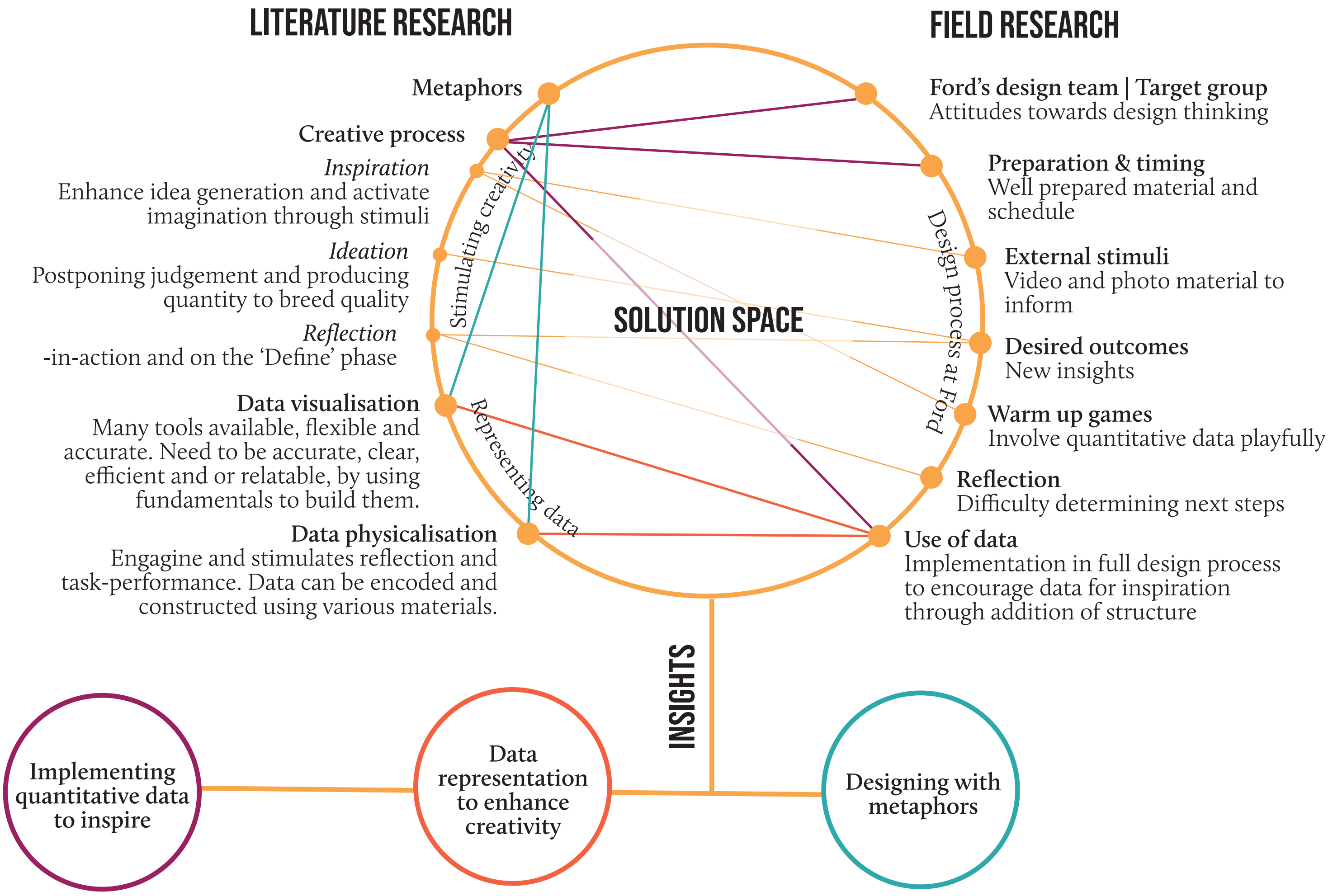


Figure 35. Conclusion figure part 3 - insights

Implementing quantitative data to inspire
The solution should facilitate finding new insights during creative sessions of the Ford design team, through increased creativity by transforming quantitative data to external stimuli, without causing fixation, and providing structure to inspire the design process rather than just inform it.

Data representation to enhance creativity
It could be beneficial for stimulating creativity to include a form of data representation that encourages reflection-in-action.

Using metaphors in design
Metaphors could be integrated into the solution as they are an integral part of both creativity and data representation. Creativity stimulates the use of metaphors while simultaneously using metaphors to express itself and metaphors playing an essential role in any type of data representation.

4.1.1 Quantitative data in the design process

After gaining a better understanding of the current design process at Ford, it could be concluded that the design team at Ford is experiencing difficulty with using quantitative data to inspire the design process rather than solely using qualitative data to inform this process. This is partly caused by the large amounts of data, which can be reduced by focusing on implementing small-thin data. Two other elements that need to be considered when designing a solution to aid this next step are the target group and the creative sessions, which form the core of the design process.

Ford design team | Target group
With the implementation of Design Thinking, some differences in backgrounds and attitudes towards change between the team members arose and should be considered while designing for this target group. This results in a constant challenge of finding the balance between pushing new, innovative techniques and styles of working while still leaving room for more traditional thinking structures and expertise areas of more hesitant team members. By introducing new design techniques step-by-step, explaining and experiencing their benefits and ensuring no getting caught up in endless discussions, the team has slowly moved towards this new human-centric approach. This approach should be taken into account when implementing the next step of implementing quantitative data to inspire the design process.

Creative sessions
Figure 36 shows relevant opportunities for implementing quantitative data have been identified, based on the found problems during these creative sessions. The outlined options warm-up game, information sharing and problem exploration seem to be most promising for a design solution.

PROBLEMS	OPPORTUNITIES
Preparation -Very time-consuming -No quantitative data presented -Often running out of time	-Combining insights from qualitative and quantitative data -Material more focused on inspiring instead of informing
Warm up game -Can be hard to get people into a creative / innovative mindset -Not all participants familiar with Design Thinking, making them question the steps or tasks	-Warm up game that includes data relevant to the content of the session
Information sharing -Audio or textual information does not hold people's attention	-Interactive material
Problem exploration -Interaction changed by ideation online, not all techniques are suitable -Obvious ideas and solutions, need for more innovative thinking -Lot of time spent discussing	-New methods / tools suitable for working remotely and including quantitative data -Method focused on data exploration
Reflection -New members afraid to be critical, enjoy the setup of the session so don't give feedback on the content -Hard to determine concrete conclusions and next steps	-Tool to facilitate early concepting -Adding summary / conclusion boards and action points -Stimulate reflection earlier in the session

Figure 36. *Design opportunities for quantitative data*

4.1.2 Data representation to enhance creativity

Literature research has shown that both data visualisation and data physicalisation share the goal of increasing our understanding of data and revealing trends, patterns and outliers. In Chapter 2.2.3, both forms of data representation have been compared by their functionality and effect on creativity. After gaining insight into Ford's design process, they could be reached regarding their implementation in this process, after which the most suitable form of data representation was identified.

As the target group is already familiar with data visualisation to inform the design process, implementing a new data visualisation solution to inspire the design process would presumably require less effort. As the team already has many tools set up, they might be more comfortable adding a solution that fits this form of data representation, allowing for smoother implementation and more confidence in the concept.
Although implementing a data physicalisation solution might require more effort, it benefits from making data more accessible for non-data experts as it focuses more on the meaning of the data and doesn't require coding or computer screens in general (Jansen et al., 2015). This can be beneficial for the target group. It could offer Craftsmen and colleagues who are unfamiliar with abstract data and information visualisations a more practical alternative to interact and understand data collected from them.

Conclusion
When looking at the two principles of data representation determined in Chapter 2.3.2: *effectiveness and expressiveness*, data visualisation could be rated higher in terms of effectiveness, the ability to express desired information (Mackinlay, 1986), as it allows the expression of more extensive datasets with more accuracy.

However, it could be argued that expressiveness described as the capacity to exploit the output medium and human visual system (Mackinlay, 1986), can be higher in data physicalisation as it makes optimal use of our innate understanding of 3-dimensional space.

Figure 37 shows an overview of the comparison between data visualisation and data physicalisation. It can be concluded that both types of data representation have their own set of strengths and benefits for the design process. To stimulate creativity, data physicalisation offers a promising direction that hasn't been researched as much yet. Even with less accuracy, flexibility and suitability to a larger scale, it is believed that a data physicalisation solution could result in a more significant impact on creativity for the target group, mainly because it doesn't only encourage reflection after the data representation is created but already during the more mindful, physical construction as well. However, as the data sets the design team uses are growing in size, a computer-aided data visualisation step might still need to be included in the process. Especially when designing for the current situation of working remotely, online data analysis, visualisation and sharing steps should be taken into account. Therefore, the final concept could be a hybrid solution between both researched data representation approaches in which digital visualisation offers the opportunity to automate and monitor data, allowing for real-time updates and physicalisation, mostly stimulating creativity to find new insights.

	DATA VISUALISATION	DATA PHYSICALISATION
Method	Graphically represents data in 2D using marks and channels	Encodes data in 3D through physical artefacts
Process	Transforms raw data into visualisations quickly using software on a computer screen and is easy to manipulate and adjust	Transforms raw data into physicalisations manually which is more time-consuming, but the process itself can be perceived as meaningful
Scale	Suitable for big data	Suitable for smaller datasets
Accuracy	High accuracy	Lower accuracy
Assumed effect on creativity	The final visualisation effects creativity by portraying outliers, patterns and trends which could lead to new insights	The final physicalisation could have a similar effect, however, the process of creating the physicalisation is an experience itself which stimulates the knowledge creation and reflection-on-action, stimulating creativity as well
Implementation design process at Ford	Familiar to the target group, requiring less effort to implement	New to the target group, requiring more effort to implement, but possibly also valuable to Ford's target group 'the Craftsmen

Figure 37. *Comparison data visualisation and data physicalisation*

4.1.3 Metaphors in design and to design with

Metaphors were found to be an essential component of both creativity and data representation, the link between them depicted in Figure 38. Metaphors can be used as an inspirational source to overcome fixation, triggering and expressing creativity (Goldschmidt & Smolkov, 2006). The use of metaphors is inevitable in data representation. Data itself is an abstract concept that only has meaning to the user by using visual elements to represent it as described in Chapter 2.2.1. It might be valuable to implement metaphors in the design process of the solution or the solution itself as it encourages reflection-in-action, leading to increased creativity and possibly decreasing fixation.

> "Metaphors and creativity require abstract thinking and expression, which help us make sense of the given in the search of the ungiven."
> - Sevi Merter, 2017

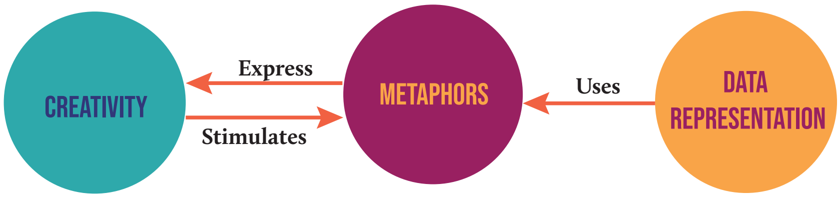


Figure 38. *Metaphors in relation to creativity and data representation*

4.1.4 Answering the main research question

RQ: How can data be represented in a way that stimulates creativity during the design process at Ford?

After extensive literature research, it was concluded that quantitative data in this project could be represented successfully through data visualisation and data physicalisation, focusing on increasing the human understanding of data through metaphorical representation. However, to stimulate creativity, data physicalisation was deemed to have a greater impact as it encourages reflection-in-action and offers a more personal, engaging way of interacting with data that allows non-data experts to actively explore and gain a deeper understanding of the data as well. This could be highly valuable during co-creation with colleagues from outside Ford's design team and their target group, the Craftsmen. With the current working situation and growing data sets in mind, data visualisation steps or a hybrid solution could also be included in the final concept. In both cases, metaphors play an important role because of their link between data representation and creativity and their ability to stimulate creative thinking through encouraging reflection and decreasing fixation. Finally, as the goal is to implement quantitative data to inspire the design process rather than just inform it, the optimal place in the design process to implement the solution is determined to be creative sessions during the Define phase. Creative sessions during the define phase are chosen to design for, as the goal was to stimulate creativity to find new insights rather than already generate ideas or create concepts. These sessions determine the outcomes from which a project is evolved. During these sessions, the Design team of Ford comes together, possibly including members from other teams, bringing together different attitudes, strengths, and behaviour, which are essential to consider to design the desired solution.

4.2 Design goal

In this subsection, the design goal is drafted due to the found insights from research, followed by a list of requirements and design direction.

Designing a data physicalisation toolkit to be used during creative sessions in the design process of Ford, that transforms small-thin (quantitative) data into external stimuli and encourages reflection through the use of metaphors to find better insights.

Data physicalisation toolkit - Research has shown that implementing various methods, tools, and techniques can positively affect creative outcomes (Gonçalves et al., 2014). Therefore, a toolkit will be designed that includes such a method and the tool to represent the data. The effect of the toolkit can be measured by comparing insights gained using the toolkit versus insights gathered without the use of this technique and tool.

External stimuli - External stimuli in different formats, including textual, visual, and physical, can positively affect creativity (Vasconcelos et al., 2017). Field research has shown that so far, visual material has been most effective to the target group. However, the effect of physical stimuli on the target group has not been studied yet but is believed to be valuable, especially when working with the hands-on mentality Craftsmen target group. After designing the concept, it will be tested in a creative session.

Encouraging reflection - Two types of reflection have been identified that could both be implemented in a creative session with a positive impact on creativity, reflection-on-action and reflection-in-action (Gonçalves, 2016). During the creative session in which the concept will be tested, participants could be asked to reflect aloud.

Metaphors - Metaphors have been found to play an essential role in data representation and creativity and should therefore be used consciously while designing a solution.

Find better insights - Although the initial assignment was to find a way to use data as creative material, after digging deeper into this goal through field research it could be concluded that the target group aims to find better insights from collected quantitative data. Better insights are defined in this context as insights that can be used throughout the entire design process rather than only in the test phase, as shown in Figure 31, and combined with insights from qualitative data.

4.2.1 Requirements

A set of requirements has been drafted next to the design goal, listed in Figure 39. They were both used to guide the Synthesis phase and finally evaluate the concept.

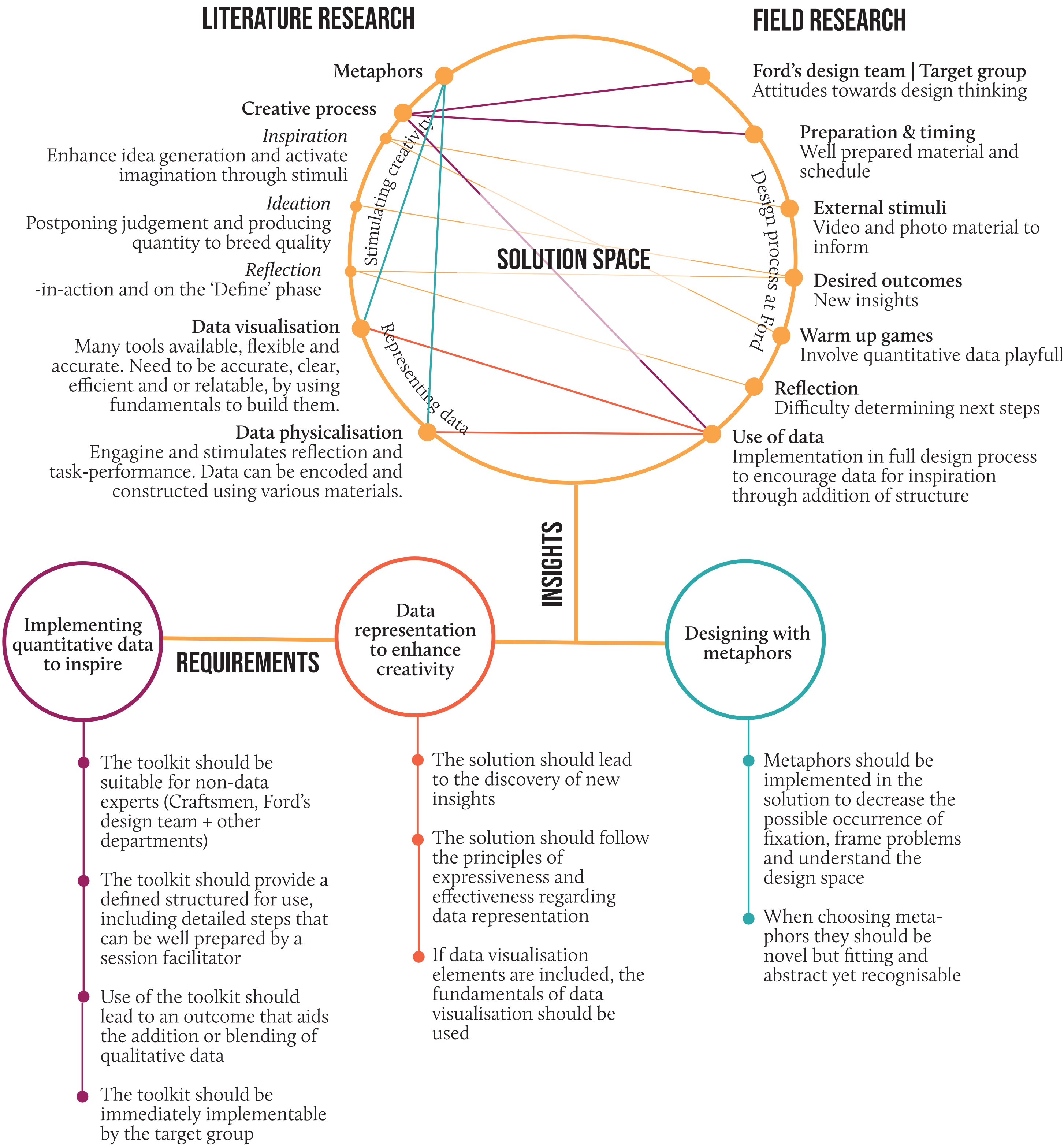


Figure 39. *Conclusion figure part 4 - requirements*

4.2.2 Design directions

Three independent design directions were drafted based on the identified opportunities of the creative sessions; see Chapter 4.1.1. warm-up game, information sharing and problem exploration. The directions are described in Figure 41. After performing preliminary ideation (Figure 40) for each direction aimed to put all early ideas on paper, the most promising ideas were highlighted and analysed.

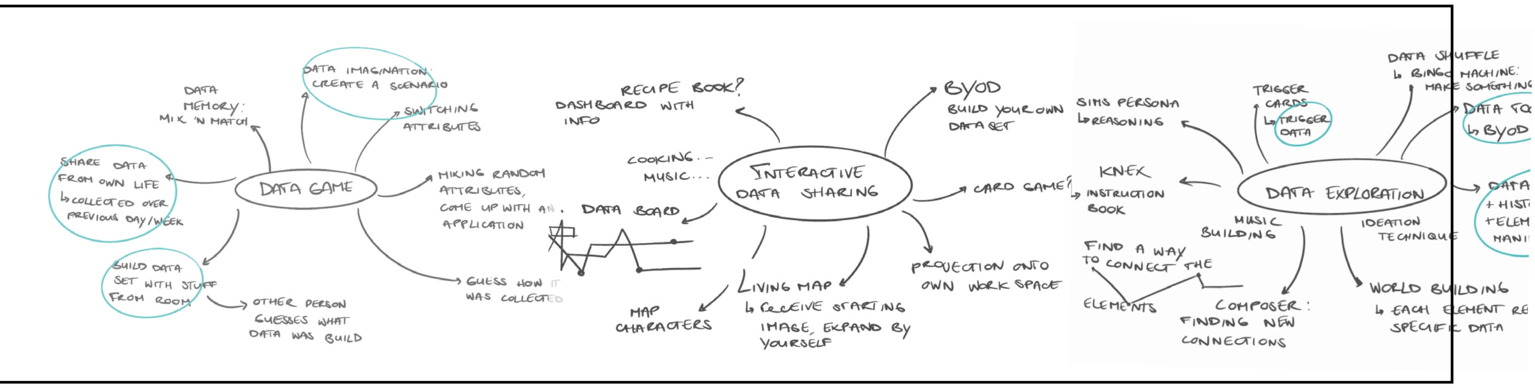


Figure 40. *Preliminary ideation*

This ideation round was stimulated by a set of metaphors used to reframe the problem, which can be found in Appendix 7. Most difficulties were found during ideating on direction 2: Interactive data sharing. This could be caused by the fact that this direction is limited and does not leave much room for design. Therefore, this direction was deemed irrelevant. Upon comparing ideas from directions 1 and 3, many similarities were found. This could be caused by the fact that direction 1: The data game isn't necessarily a direction by itself, but rather a type of use. This resulted in the combination of directions 1 and 3, creating the final direction called:

DATA PLAY - A PROBLEM EXPLORATION TOOLKIT

Data play: A problem exploration toolkit
This direction focused on designing a solution that facilitates interactive play with data to explore the potential problem space, leading to new insights. Playing with data can be defined as interacting with the data without a specific goal in mind yet but by getting to know the data discovering what might be interesting to explore further. Some first ideas within this chosen direction can be found in Appendix 8.

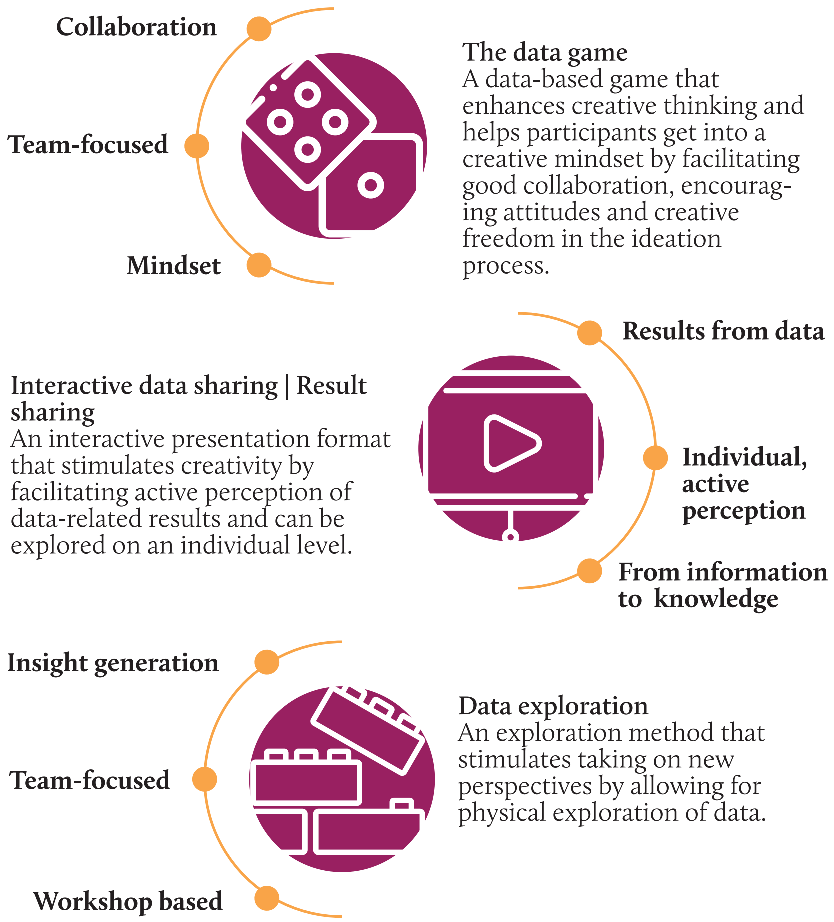


Figure 41. Design directions

DEVELOP.

SYNTHESIS

In this chapter, previously acquired information and knowledge were brought together to function as the base for the ideation process. This ideation process resulted in a solution structure, from which each element was developed into components of the final concept. The different elements of the structure were developed by performing research through design and prototyping partial solutions.

5

5.1 Ideation

The ideation process was initially designed to follow a traditional process using multiple techniques and resulting in several ideas from which three concepts could be chosen, evaluated and developed into one final concept. However, as the assignment is quite complex and the final solution will be a toolkit rather than a traditional physical product, the ideation process also had to be adapted. Instead of a series of ideas, the outcome of this ideation process consists of a solution structure that outlines all the elements of the final solution. This chapter describes how this structure came to be due to the ideation process and how each element was developed further.

The ideation phase was started from the final design direction developed in Chapter 4.2.2: *Data play - a problem exploration toolkit.* Figure 42 shows an overview of the entire ideation process, including the outcomes per step leading to the next step in the process. The first method 'absurd questioning' was chosen as it results in highly creative outcomes, which was found to be especially useful during the first phase of the ideation process. This method required experienced designers and was therefore highly suitable to use during the midterm presentation. Metaphors were included as a method as they were an essential part of the research phase. Using them during ideation led to a broader, more practical understanding of using metaphors in design. After two methods mainly focused on inspiring and opening up for creative ideas, the more structured, practical How Might We method was chosen, which helped steer the ideas back to the original problem and context. The morphological chart offered an effective way to cluster the results.

Design Directions 3x
Preliminary metaphors
Preliminary ideation rounds
Final design direction

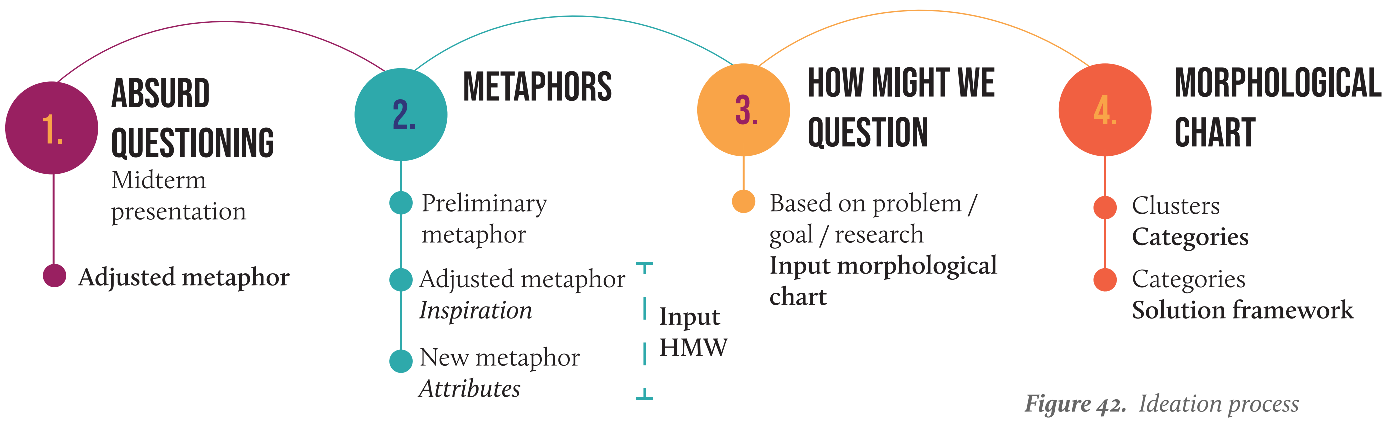


Figure 42. *Ideation process*

Step 1: Absurd questioning
The technique 'Absurd questioning' from the book 'Road map for Creative Problem Solving Techniques' (Heijne & van der Meer, 2019) was chosen to generate early out-of-the-box ideas. This technique is highly suitable to perform in a more experienced group setting and starts the ideation process with a diverging mindset. This method resulted in invaluable ideas but led to the formulation of new metaphors that formed the next step in the ideation process. The complete method can be found in Appendix 9.

Step 2: Metaphors
The metaphor included in this step led to the formulation of a set of attributes that would be valuable to have in the final solution: transparency, modularity, flexibility and thought-provoking. To formulate a metaphor, the drafted problem definition was first simplified to: '*No method to use data as inspiration*'. A solution to this problem could be drawn using the following metaphor:

The open house
This metaphor refers to building a house to learn how people live inside it. All elements of the house (data) are available, walls, floors and even furniture, but there is no floorplan (method) explaining how to build the house.
With the design team at Ford generally knowing what a house should look like, the house is put together to the best of its ability (current data analysis process). However, they still don't know anything about the people living inside (insights). The question that needs to be answered in this metaphor is how to build a house to provide insight into how the people inside are living. Answering this question led to a set of attributes , shown in Figure 43, that were incorporated into the final concept.

Figure 43. *Solving the problem with a metaphor*

Step 3: How might we questions
A series of How-Might-We questions (van Boeijen et al., 2019) (HMW-questions) was drafted to guide idea generation. Some reformulate the design goal and others focus on partial solutions by asking more specific questions based on performed research. These questions were then answered with as many ideas as possible, keeping the developed metaphors in mind to ensure a broader range of ideas. The complete documentation of this process can be found in Appendix 10, and the asked and answered HMW-questions are listed below:
1. How might we represent data?
2. How might we interact with data?
3. How might we stimulate creativity?
4. How might we collaborate during creative sessions?
5. How might we make data playful?
6. How might we use materials to interact with data?

Step 4: Morphological chart
The HMW-questions and ideas are summarised in a couple of words and structured using the morphological chart, which can be seen in Figure 44. Each row represents one HMW-question and can be seen as a sub-function of the overall solution. However, the morphological chart has not been used in its traditional sense with the goal of generating new ideas by combining ideas from each row or subfunction. Instead, all similar ideas have been grouped together revealing a set of clusters which can be found in Appendix 11. Idea clustering is a separate technique used to organise and analyse ideas by categorising them, which in turn helps to reveal new context and patterns among them. The found clusters including the most valuable ideas are identified and described in Figure 45.

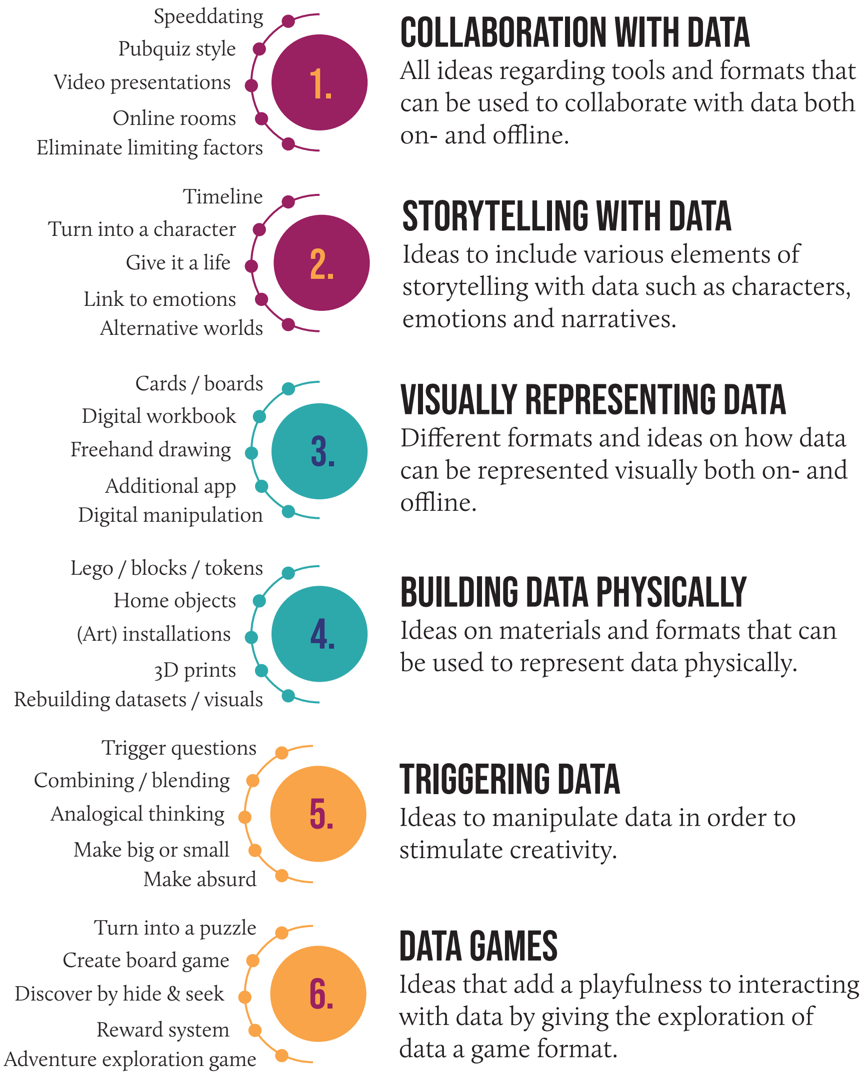


Figure 45. *Clusters extracted from morphological chart*


Figure 44. *Morphological chart*

5.2. Solution structure: Instruction - Physicalisation tool - Methods

Similar clusters that were found after creating the morphological chart have been grouped, revealing three categories. To name these categories we referred back to the goal and direction of creating a toolkit that encourages data exploration to stimulate creativity. The categories form the three components of the to be designed toolkit, an instruction (purple in Figure 45 and Figure 46), a physicalisation tool (blue in Figure 45 and Figure 46) and methods that can be applied using the tool (orange in Figure45 and Figure 46).

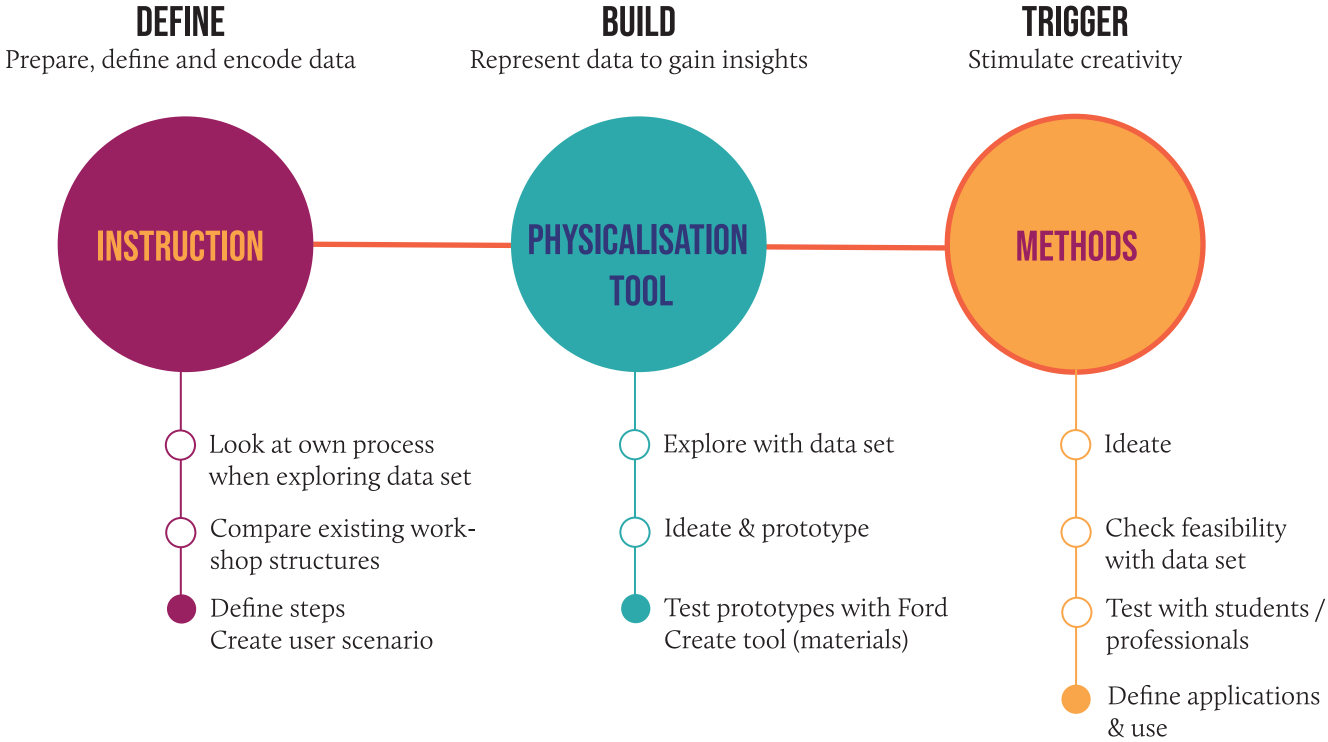


Figure 46. *Solution structure*

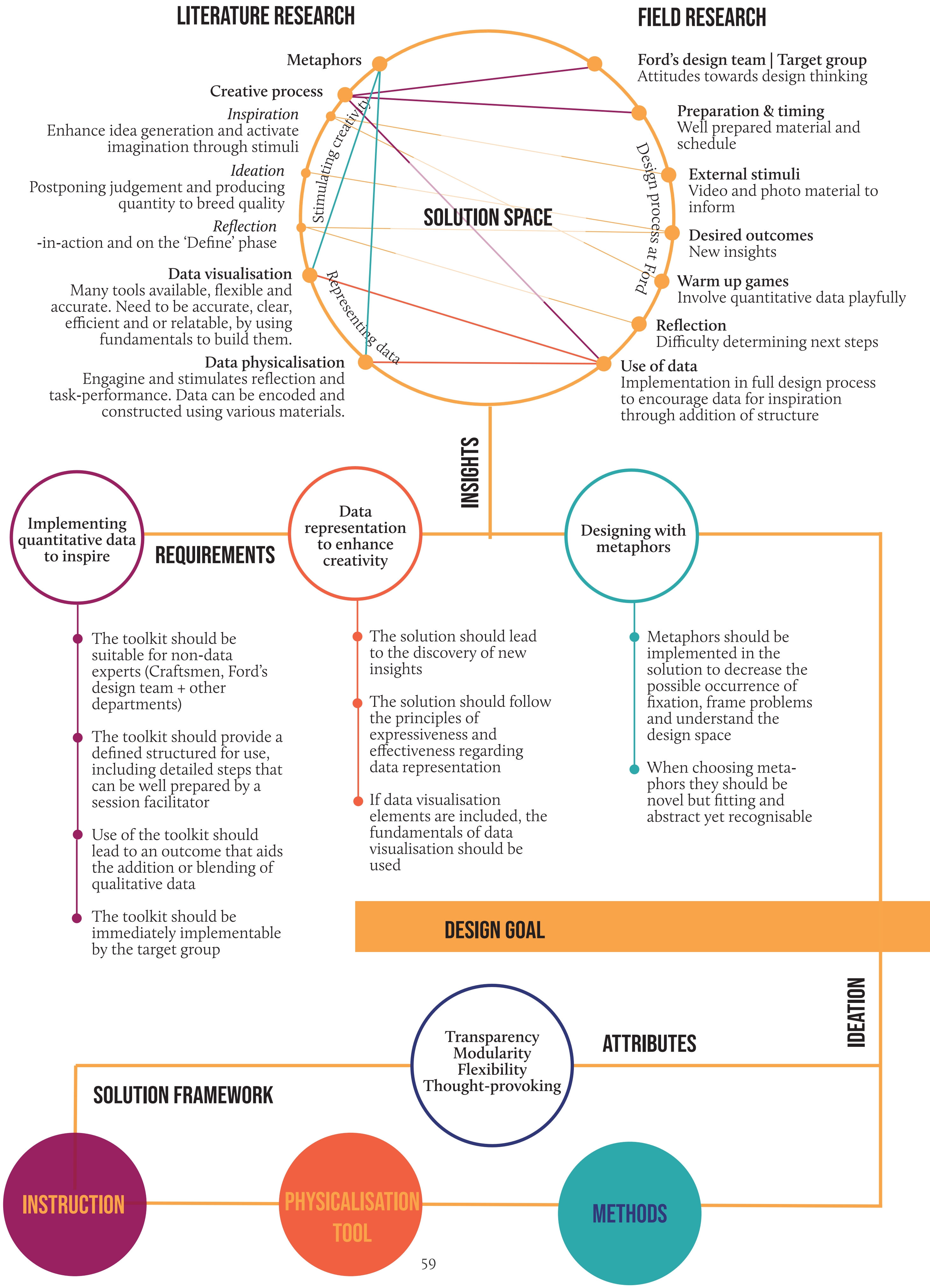
Instruction
The instruction describes how the tool should be used during a creative session. It outlines in multiple steps how the goal of the session can be formulated, and outcomes can be generated, creating a structure that can be adapted to each specific session. These steps were defined by comparing working methods from existing workshops, products, and projects and extracting relevant actions (see Chapter 5.2.1).

Physicalisation tool
With the tool, the chosen data set can be represented and interacted with by the target group. The tool should allow for reflection during construction and analysis and exploration after the initial data is constructed. The tool was developed by creating prototypes and testing these during creative sessions (see Chapter 5.2.2).

Methods
After constructing the initial data using the tool, different ideation methods aimed to stimulate creativity and reveal new insights. Within this structure, methods can be applied to the data set using the tool to stimulate users to look at the data from a different perspective, pushing more conscious reflection (see Chapter 5.2.3). These methods mainly consist of ideas that were part of the clusters 'Gamification of data' and 'Triggering data'.

Image 47 shows the results of the research and ideation phases, including the created solution structure. From this overview, iterations and prototyping of the solution structure to develop this structure into a concept could be started.

Figure 47. Conclusion figure



5.2.1 Shaping the instruction process

From the existing solutions described in Chapter 2.2.4 and mapped in Figure 20, I selected four solutions that include a specific process and compared them using a comparison table to extract a process that suits the solution structure and the to-be-designed solution. This table, including a description of the process can be found in Appendix 12. The four compared solutions have been selected because they all involve a step by step process, but range in type of data representation and application. The complete studies can be found in the reference list.

Process steps

The steps extracted from the comparison table are listed in Figure 48, including a short explanation. The preparation phase includes all the tasks that need to be performed before the start of the creative session by the session facilitator.

The preparation process starts with the selection and cleaning of data, followed by defining the context. Based on the selection, the session facilitator determines if the data set can be classified as extensive (a large number of variables) or focused (a smaller number of variables). There are no rules in place yet to make this distinction and should be further researched, the session facilitator makes this distinction based on experience. This step is crucial because it helps to determine what method would work best in the reflection stage. In this same step, the perspective from which the data will be explored is determined, to guide the use of the tool. Then, the material that will be used to physicalise the data needs to be encoded and prepared. Encoding the material means giving a specific meaning to the different elements that will be used to represent the data. This step can be predefined by the session facilitator before the start of the creative session if there are time constraints or a large number of participants, but could also be determined together during the session itself. Then the data can be built using the tool, which was further developed in Chapter 5.2.2 and reflected upon using the methods, further iterated in Chapter 5.2.3.

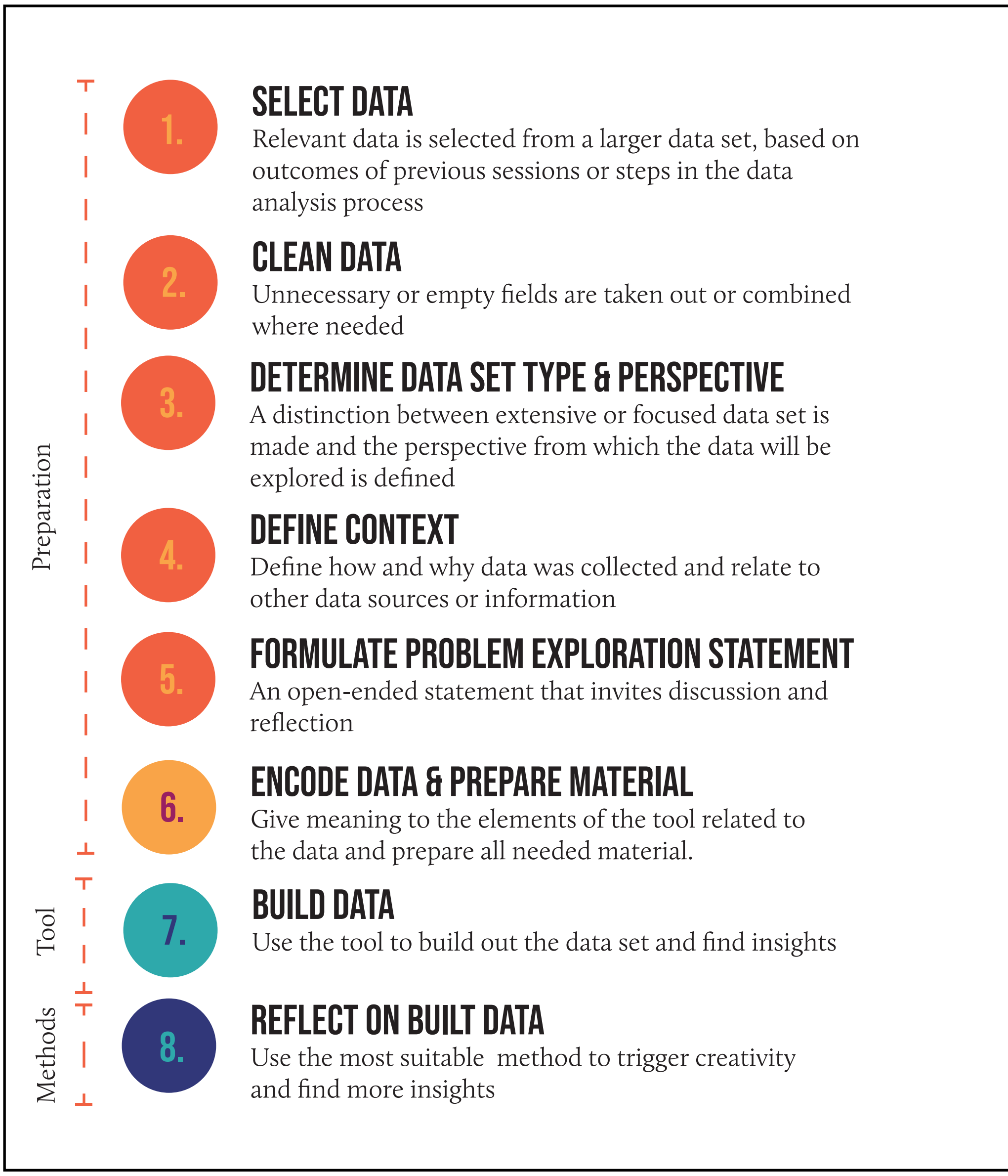


Figure 48. Process steps

5.2.2 Developing the data physicalisation tool

Building data using the tool forms the core of the creative sessions and results in a physicalised data set after all the preparation, and building steps are completed. Research has shown that reflection-on-action is encouraged by physically building the data set, which positively affects creativity (Sosa et al., 2018). This activity is already expected to lead to new insights, which was tested in the first study.

Set up
To define the most suitable format for the data physicalisation tool, the main component of the solution framework, I designed a user test in the form of a creative session. The tool consists of a set of (online) materials that can be used to represent a data set through physicalistion. To allow participants to look at a given data set from different perspectives, a prototype was tested that consisted of two separate parts, with each piece focusing on a different perspective. Due to the current remote working situation, the data physicalisation prototypes were designed to be tested online. Although this resulted in a lack of physical interaction with the prototype, the study's goal could still be achieved.

Goal
The goal of this study was to determine if the designed prototype was suitable to represent data, how it could be optimised and if this way of data building stimulates reflection on the data itself. To have a focused study with valuable outcomes feasible within the available time frame of the participants, the other elements of the solution framework were excluded from this study.

Method
A creative session was chosen as a format for the study because the final solution was also designed to be used during creative sessions. The creative session was split into three sections: an introduction, a data building part, and an evaluation guided by interview questions. As the session facilitator, I performed the tasks described under preparation in Chapter 5.2.1 before the start of the creative session and explained made decisions during the introduction.

The session facilitator did not take an active role in the building phases of the session other than assisting, which allowed the facilitator to observe. The full session was voice recorded to transcribe comments made during the assignments and evaluation.

Procedure
The different phases of the study are portrayed in Figure 49. During the introduction, the session facilitator explained the goal and setup of the session, introduced the data set and prototype used, and explained the assignment. Part two consisted of building different parts of the data set using the two parts of the prototype. During the evaluation, the participants were asked how they experienced the session, observations were discussed, and assumptions were reflected upon. The evaluation criteria can be found in Appendix 13A.

Participants
The study was conducted with four participants, among which three members of the target group, the design team of Ford. These participants all have different backgrounds, including industrial design, marketing, and engineering, to represent the larger design team. The three participants from Ford were all part of the field study and can be found in the overview of Figure 26. The fourth participant was a member of the Ford Graduation Community and shifted between assisting observation and building data.

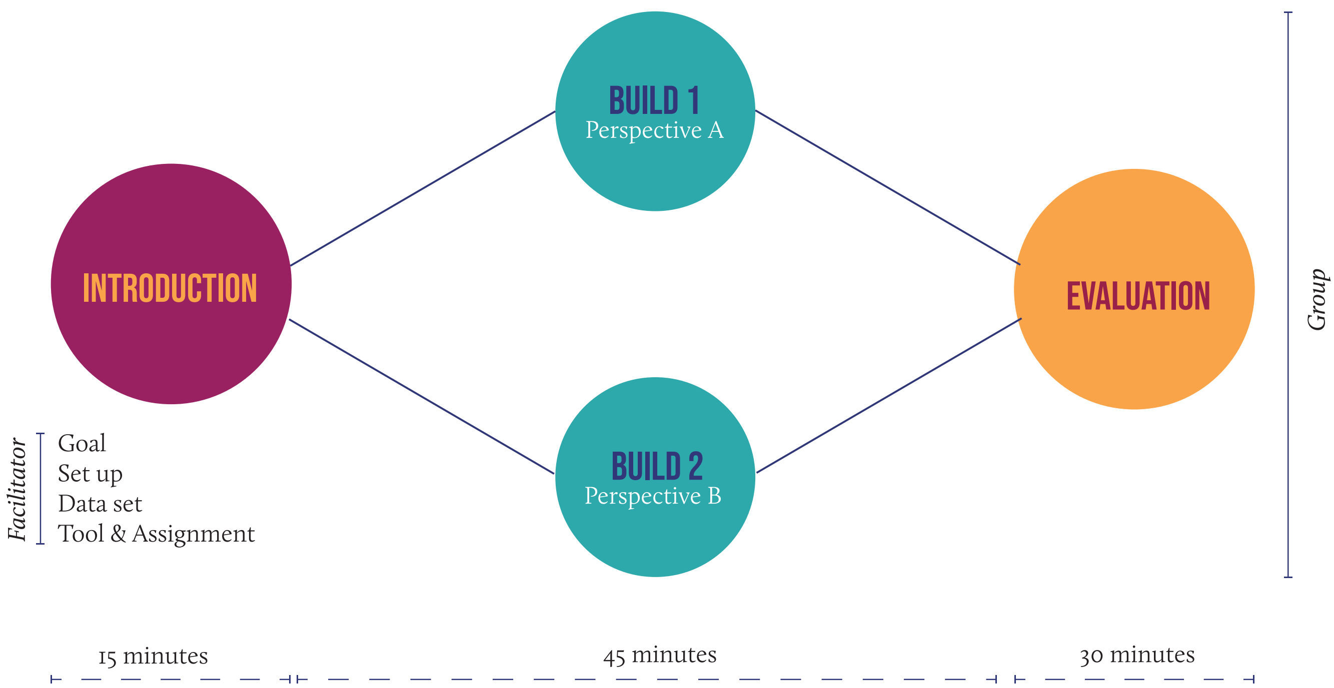


Figure 49. *Procedure study 1*

Creative session

Data set
The data set used in this creative session was part of an ongoing project at Ford and can therefore not be disclosed in this report. A selection of this larger data set was made for the sake of this study including 8 different variables and therefore classifying it as a 'focused' dataset. Part of this selection can be found in Appendix 13B. The data was selected, cleaned and modified based on relevance and the schedule of this study by me as the session facilitator. To a certain degree, all participants were familiar with the data, using this study to build on previously gathered insights.

Assignment
Participants were asked to build out a dataset using the prototype provided in Miro. They had to complete this assignment as a group but could decide how to divide roles or tasks among themselves. As the goal was to see if the prototype was suitable to represent data and how it could be optimised, participants were asked to think and discuss out loud to identify problems and opportunities for optimisation.

Prototype
The prototype consisted of two parts and can be found in Appendix 13C developed after ideating on two original ideas presented in Appendix 13D. As the dataset can not be made public, the specific wording and clues on the prototypes have been generalised. In the first part, participants are asked to build out the data set according to the days of the week that are already filled in. A set of building elements has been prepared that represent physical materials that would be used in a real-life setting. These elements were encoded and placed on the mapping board by the participants by copying and pasting them following the data set. The second part explores the same dataset from a different perspective but uses the same interaction.

Results
The study was evaluated through observation and a short evaluation interview. Additionally, Figure 50 shows what the filled-in prototype looked like at the end of the building exercises (with specific information left out). The prototype was evaluated on four categories: data & insights, communication, process and tool. The full analysis, including substantive quotes mentioning specific data, could not be included in this main report but can be found in Appendix 13E.

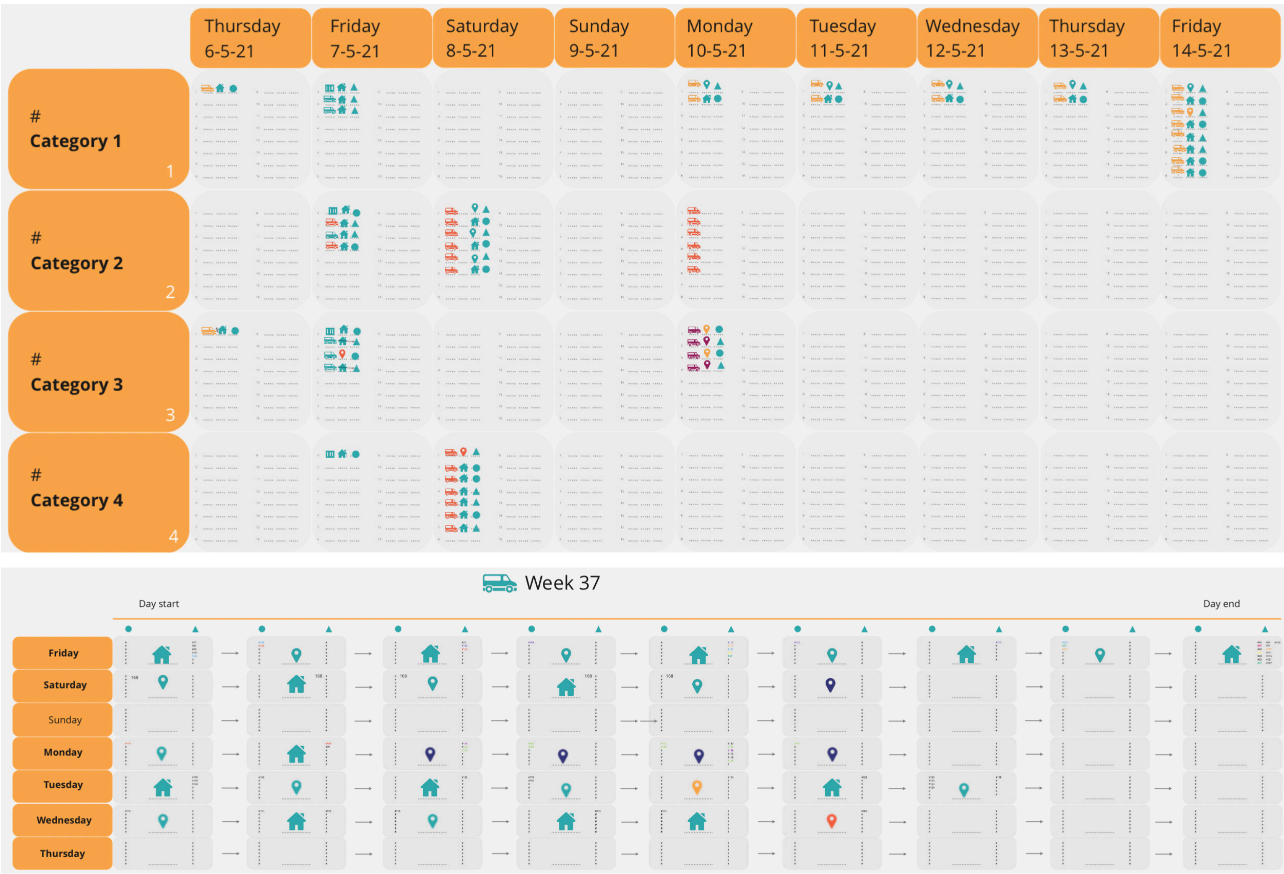


Figure 50. *Filled-in prototype*

Discussion
From the results summarised in Figure 51 it could be concluded that new insights were found during the study as the tool encouraged reflection. However, it is unsure if these insights could also have been found when provided with a data visualisation only, instead of going through the whole process of building the data manually. To verify this and eliminate factors caused by testing online, and the tool was optimised based on the comments made during the study and physically prototyped and tested. Based on the type of insights gathered, mainly in the form of questions and how intensely participants interacted with the data, this type of interaction with data might be called *'data immersion'.* This data immersion state could help determine interesting elements within the data set, filter out errors and define the types of data representations that would be useful. The desirability for Ford's design team and suitability to different datasets and projects should be considered upon further development of the tool.

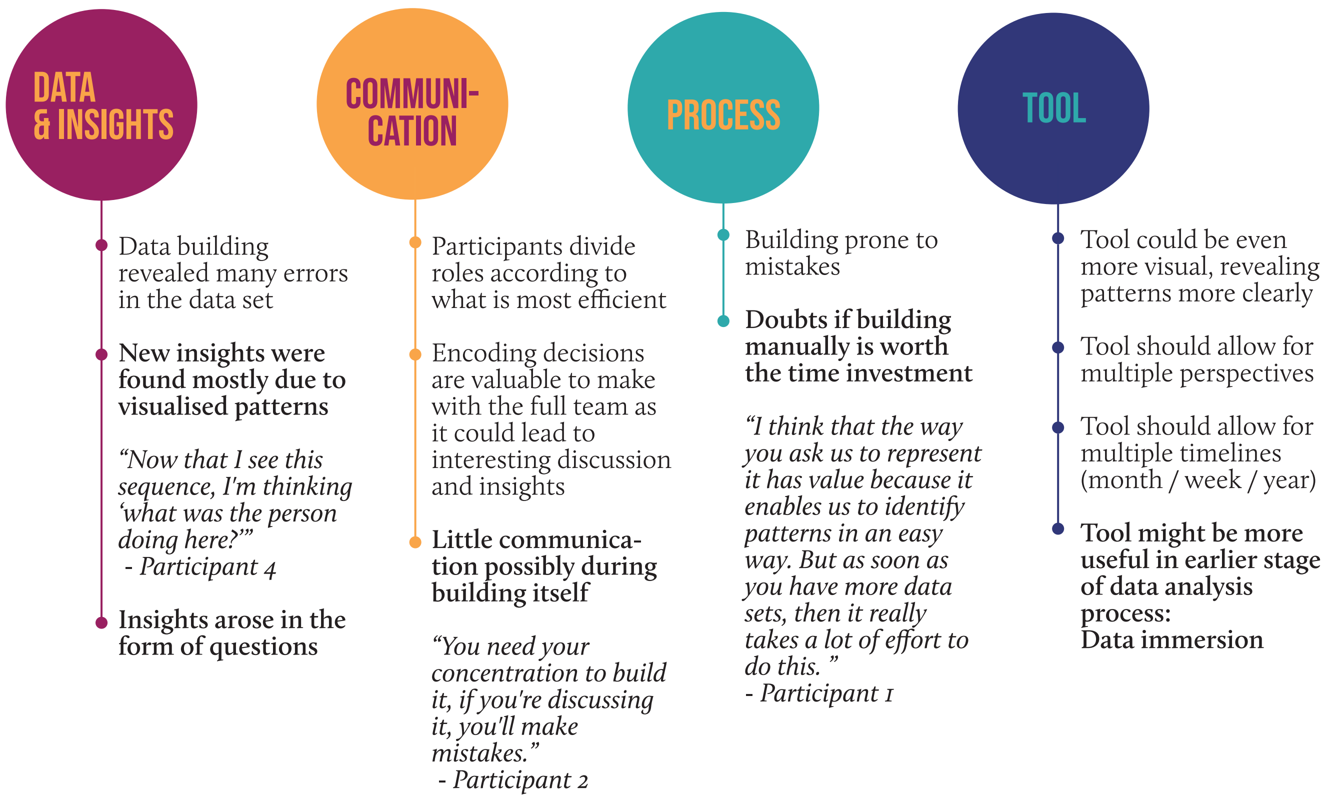


Figure 51. *Results study 1*

Limitations & Future study
Although exact effects of the used data set on the generated insights are unclear, it can be assumed that a more accurate data set would lead to more valuable insights. An online prototype was used as the current pandemic did not allow physical interaction with the target group. However, some of the errors and comments made by the participants could be prevented by testing the prototype physically. Therefore it would be valuable to use a physical prototype in a future study, with an updated data set. To validate the value of physicalisation, the found insights could be compared to insights found when only presented with a visualisation.

5.2.3 Exploring suitable methods to trigger creativity with data

Although reflection-on-action is already implicitly encouraged while building the data, after the construction, another round of reflection is invited by using different methods to stimulate creativity, which is assumed to lead to new insights. To learn more about this part of the solution framework, a user test was conducted.

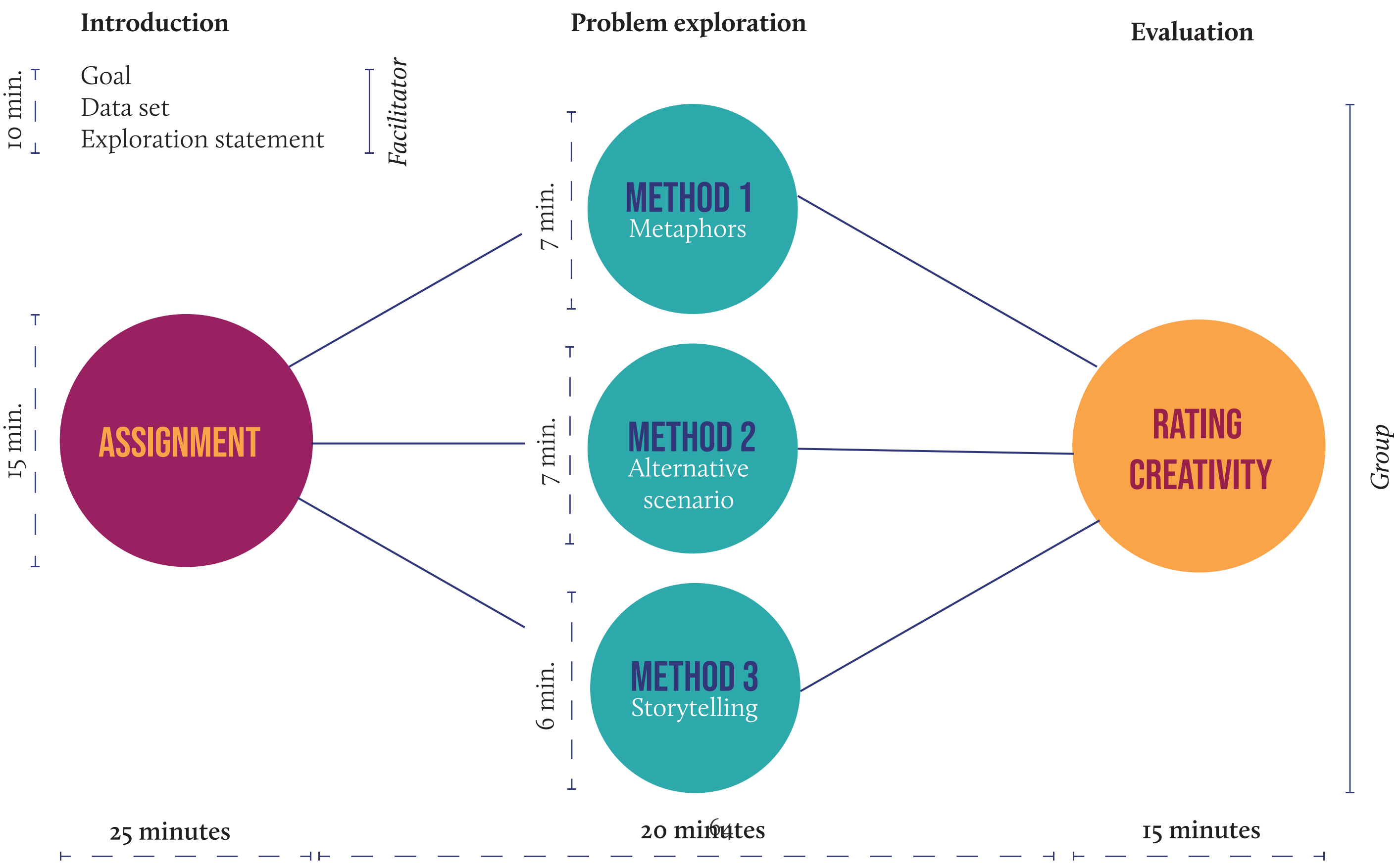
Set up
A creative session was chosen for the study to replicate the situation in which the concept will be used at Ford as closely as possible. During the session, multiple ideation methods as named in Chapter 5.1 were tested. In this chapter, metaphors, data games, trigger questions, alternative scenarios and storytelling were all named as possible methods of the tool that could trigger data in order to stimulate creativity. However, to ensure a comprehensive user test a selection of the three most promising ideas was made to be tested. 'Data game' was excluded from the list as this method was simply too vague and would require much more development before it could be tested. Secondly, the method 'Trigger questions', which can be described as asking questions that force designers to take on new perspectives, was merged with 'Alternative scenarios' as these questions could help create alternative scenarios. This resulted in a list of three tested methods: 'Metaphors', 'Alternative scenarios' and 'Storytelling'. A more detailed description of each method and the set-up of the study are described in this chapter.

Goal
The main goal of this study was to determine the suitability of the chosen methods on a data set, focusing solely on the last element of the solution framework to run a comprehensive sub-study. Although research has already shown that these methods can positively affect creativity during ideation sessions (Gonçalves et al., 2014), I wanted to find out if these methods were also suitable to use during problem exploration with quantitative data. Secondly, the study was used to gain more insight into the method's influence on creativity and optimise it during creative sessions.

Method
The creative session consisted of an introduction, a problem exploration phase and an evaluation during which the suitability of the methods and impact on creativity were discussed.
This structure allowed me to observe the participants during the problem exploration, evaluate a small set of quantitative data gathered during the evaluation, and discuss the session during a short interview. The full session was audio-recorded to be transcribed, and notes were taken during the session. I also acted as the session's facilitator, guiding the session but not actively participating.

Procedure
Figure 52 shows an overview of the creative session. After introducing the session's topic and goal, the problem exploration phase by explaining a fictitious data set and introducing a problem exploration statement. The participants then got the assignment to present one relevant insight extracted from the data set. With a sheet of paper and multiple markers to present their insight, they were encouraged to use the data visualisations in any way they liked. This assignment was then repeated in three follow up rounds, using the same data set, but each round using a different method, explained by the facilitator. The session concluded with an evaluation of the insights and a discussion guided by a set of interview questions that can be found in Appendix 14A.

Figure 52. *Procedure study 2*



Participants
The study was conducted with two participants as this is the minimum number of participants to have discussions. Both participants have design backgrounds, one of which is a master student and one an industry professional. No additional requirements were imposed besides having a design background and the right availability. Participants with a design background were chosen as they are already familiar with the ideation process, partly resembling the target group in this aspect and saving time in terms of explanation. The study was not conducted with members of the Ford design team as they are still working remotely, and based on the first study, it was assumed that online collaboration would restrict creativity.

Creative session

Data set
The fictitious dataset used can be found in Appendix 14B. In this creative session was created by Jacques Bertin to explore data visualisation. The dataset shows the average monthly occupancy of a hotel, dividing guests by gender, origin country, length of stay etc. When working with this dataset, it is essential to consider the importance of the data in the context of a hotel and to note the differences in metrics. As explained in the assignment, only one relevant insight must be presented per round, meaning not all the data needs to be visualised.

Problem exploration statement
During this session, the data set is explored, leading to new insights rather than solutions, relatable to the creative sessions of Ford in the Define phase of their design project. To encourage reflection and discussion, an open-ended problem exploration statement is introduced. This problem exploration statement gives some context around the data set and some direction to steer the exploration. For this session, the facilitator previously determined the statementand states:

Finding opportunities to increase occupancy throughout the year.

Measuring creativity
One of the goals of the session is to assess the impact of different methods on creativity. However, creativity is an abstract phenomenon that was defined as the production of novel, original and valuable ideas (Boden, 2007) that are still appropriate (practical) to the task at hand (Amabile, 1983), can not be measured directly. Therefore, a qualitative outcome-based method was used. A system that measures the insights of each exploration round using different dimensions relating to the mentioned definition of creativity was created. These dimensions are based on earlier research regarding inspiration and fixation by Vasconcelos et al. (2017) and Goldschmidt and Smolkov (2006), in which they are used to measure creativity by assessing ideas.

General quality: This dimension covers the quality of the insight without looking at a specific element. The general quality is expected to increase after exploring a method, as the most apparent insights are already filtered out.

Originality: The originality describes how unique the generated insight is and how much the insight differs from existing knowledge. Expected is that the originality of insights increases after applying one of the chosen methods.

Practicality: Practicality, or implementability, is essential to the target group as the generated insight should eventually be implementable and lead to a subsequent session. This dimension is expected to score slightly lower after introducing a method, caused by increased originality and, therefore,more out of the box ideas.

Methods
1. Metaphor - A metaphor for the described problem exploration statement is thought up by the group, guided by a simplified set of steps shared by the facilitator and based on the method as described in the Delft Design Guide (van Boeijen et al, 2019).

- Define the most important attributes of the problem exploration statement
- Think about other fields where these attributes occur (for example nature, other industries)
- Choose the most suitable metaphor
- Look at the data set through the glasses of this metaphor and try to find new insights
- Force fit one of these new insights to the original context of the hotel

2. Alternative scenarios - The group thought up alternative scenarios, fueled by a series of trigger questions. The group looks at the data set with this alternative scenario in mind.

- What would this situation look like 50 years from now?
- What would the ideal situation look like?
- What if the target group would consist of astronauts/children/single fathers?

3. Storytelling - A story is created around the problem by imagining a detailed character representing the target group. By looking at the data set from this character's perspective, new insights might be found.

- Create a character that could represent the target group, think of its personality, behaviour, daily life etc.
- Create a story for this character addressing the problem exploration statement

Results
The study was evaluated through an evaluation interview, observation, and the generated insights using the defined dimensions: general quality, originality, and practicality. The full study was evaluated in the following categories: experience, generated insights and suitability. The insights generated by the participants (Figure 52) and all relevant observations with accompanying quotes can be found in Appendix 14C.

Experience of the creative session
The session was perceived as fun, mainly because the participants could work together as a team and that the problem statement could be explored in a very open way, without the pressure to deliver well-designed data visualisations or concepts.

> *"I thought it was really fun. What I really liked was the fact that we could work together because if I was alone, I wouldn't know if I could do the assignments without discussing it together."*
> *- Participant 2*

> *"I think it's also a good thing not having to make a beautiful drawing. It's exploration and the fact that it was so open and didn't have to be presented in a specific way, took away the pressure. Because I think it should be something that comes natural to you. And when it comes to being natural, it's easier to just visualise a story than to, let's say, make a bar chart."*
> *- Participant 1*

Generated insights
The participants perceived their generated insights as surprisingly valuable as they thought the assignment would be tough upon receiving the data set and only seeing numbers. They were surprised that their ideas generated in a relatively short amount of time-based on a single data set made sense. Assignment 1, without the use of any method, was perceived as more challenging and less fun. The result was considered dull and obvious but also more practical and easily implementable for the hotel.

> *"Yeah, the first one, I'm looking at it like it's really, really boring. But it is, I think, the most practical one. But it is the most boring. And in your face. I think it's obvious. It probably does better suit their existing business model. And the others are more future opportunities, probably a whole new business model."*
> *- Participant 1*

Both participants agree that the insight generated in assignment 1 could implement a solution right away but would have less impact than using the insights generated with the methods. Using these insights would be more future proof but require radical change.

Suitability with data and influence on creativity
The participants were able to generate insights from the data set with all three methods. However, participant 2 thought it was harder to link the storytelling method back to the data.

> *"With storytelling I think it's quite easy to get lost in the story and forget about the data. I think that makes it hard."*
> *- Participant 2*

Using and altering the data and world with the alternative scenario method resulted in an exciting context and, therefore, insight. Still, it was perceived as more complex as there are unlimited options and scenarios you can create. Having a known structure when using metaphors gives more guidance when working with the data but only works if the metaphor is well chosen.

> *"This one, alternative scenario, I really liked. The insight that we got out of it was really interesting. But I think it is quite hard, because there's so much you can do. You can do anything. And then with metaphor, you do have some handholds. But we had a good metaphor, we could really connect things."*
> *- Participant 2*

The participants agreed that the alternative scenario method resulted in the most out-of-the-box insight, where metaphors and storytelling were a bit more straightforward, but at the same time, also offered more structure. However, because the alternative scenario method gives you the possibility of still thinking about the hotel context in a different world, the insight was still very practical. Practicality scored less high when using a metaphor that participant 2 thought could be explained because it required them to link back and forth between two different contexts.

> *"Yeah, I think this one, the alternative scenario, was the most creative. You go that crazy and far and it's still relevant. But it's also because you are still thinking in a hotel context. It is still the hotel, so that was really nice, because you don't need to link it back to a hotel like with the beehive metaphor."*
> *- Participant 1*

Finally, the participants think that storytelling results in interesting insights that may stray a little from reality, whereas metaphors deliver more abstract insights as metaphors are already a highly abstract way of thinking.

Discussion
The results suggest that the methods are suitable to use with data during problem exploration and lead to insights that are considered more creative than when exploring a problem without any method.
In this small study, the methods stimulated participants to think more conceptually and visually, which led to insights that were more out-of-the-box and less practical as they are harder to implement in the short term. The results are summarised in Figure 53.

Figure 52. *Participants during study 2*

The three methods could all lead to different types of outcomes and have different strengths, making each suitable for different types of problem exploration statements and data types. A participant mentioned that using metaphors gives more structure when chosen well than using a known concept while still creating original insights. However, as the metaphor needs to be linked back to the original context, the insight could be less practical and on a more abstract level as the method itself is abstract as well. Therefore, using metaphors could be used with both focused and extensive data sets and possibly leads to more abstract insights that can be implemented right away or in future scenarios. In this study, using alternative scenarios resulted in highly creative insights, but using them was experienced as more challenging as the method offers a lot of freedom. Therefore, it is assumed to be most valuable to use with a focused data set to limit the opportunity pool when more radical, future-focused insights are expected. Lastly, storytelling from a user perspective also resulted in a highly creative insight, although participants mentioned that they could easily get lost in irrelevant details of a story. Therefore, this method is most helpful with a focused data set when exploring the problem from a user perspective, resulting in concrete, user-driven insights.

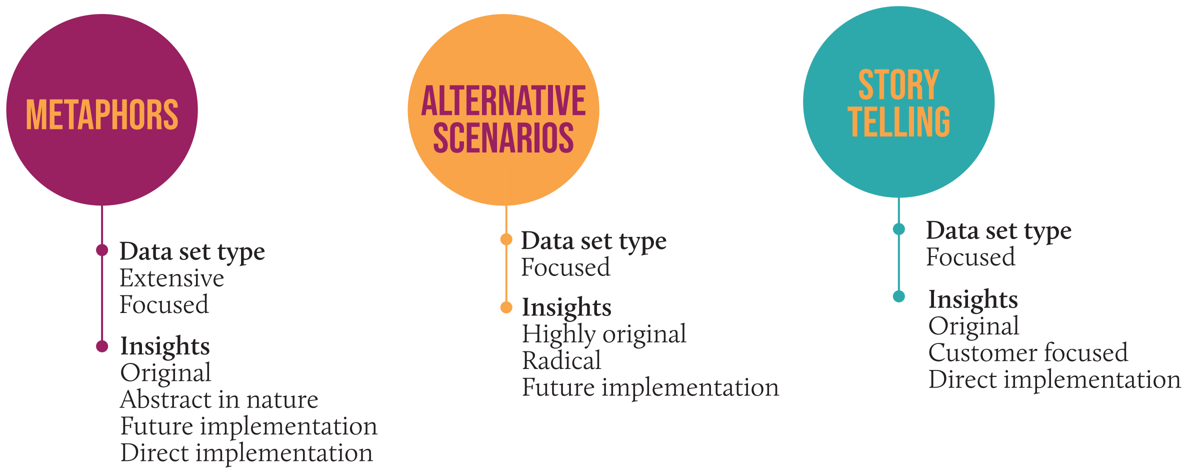


Figure 53. *Conclusions study 2*

Limitations & future study
As this study was conducted with a minimal number of participants, none of the results can be seen as significant and only indicate how the methods can be used most effectively. The design background of both participants helped to run an efficient study but is not fully representative of the target group as the group also includes non-designers. Lastly, as the same assignment was executed four times, starting without using a method, there might have been a learning curve that could have influenced the creativity score. This was presumably partly countered by using an extensive data set, from which different elements were used. However, to achieve more accurate results, the second round of this study could include a combination of a designer and a non-designer. The order of assignment and methods is switched around. Although we now know how the methods can be used with data and the type of insights they will generate, the next step is to incorporate the methods in a data analysis process, specifically in combination with data physicalisation. This combination was studied in the final user test, see Chapter 7.1.1.

5.3 Conclusion

Figure 54 contains a summary of the results found after iterating on each element of the defined solution framework to create the final concept. The process steps are outlined as well as the insights from both performed studies, leading to the final format of each element of the final concept that will be introduced in Chapter 6.

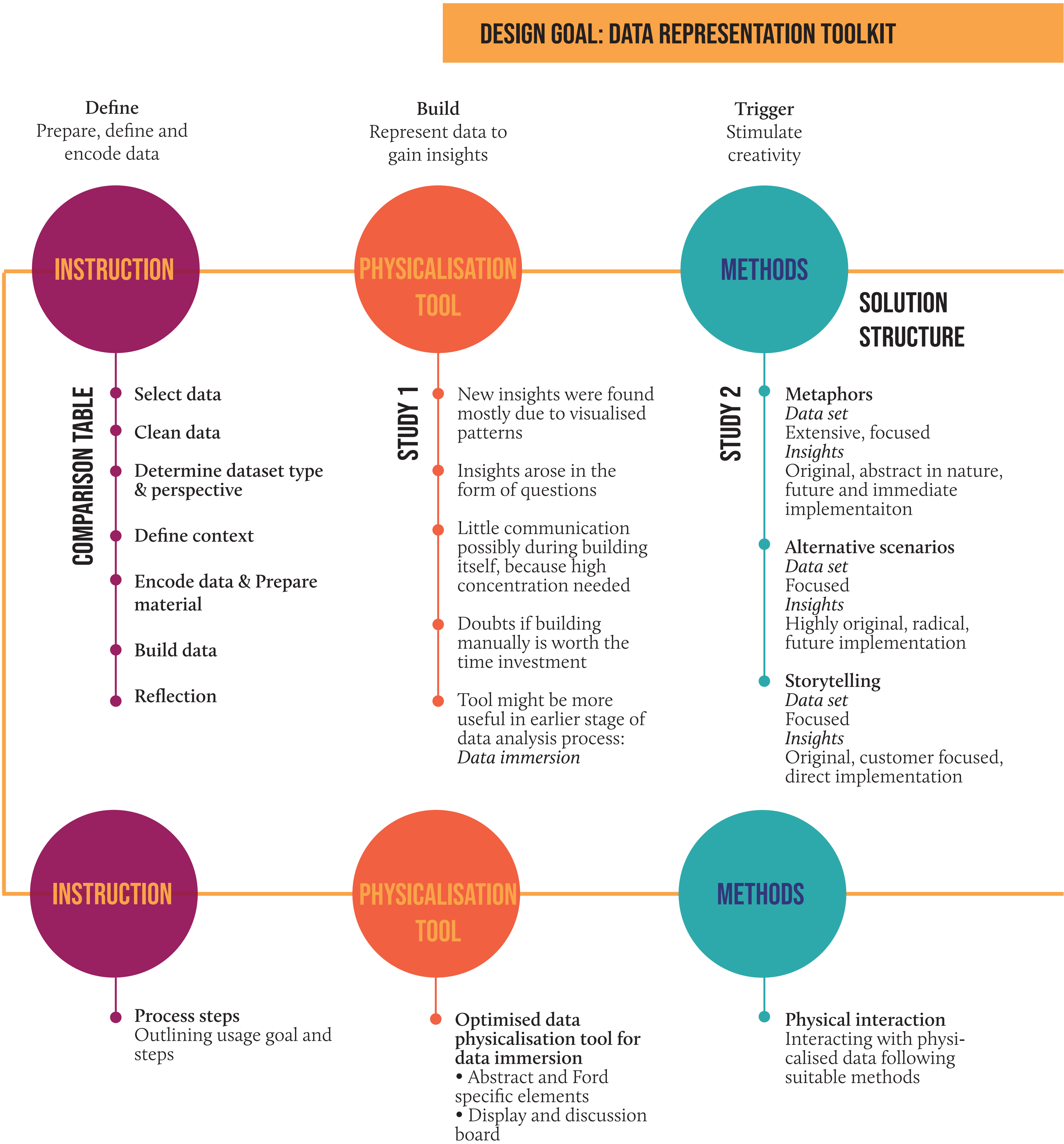


Figure 54. Conclusion figure iterated solution structure

THINK WITH YOUR HANDS!
-LEGO

DELIVER

6

FINAL CONCEPT

After introducing the final concept, this report section describes all elements of the final concept: the instruction process, the physicalisation tool and the reflection cards. Then, the use of the concept and how it can be placed in the context of Ford are explained.

The Ford Concreate, displayed in Figure 55, is a collaborative data physicalisation toolkit designed for Ford that leads to inspiring insights by stimulating reflection and creative thinking through data immersion.

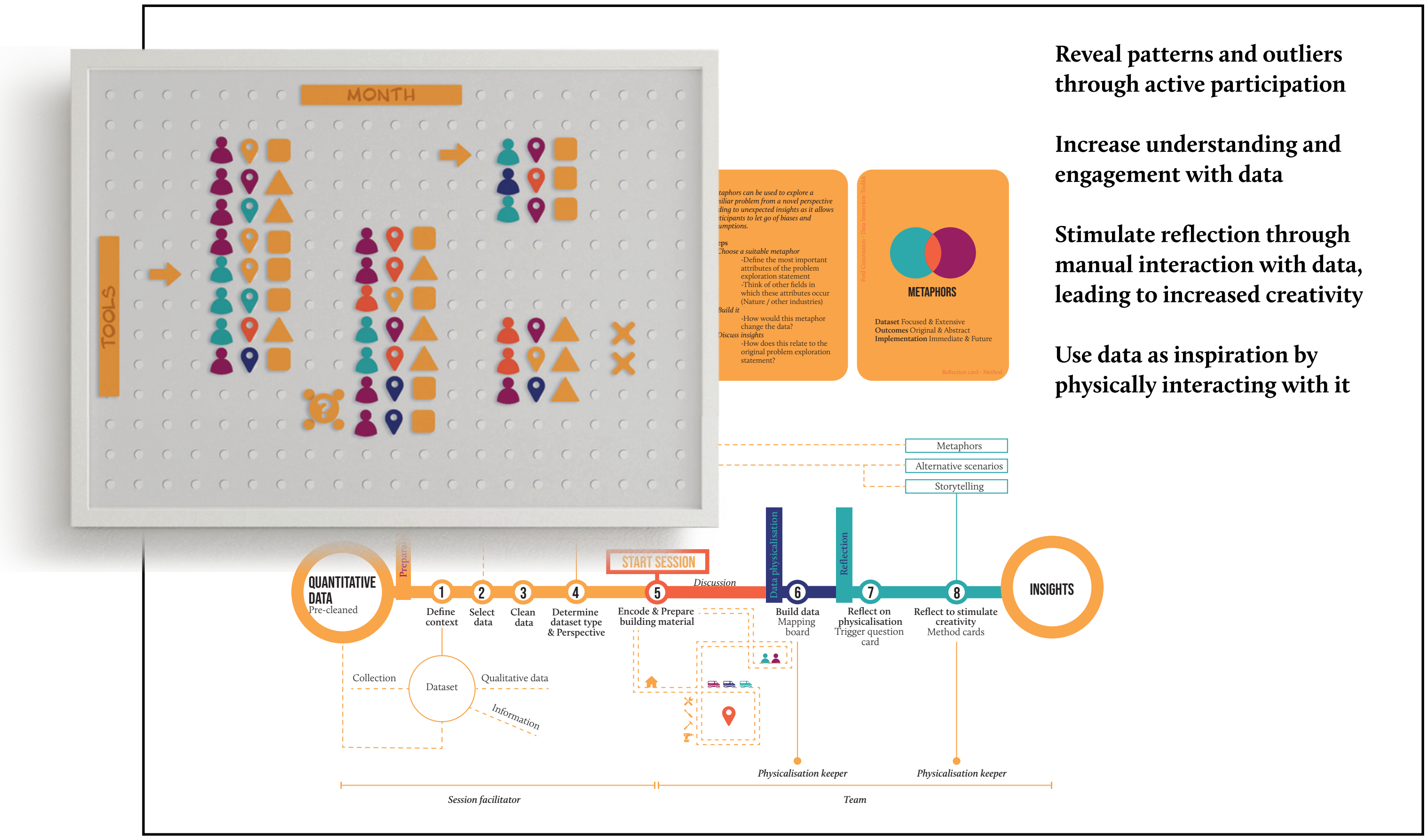


Figure 55. Overview final concept

Immersion is defined as 'the fact of becoming completely involved in something' (Cambridge Dictionary, 2021), which perfectly describes the effect of the Ford Concreate as it asks users to spend their undivided attention and motor skill on a given data set. By engaging with data by physically building it out using the Ford Concreate, users get a better understanding of the data, which prompts new questions and reflection and reveals patterns that lead to new insights. The flexible tool, designed to be used during creative sessions, allows for active interaction with the data stimulated by metaphors, alternative scenarios and storytelling, which open up the creative mind and invite discussion. The toolkit consists of an instruction process outlining all the steps that can be taken to ensure optimal use of the toolkit. This physicalisation tool includes a board, a variation of building elements to represent the data, and a set of reflection cards encouraging reflection.

6.1 Features

The final concept consists of three elements that complete the toolkit: An instruction process, a physicalisation tool and a set of reflection cards. Each element and its functionalities are described, including decisions that led to its final shape.

6.1.1 Instruction: Process steps

The instruction, Figure 56, that explains how the toolkit should be used is portrayed as a visual process, outlining each step. The process starts with the input of quantitative data pre-cleaned by either the GDIA or a member of Ford's design team and ends with the formulation of new insights. As determined and explained in more detail in Chapter 5.2.1, the steps are indicated in order, including sub-steps that need to be taken where needed and their connection to other steps in the process. Step 1 till 4, which make up most of the preparation phase, are performed before the start of a creative session by the session facilitator. The last step of the preparation phase, encoding and preparing the building material, is done during the session itself by the whole team, as this step could lead to valuable discussions and insights. Depending on the size of the group, the following steps, building and reflecting on data, can be performed with the entire team or in smaller groups. The session is concluded by formulating new insights that can function as input for future sessions, research or next steps in the data analysis process.

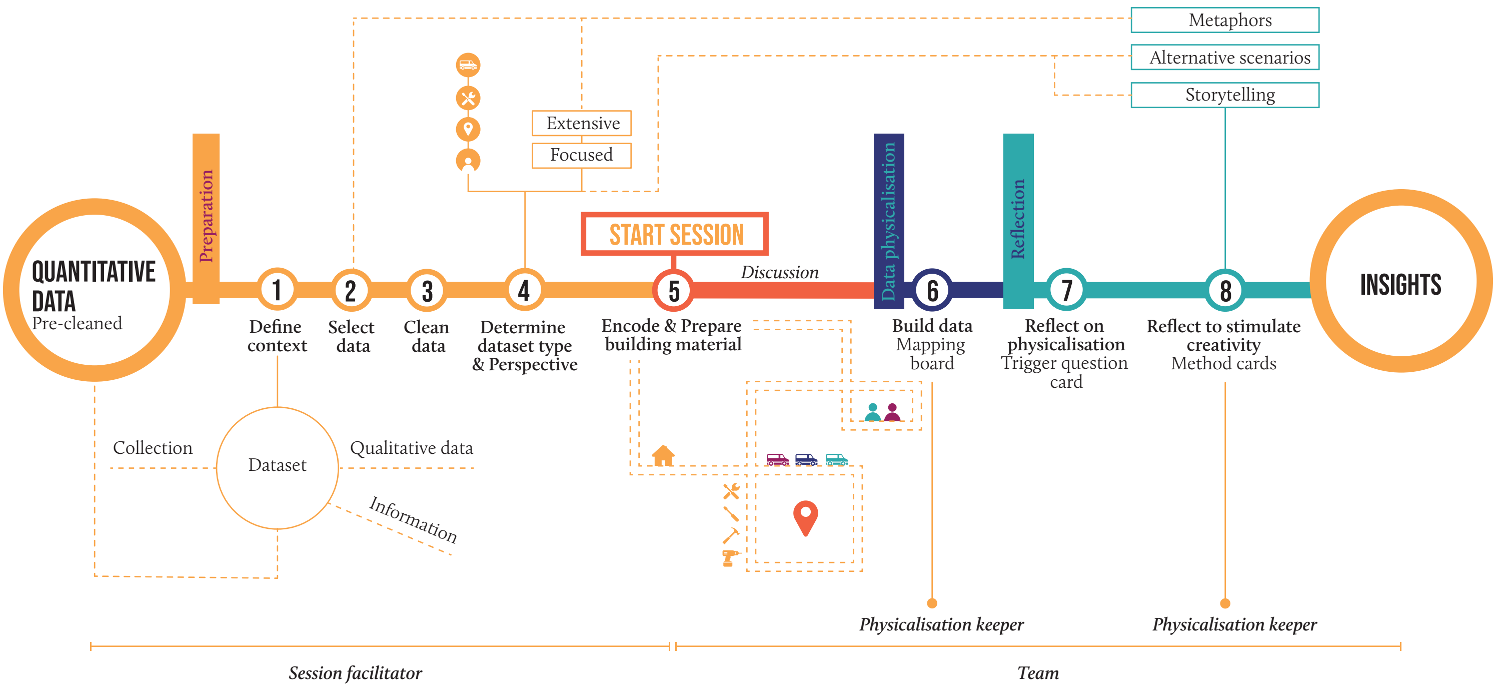


Figure 56. Instruction process steps

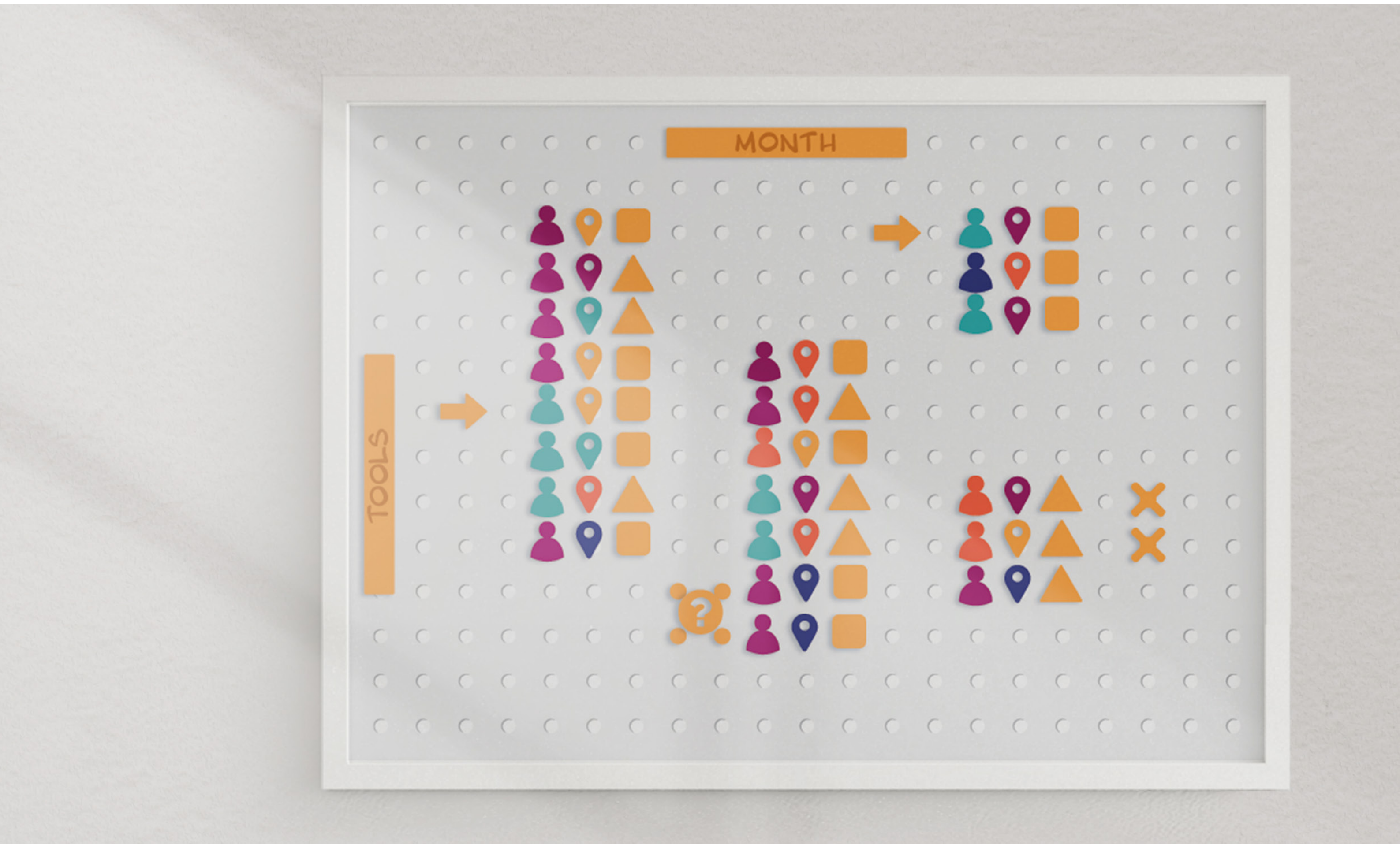
6.1.2 Physicalisation tool: Mapping board

The physicalisation tool is designed to build out a data set, facilitating reflection-in-action and resulting in physicalisations that reveal insights about the data. As shown in Figure 57 the tool consists of a mapping board on which datasets can be mapped out using a set of physical building elements. Preferably, the board can either be hung on the wall of a meeting space or put flat on the table and easily moved from room to room, to ensure flexibility and transportability.

Mapping board

A whiteboard is chosen as the base of the mapping board as this tool is already owned by the company and offers a lot of flexibility when used in combination with magnetic building elements. After ideating and evaluating a number of ideas on the attributes drafted in Chapter 5.1, modularity, transparency, flexibility and though-provokingness. The alternatives included cork walls, pegboards and stickers. However, the whiteboard was most suitable because it allows for easy adjustability and building freedom while still allowing to provide structure in the form of a grid. When working with data, a grid can be helpful to keep all elements organised and ensure physicalisations that are readable. This grid could be drawn or projected on the board. Using projection would also offer the opportunity to project more detailed backgrounds like maps or tables, on which data can be physicalised. Besides the grid, a second fixed element on the mapping board is the legend that can be filled in by the participants before the start of each session after encoding the building elements. Doing this on the board helps to process the made decisions regarding the encoding of the elements by making them explicit to each participant, which also aids reflection afterwards. The board itself can be used to draw connections between different elements, add remarks, highlights or additional sketches to the physicalisation.

Figure 57. Mapping board



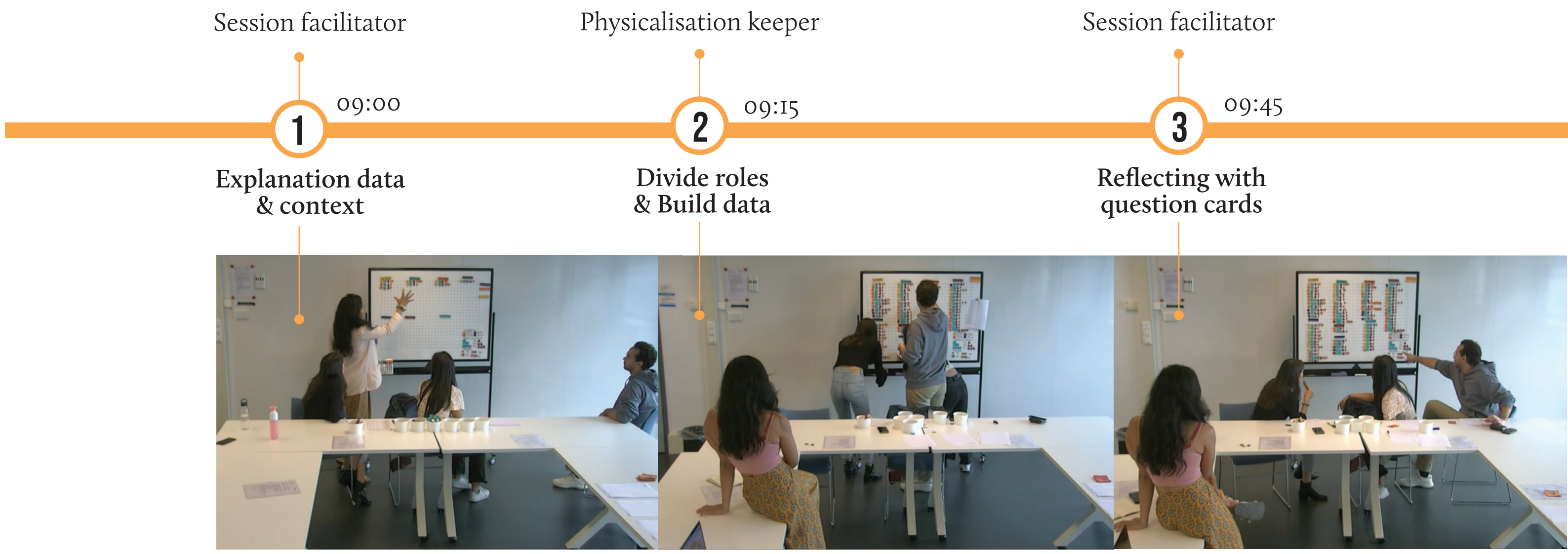
Building elements
The building elements are sets of shapes used to represent data and build out a data set by placing them on the mapping board. These shapes are divided into three categories defined in Figure 58: Ford specific elements, process symbols and abstract elements. The Ford elements represent data fields and items that often occur in the data gathered by Ford, like cars, users and locations and can be adjusted and expanded over time. Process symbols help indicate insights found in the data. Lastly, abstract elements consist of basic shapes in different colours that can be encoded depending on the data set. This set also includes boards that can be used for writing out titles, insights or other comments.

Ford elements
Recurring elements in collected data

Process symbols
Symbols that can be used to express or highlight occurences and insights

Abstract elements
Basic shapes that can be encoded depending on the dataset

Figure 58. *Building elements*



6.1.3 Methods: Reflection cards

Although physicalising data already facilitates reflection-in-action, explicit reflection-on-action steps are implemented in the process to ensure the generation of more valuable insights. To achieve this goal, the toolkit includes two types of reflection cards: question cards and method cards, both pictured in Figure 59. An overview of all cards can be found in Appendix 15.

Figure 59. *Example reflection cards*

The question cards include one main question card and multiple sub-questions cards designed to stimulate reflection-on-action after building out a data set and formulate insights based on the created physicalisation. The method cards explain three methods: metaphors, alternative scenarios, and storytelling. The built data can be interacted with to encourage creative thinking to come up with another round of insights. Each method is suitable for a different dataset type and leads to different results, which is depicted on the front of the card. A description can be found on the back of the card explaining why the use of the methods can be fruitful and the steps to apply them.

6.2 Concept in use

The exact steps of using the concept are already outlined in the instruction process. Only a few key moments of the concept in practice are highlighted here, using images extracted from the performed user test, see Figure 61. The two roles mentioned in Figure 60, the session facilitator and physicalisation keeper, are the two specified roles that should be appointed at every session.

Figure 60. *Key moments of use*

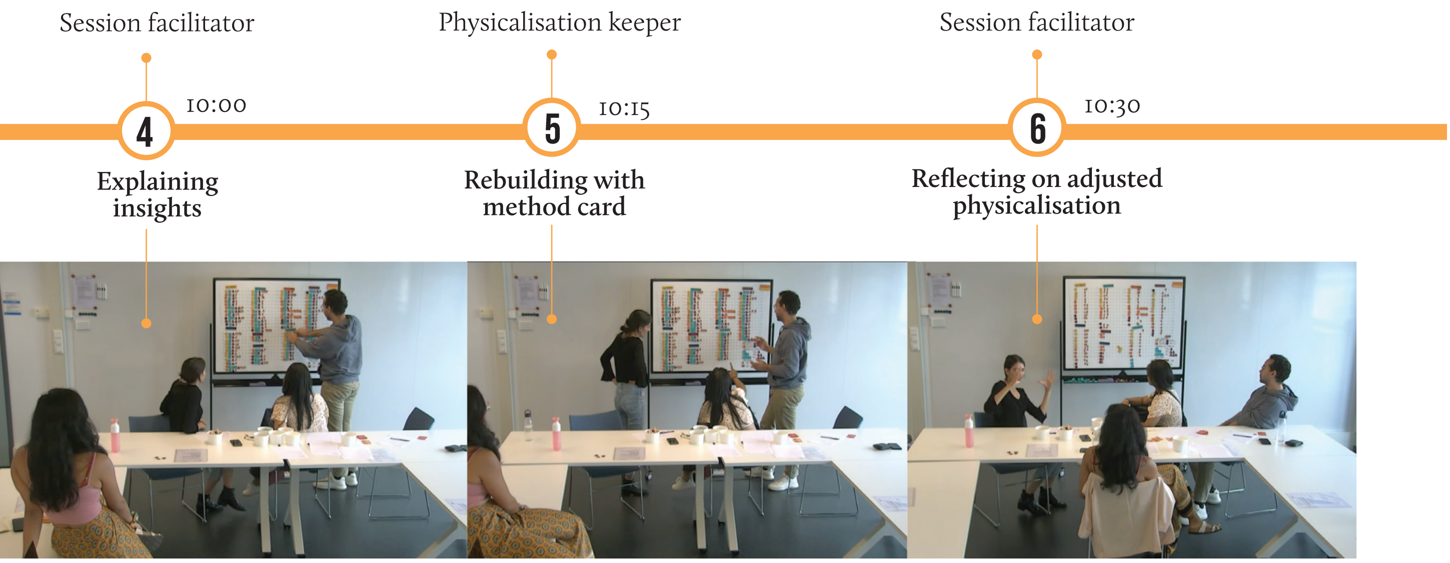


Figure 6. *Impression of concept in use*

Session facilitator
The session facilitator plays an essential role during the preparation of the creative sessions and during the session itself. The session facilitator performs all the steps of the preparation phase before the start of the session and should therefore be familiar with the data set that will be physicalised and have some experience with data analysis. During the session itself, the facilitator does not take an active role in the building or discussions but is focused on leading the session by giving needed explanations, guiding the participants through the material and exercises, noting down insights and keeping the time.

Physicalisation keeper
An additional role that needs to be fulfilled by someone with some knowledge of the fundamentals of data visualisation is the physicalisation keeper. The physicalisation keeper audits the mapping board by making sure the data is physicalised correctly and understandably. They are following the fundamentals of data visualisation and the Gestalt principles as much as possible. For example, the keeper checks if the correct building elements are used for each data input and similar elements are placed evenly across the mapping board. This is important as the board offers much freedom but needs to be used correctly to reveal patterns and insights.

6.2 Concept in context

Now that the final concept has been designed, we can define where the concept fits in the overall data analysis process at Ford and how the concept achieves the drafted design goal.

Data physicalisation before data visualisation
The data that is suitable to use with the Ford Concreate can be classified as small-thin data. This data is gathered by selecting the big-thin data that is being collected, creating more focused, structured data sets. The goal is to combine insights from this data with insights from small-thick data, as portrayed in Figure 62. However, as study 1 has revealed, the data physicalisation is highly useful for getting immersed into the data and better understanding. Still, it fails to show patterns over more extended periods as only small data sets can be physicalised. Therefore, this data physicalisation step is placed before the data visualisation step in the data analysis process as it reveals interesting opportunities to explore on a larger scale. Combining these steps creates a hybrid process that uses the strengths of both types of data representation (Chapter 4.1.2).

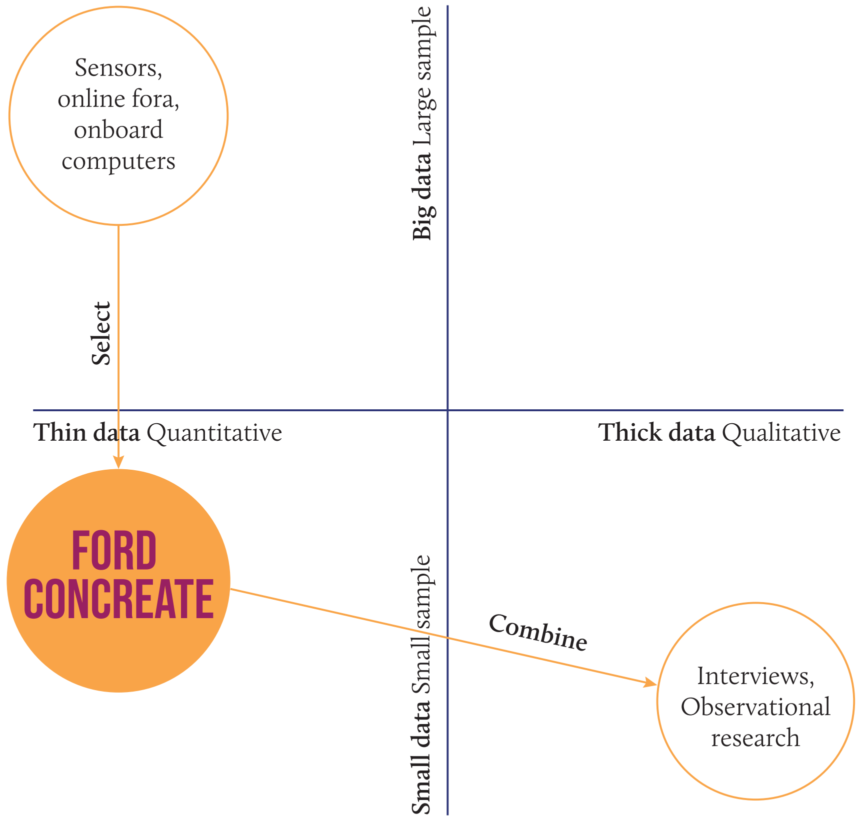


Figure 62. Use of data Ford Concreate

Design goal achieved
Figure 63 shows how each element of the concept achieves a separate part of the goal, together forming the toolkit that can be used to physicalise different data sets for any project the target group will be working on now and in the future.

Designing a data physicalisation toolkit to be used during creative sessions in the design process of Ford, that transforms small-thin (quantitative) data into external stimuli and encourages reflection through the use of metaphors to find better insights.

- **Instruction process**
  Allows the toolkit to be used during creative sessions in the process and described the selection and cleaning process of the right data
- **Physicalisation tool**
  Transforms the selected data into interactive stimuli, while the physicalisation process stimulates reflection
- **Reflection cards**
  The cards are designed to stimulate explicit on-action reflection to find better insights, with one method being the use of metaphors

Figure 63. Design goal dissected

IMPLEMENT.

7

IMPLEMENTATION

To evaluate the designed concept, a prototype was created that was tested in the final user test. The main focus of this prototyping step was creating the mapping board and building elements, of which the building process can be found in Appendix 16. The reflection cards were prototyped for testing as well. The final user test resulted in a list of optimisations, a vision for the future concept and opportunities for future work.

Figure 64 gives an overview of the prototyping process, which started with some fast paper models created to determine a suitable size for the building elements and grid. The 30x30cm grid was added to a designated whiteboard by placing round stickers. By interacting with the paper models, the need for a legend on the board was discovered and the need for open space around the grid. After the shapes and number of the building elements needed for the final user test were decided, an illustrator file was prepared for laser cutting. The laser cut elements were painted, and magnets were added, resulting in a large set of building elements ready for physicalising data.

Figure 64. *Prototyping*

7.1 Evaluation

After extensive research, it was determined that data physicalisation could stimulate creativity and lead to better insights from quantitative data. It encourages reflection and creates deepened understanding through active interaction with data. This assumption was tested in the final user test, using the developed prototype, after which the concept could be evaluated on the drafted requirements.

7.1.1 Final user test

The final user test took place in the form of a creative session as this format closely simulates the situation at Ford. The final user test combines elements from both the first and second study described in Chapter 5 and focuses on using the physicalisation tool and reflection cards. Testing the instruction method was left out of the study as most of the steps were performed by myself, as the session facilitator, to provide controlled circumstances. This allowed for more elaborate testing of the building and reflection steps within a decent time frame. Using a tangible prototype in a physical user test resembled the final concept more closely than an online prototype and was expected to lead to richer insights.

Set up

Goal
The goal of the final user test, is to determine if the concept leads to the collection of better insights compared to the current data analysis process at Ford mainly using data visualisation and find opportunities for improvement of the concept. As described in the design goal in Chapter 4.2, better insights are defined as insights that be used throughout the full design process, reveal interesting opportunities to visualise on a larger scale and can be combined with qualitative data.

Method
The final user test was performed under two conditions. The first group extracted insights from a selected data set using the toolkit, and the second group, a validation group, generated insights from the same data set after only being presented data visualisations. These insights were compared to one another afterwards. Both groups went through multiple phases, starting with an introduction given by me as the session facilitator, then some assignments and discussion and an evaluation interview. The session facilitator guided participants through the study but did not actively participate in the assignments. The study was video and audio recorded to allow for evaluation through observation as well. Therefore, participants were asked to discuss and think out loud as much as possible and signed a consent form (see Appendix 17B).

Procedure
The study was divided into two individual creative sessions, performed one after another, without interaction between groups (Figure 65). The first group was asked to build out the data they received using the prototype and start formulating some first insights about this data, found due to physicalising it. During this task as physicalisation keeper was appointed in order to keep the physicalisation organised and useful.

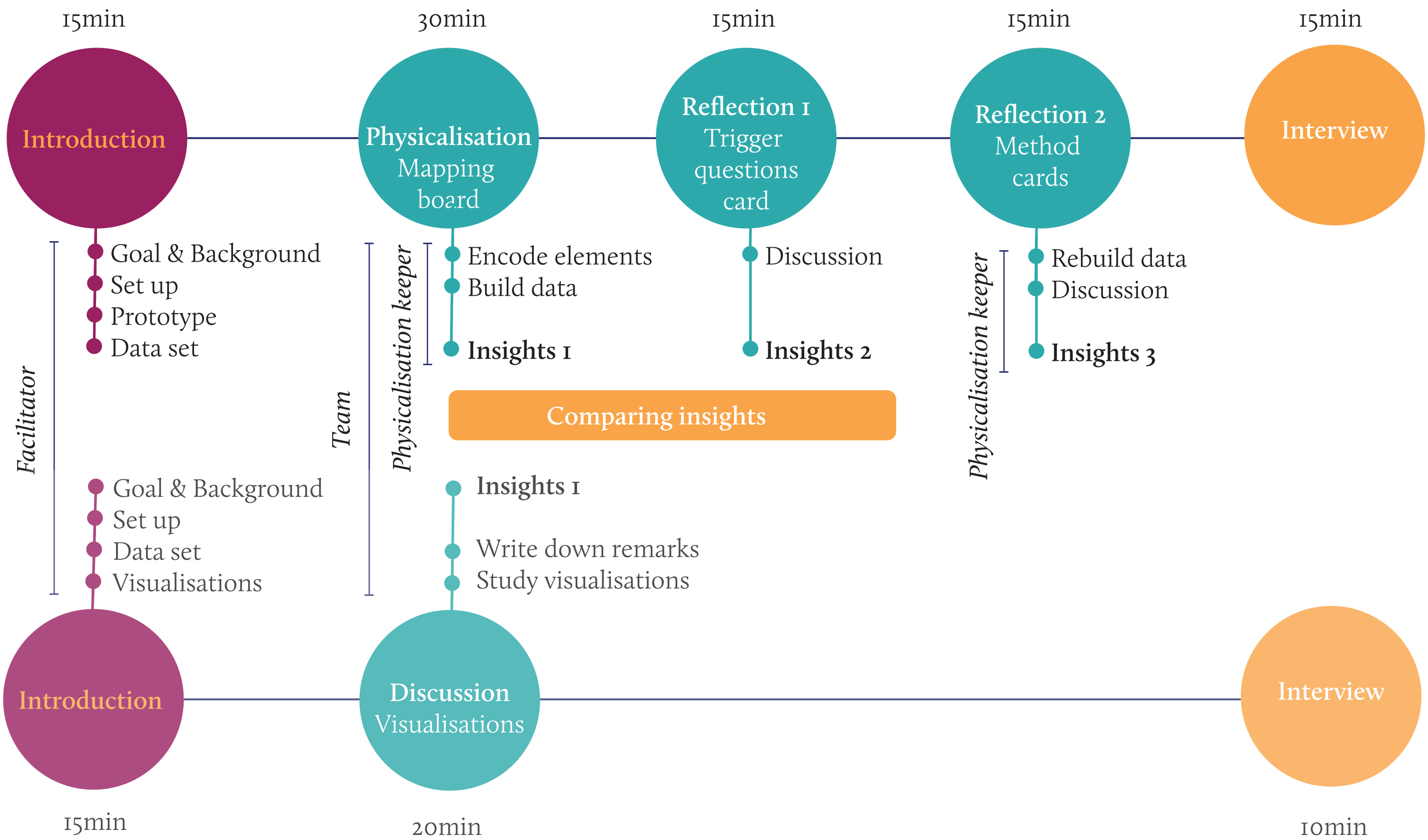


Figure 65. *Procedure Final user test*

The building assignment was followed by reflection round 1, in which the question cards were used. Participants were asked to again formulate insights after reflecting, which could either add to the first set of insights or provide more depth. In the last assignments, participants were asked to reflect on the data by interacting with it on the mapping board, using a method card and adding insights to the list afterwards. Group 2 was presented with four data visualisations selected from the same dataset and asked to formulate insights by looking at these visualisations and discussing them among the team.

Participants
Each group consisted of three participants, with the primary condition being that these participants are non-data experts. Ranging experience with data was allowed, but the participants could not have data science backgrounds or be working in the field of data. A number of three participants per group was deemed the ideal number for this study. It allowed for active discussion while keeping the building phase effective without splitting the group into smaller teams. Each group had of one or two designers and participants outside the design field to resemble the creative sessions at Ford.

Creative session

A complete list of the materials used and presented during this user test can be found in Appendix 17A.

Goal for participants
The goal both groups were presented with was to find as many valuable insights from the given data set as possible. Valuable insights were defined as insights showing interesting design opportunities, exploring further, or visualising on a larger scale.

Data set
The open dataset used was a small selection of data attributes from a much larger dataset about charging electric vehicles. The chosen attributes are dates and times of charging transactions, how long vehicles stay connected to a charging point, how long they are being charged for, and the total amount of energy transmitted during this time.

Additional material
After the prototype was introduced and explained to the first group; the data sets were distributed among the team, and forms to write down insights and hypotheses were provided. The reflection cards were given to this group with the accompanying exercise. Group 2 first received the data set, after which they were presented with the data visualisation one by one. Insight forms were provided as well.

Results
The study was evaluated through observation, an evaluation interview and by comparing insights found by the two test groups. Observations and complimentary quotes can be found in Appendix 17C, as well as the interview questions. Relevant observations and conclusions from the interview were combined and resulted in a list of optimisations that can be made to the final concept, which can be found in Chapter 7.2.1. The analysis of insights shows that data physicalisation might result in a lower amount of insights than data visualisation, but these insights are of higher quality. Figure 66 summarises the performed analysis, including the conclusion. Lastly, a full list of insights can be found in Appendix 17D.

FORMATION OF INSIGHTS

How insights were drafted over the course of the session

	Part 1 - Data physicalisation	Part 2 - Data visualisation
Insight	*Little correlation between charging time and total energy.* - Round 1 *Lack of correlation between charging time and total energy might be caused by less available energy during peak hours.* - Round 2 *The amount of total energy should be more predictable as it would be useful for users to know that if they connect their car for x hours, it gets x amount of total energy during that time.* - Round 3	*To accommodate travellers, more charging stations could be placed along highways.* - Visual 1 *Quite a lot of charging during the day, maybe charging stations are occupied and people are forced to share stations so charge after another user is done.* - Visual 1
Description	In the session conducted with group 1, a clear build up of insights was measurable. The insights found in round 1 (during building) were solely observational. In round 2, reflection after building using the reflection cards, the team built upon these observational insights by adding possible explanations extracted from looking at the data in more detail. In round 3 while using a method card to reflect, possible improvements or solutions were drafted for insights found in previous rounds.	After understanding a presented data visualisation, the team of group 2 immediately started discussing possible user behaviour to explain the graph and solutions to accommodate accompanying behaviour. Insights gained from different data visualisation were not necessarily related to one another or built upon.

FORMULATION OF INSIGHTS

How insights are presented

Insight	*There is not a lot of charging started during the night (00.00-06.00), however, this does not seem to be safety related as a lot of cars are charged overnight that start charging in the evening. The lack of charging started during the night is probably caused because people do not leave their house during the night, however, people who are awake after 00.00, for example to walk their dog, could be incentivised to start charging during the night.* Round 2	*Does more driving means more charging?* - Visual 1 *Outlying long charging times might be explained by having something in the car on while charging, that drains the battery.* - Visual 3
Description	Insights start from a clear observation in the data physicalisation and are stated as facts. These are then explained by relating this statement to other physicalised variables, previously obtained knowledge or experience.	Many insights are either formulated as questions or assumptions, which becomes visible from the regular use of the word 'might' to draft explanations.

TOPICS OF INSIGHTS

Insight	*Create a normal distribution graph as part of preparation for each data field, in order to find more suitable categories for encoding building elements (confidence retrieval).* - Round 2 *As there is a lot of overcharging happening (cars being connected longer than the time they are actually charging for), it can be assumed that users charge their car before the battery is actually empty. They could be encouraged to only charge when their battery is almost empty, instead of trying to keep it full all the time.* - Round 3	*Uber drivers with electric cars could charge at night to increase charging events during the night.*- Visual 2 *The dip in efficiency could possibly be a very old battery.*- Visual 4
Description	Although discussions during the physicalisation and reflection exercises included multiple topics, the insights written down on paper are mostly focused on optimising the physicalisation itself in order to gain more accurate insights and on the mapped variables.	Insights written down by group 2 included many different topics, ranging from possible solutions and car components to user behaviour. However, insights regarding (possible) target groups of Ford was relatively much higher than in group 1.

OVERALL NUMBER AND QUALITY OF INSIGHTS

Part 1 - Data physicalisation	Part 2 - Data visualisation
In comparison to part 2 of the test, less insights were found. However, these insights are determined to possibly be higher in quality as they provide information that can be implemented into the design process immediately and are based on facts revealed by the full data physicalisation.	During this session a high amount of insights were found, divided over the four presented data visualisations. However, these insights are determined to possibly be of less quality than insights found in part 1 of the study, as they lack connection to all visualised variables and need to be researched in more detail before they can be used in the design process.

Figure 66. *Conclusions Final user test*

Discussion
The study indicates that the higher value of insights generated as a result of data physicalisation is caused by the fact that data physicalisation results in a much better understanding of the data set across the team, eliminating discussion about the data set itself and leaving more room to find insights. Physicalising the data set revealed connections between all variables, whereas visualisations only show connections between two variables at the time. This resulted in more robust insights that could be implemented into the design process immediately. However, additional studies are needed to validate the increased effect of data physicalisation on creativity compared to data visualisation.
Conclusions from study 1, see Figure 51, that relate to the insights found in the final user test include communication during building, data immersion, finding insights through patterns and time investments. Similar to study 1, participants struggled to communicate during building as this exercise required much concentration. However, we saw that this became easier over time, and reflection after the building was still fruitful. The final user test showed that the toolkit is indeed useful in an earlier stage of the data analysis process, immersing users in the data and revealing insights through the physicalisation of patterns. Lastly, the valuable insights found during the final user test after physicalising for 30 minutes are assumed to alleviate doubts concerning the time investments being worth it that were stated in study 1. Study 2 showed that the tested method 'Alternative scenario' would be most suitable for focused data sets. This can be confirmed based on the final user test, although the generated insights are not necessarily radical or future-orientated.

7.1.2 Requirement check

Figure 67 shows an overview of drafted requirements, including an indication if these requirements are met (checkmark) or need further study (question mark). The final user test proved that most requirements were met. However, as the toolkit has not been studied in the context of Ford, it is still unclear how the outcomes could be combined with qualitative data (requirement 3). Even though the found insights are determined to be valuable and expected to offer a starting point for the addition of qualitative data, this would require further study. Requirement 9 has not been tested during the final user test as only the method 'alternative scenarios' was used.

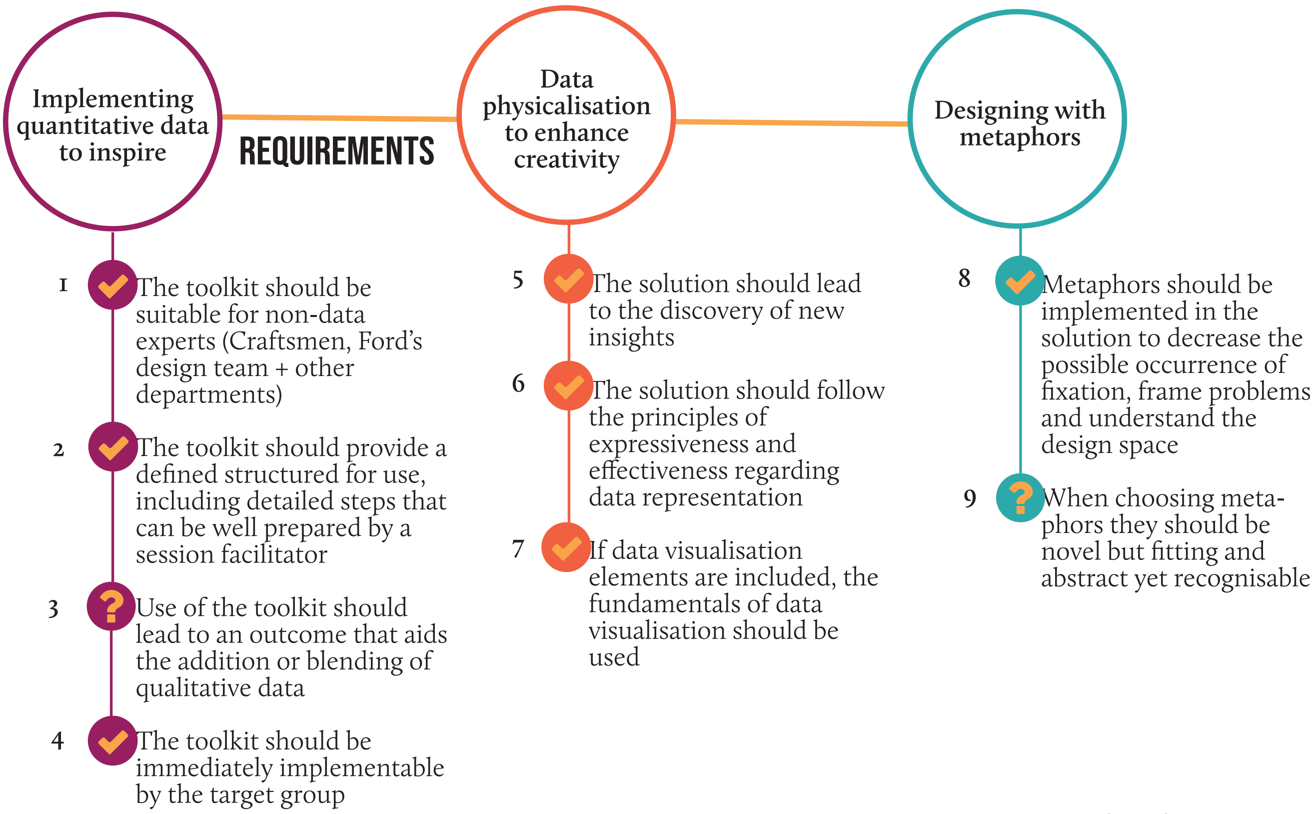


Figure 67. *Evaluated requirements*

7.2 Recommendations

This subsection contains the optimisations that can be made to the concept drafted as a result of the final user test, a vision for the future concept and listed limitations and opportunities for future work.

7.2.1 Optimisation concept

Figure 68 shows an overview of possible optimisations for each toolkit component, including accompanying quotes, collected during the final user test.

MAPPING BOARD OPTIMISATIONS

Board size
Add more horizontal space to the board, to allow more room for participants to build next to each other and have a neater looking physicalisation.

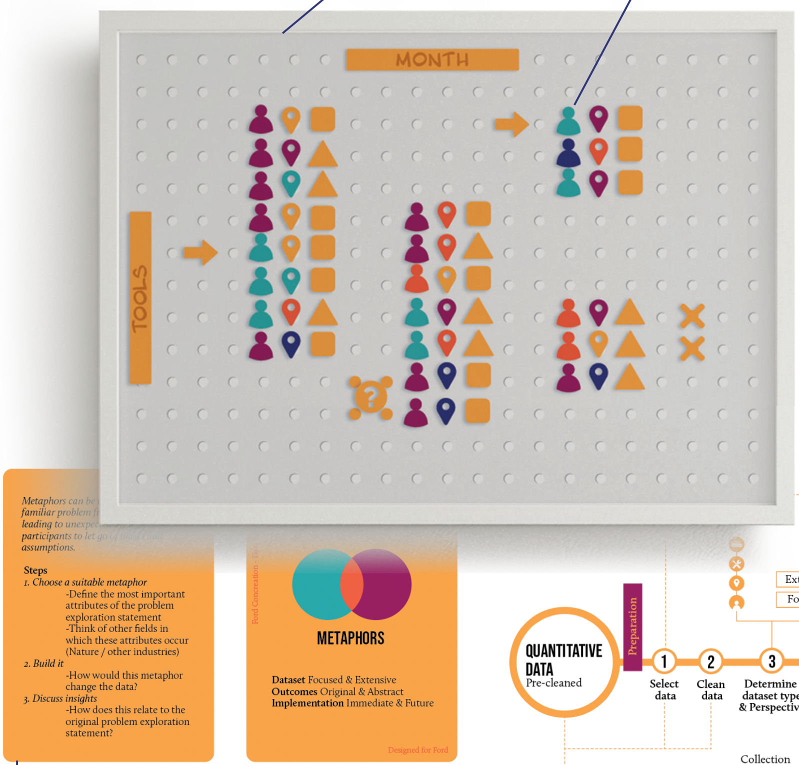
Building elements
Have building elements on display, close to the mapping board so they can be selected and placed easily. Include as many project specific elements as possible, rather than abstract elements.

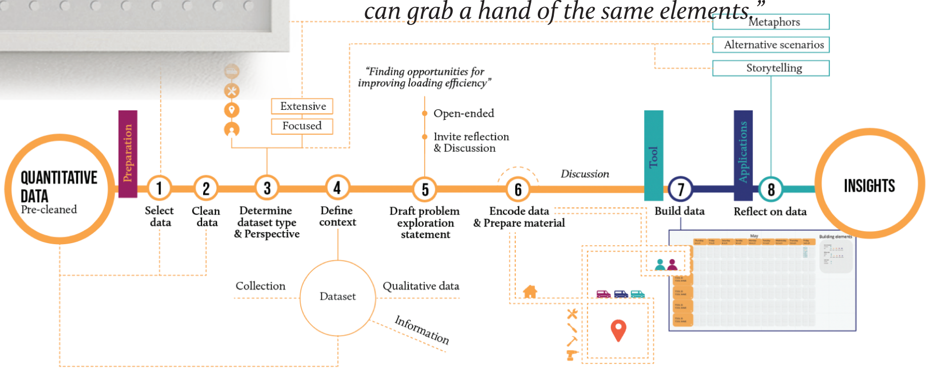
“Turning around and picking the elements up is annoying. Maybe I would even like something like a painter’s palette so I can pick and choose more easily.”

“The total energy elements are easiest to read, as you can immediately recognise them.”

Data set presentation
Make the dataset easy to read and handle, by ordering the dataset in a way which allows for easy building, for example by ordering columns.

“So you can see, okay, the first five are a certain colour. It makes it faster. We are all building first vertically and then horizontally. Because then you can grab a hand of the same elements.”





Reflection cards
The trigger questions are useful to stimulate reflection, however, as it was unclear in which order to answer them it would be better to differentiate between the main questions and subquestions rather than trigger questions. The subquestions do not need to be numbered as the order in they are answered is irrelevant.

“I think I would like the term subquestions. Then it would be more clear that they are part of the main question. So you have all these steps that lead to the main answer.”

CREATIVE SESSION OPTIMISATIONS

Data encoding categorisation
To run the session more smoothly, include a step in the preparation process creating the most optimal categorisation for data encoding.

“The extremes have a lot of data. So we decided that we want to have a confidence interval, to see where the most data falls so that you can make a better categorization of this.”

Timing the session
Give participants enough time for building data without forcing reflection or discussion yet, followed by a short break to let the physicalisation sink in before moving on to the next reflection steps.

“If you're doing this in a session, after you build you need some time to let it sink in. And then you can discuss after having coffee or something.”

Recording insights
Let the sessions facilitator write down all relevant insights on a white board or big screen visible for all members of the design team.

“Also while writing down, you can write pretty fast to keep up, but then you cannot join a conversation. So it will be better if someone separately does this.”

“With an extra board, you can see what you've done during each round. You can build on that, because now I forgot what was in the first round. So maybe we miss a lot of insights here.”

Figure 68. *Optimisations concept*

7.2.2 Future concept

Figure 69 shows an impression of what a future iteration of the concept could look like. This future concept consists of the same concept and elements, an instruction, a mapping board and reflection cards. However, the mapping board and accompanying building elements would be replaced by electronic versions. A magnetic smart screen allows for displaying different backgrounds like maps, grids or visualisations to physicalise upon. By using electronic magnets as building elements, interactions like changing colours effortlessly or giving special effects to specific elements can be added. Combining a smart board and electronic building elements would also give participants the chance to recreate original physicalisations after interacting with them. The board could be kept portable or enlarged to cover a whole wall to increase the impact and building space.

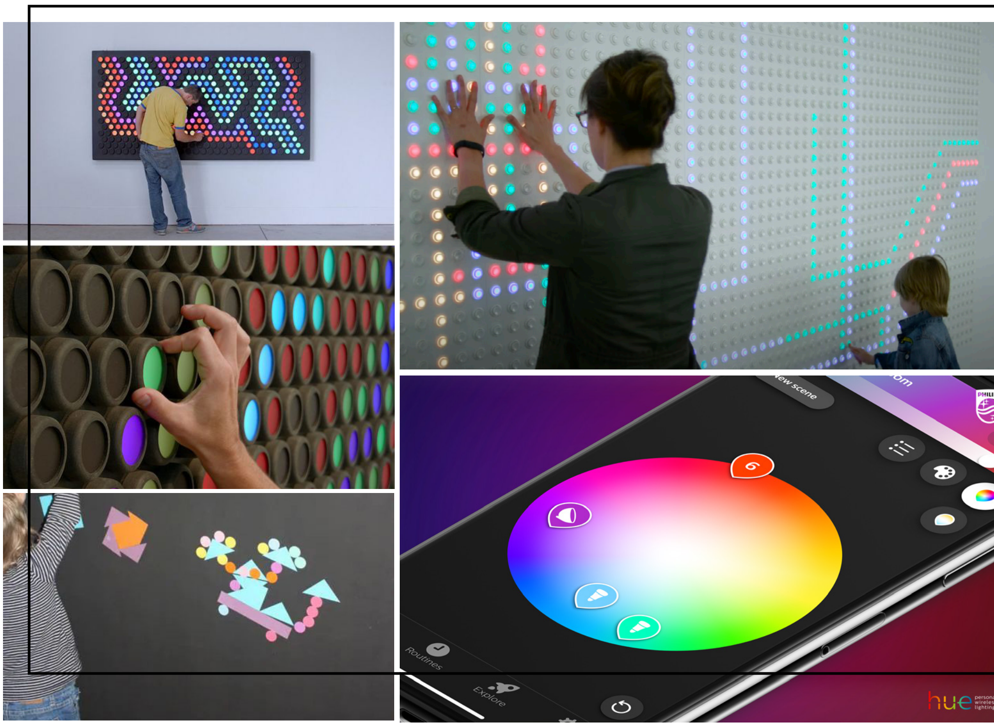


Figure 69. *Impression of future concept ideas*

7.2.3 Limitations & Future work

Concept testing
Even though the final user test resulted in many valuable insights and optimisations to the concept and validates data physicalisation, the study should be repeated more than once to gain significant results. As some of the found results might be caused by the personal profiles of the participants, it would be valuable to include teams with different compositions in terms of backgrounds and characters. Additionally, the concept should be tested within the context of Ford in order to determine the value of the found insights and its usability when participants have existing knowledge of the data set that will be physicalised. Lastly, the concept and an earlier iteration of the concept have been tested with two different datasets, but to optimise the building elements and structure of the mapping board, physicalisation of other types of datasets should be performed.

Development methodology
Although the toolkit consists of three elements, the instruction, the tool and the reflection cards, the focus of this project has mainly been on the development of the latter two. To ensure usability and understanding of the toolkit for users with no previous knowledge of the project, the instruction element of the toolkit should be developed into a complete methodology. Transforming the process steps from the instruction to a methodology would mean including full explanations of each step, adding a detailed manual for the session facilitator and providing all accompanying material and the opportunity to expand the toolkit when needed. This report could offer a base for developing a data physicalisation methodology and future study into the field of data physicalisation in practice or in relation to creativity and other areas.

Effect on the entire data analysis process
After developing a data physicalisation methodology that includes the toolkit, the effect on the full data analysis process can be studied. This would consist of determining the most effective place in the data analysis process and how insights found by using this methodology would relate to the next steps in the data analysis process.

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Development of the Ford Concreate by Tiara Spalburg | Delft University of Technology

APPENDIX

DESIGN FOR our future

Appendix 0 | Project brief

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Spalburg 4704

initials: T. N. P given name: Tiara

student number: 4361385

street & no.:

zipcode & city:

country:

phone:

email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD / DfI / SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: Honours Programme Master

specialisation / annotation: Medisign / Tech. in Sustainable Design / Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Milene Guerreiro Gonçalves dept. / section: DOS/MOD

** mentor: Senthil Chandrasegaran dept. / section: DOS/MOD

2nd mentor: Nicole Eikelenberg

organisation: Ford

city: Aachen country: Germany

comments (optional): Dr. Gonçalves is experienced with the client and project and will focus on her expertise area of creativity and the design process, where as Dr. Chandrasegaran will mostly be consulted as a data visualisation expert.

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Milene Guerreiro Gonçalves date 09 - 02 - 2021 signature Digitally signed by Milene Goncalves Date: 2021.02.09 11:14:14 +01'00'

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 30 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name J. J, de Bruin date 11 - 02 - 2021 signature J. J. de Bruin, SPA Digitally signed by J. J. de Bruin, SPA Date: 2021.02.11 14:33:12 +01'00'

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED / NOT APPROVED

Procedure: ★ APPROVED / NOT APPROVED

- remark: title does not indicate what the project is about

comments

name Monique von Morgen date 02 - 03 - 2021 signature

TU Delft

Data Play with Ford

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 08 - 02 - 2021 | 20 - 07 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

With recent advances in data based technologies like AI, machine learning and IoT, designing with data will soon be impossible to avoid. Although most multinational companies are aware of this fact and are already using data to optimise their processes, many still haven't reached the full potential of combining data and design. The advantages of data-enabled design are highly noticeable with companies that tightly interweave data and design capabilities to solve business problems experiencing a 10% to 30% performance improvement (Chhabra, A., Williams, S., 2019)1. An important characteristic of data-enabled design is that data is not only used to inform the design process, but also to inspire the design process (Bogers, S., Van Kollenburg, J., 2020)2. To achieve this, having designers and data scientists work separately on their specific functions isn't enough. Instead, stimulating both parties to work in symbiosis results in the most benefits for companies.
Ford recognised this need and started working on implementing a more data-driven approach throughout the whole enterprise in 2014. In 2015 the Ford Global Data Insights and Analytics (GDIA) unit was formed in order to centralise the use of data in the company, in order to allow different teams to share knowledge and make the most out of available data science expertise throughout all departments (Henschen, D., 2017)3.
Ford's data consists of big and thick data and offers the opportunity to be combined. Big data is the term used for big, complex data sets sourced from large samples that relies on machine learning to reveal patterns or insights. This type of data is based on scale and less suitable for zooming in on details or gaining understanding of why certain patterns and insights exist (Bornakke, T., & Due, B. L., 2018)4. Some sources of Ford's big data are onboard computers from its vehicles, customer demographics and online comments from customers on blogs, chatrooms and auto sites (Noria corporation, 2019). Thick data is qualitative information generated by studying human behaviour, collected from a small sample. Thick data relies on human learning, revealing connections between data, giving social context and understanding into patterns revealed by big data, but loses scale (Bornakke, T., & Due, B. L., 2018)4. At Ford, this type of data is gathered by performing one-on-one interviews with clients, engaging in clinics or focus groups, questionnaires and spending time with customers in general. Just like data and design, big and thick data should be used to supplement each other, using thick data to evaluate found insights from big data.
With its data growing in quantity and new data analysis tools and technologies arising, Ford is looking for new ways to integrate its data in order to keep improving continuous product innovation. The team playing an important role in this process, the target group of this project, is the multi-disciplinary design team called 'Innovation management for smart vehicle concepts' at Ford's Research and Innovation Center Aachen. This team consists of experts from different backgrounds and is using the Design Thinking methodology to shift the design focus from vehicle to users, often working together with the GDIA. The data science department delivers relevant data and information as raw data that is then developed in Matlab by the design team or using data visualisation tools like Qlikview and Tableau. These data visualisations are then used to evaluate and inform the design process. However, in this current format data may not inspire the design process yet, therefore not reaping the full benefits of using data-enabled design. This project will look into how the design team can go from using data visualisation to inform and evaluate their design to using data as 'creative material', data in a format that triggers creativity during the design process.

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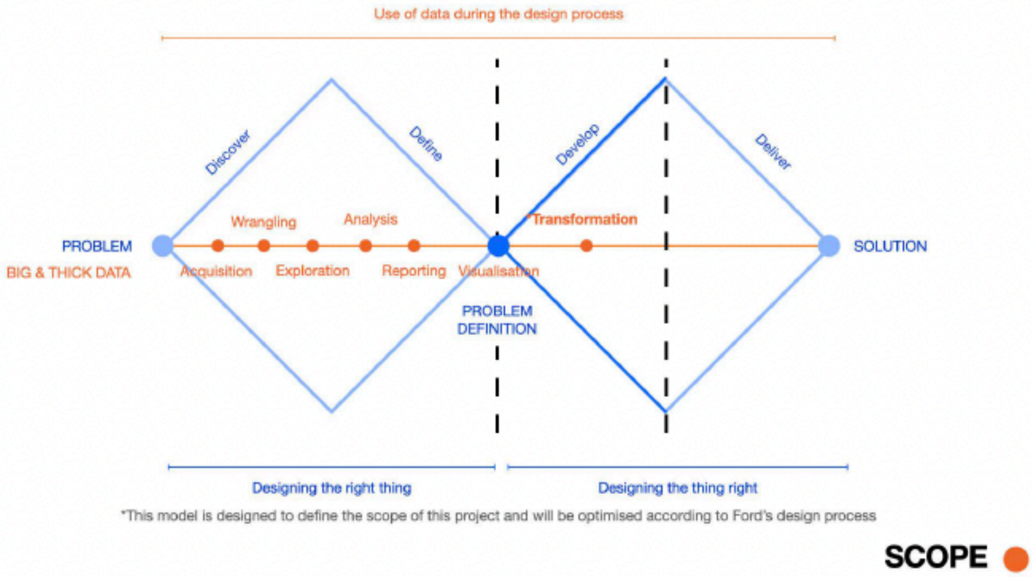

image / figure 1: Scope within the design process

References

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2. van Kollenburg, J., & Bogers, S. J. A. (2019). Data-enabled design : a situated design approach that uses data as creative material when designing for intelligent ecosystems. Technische Universiteit Eindhoven

3. Wires, R. (2006, December 11). Market research drives product development at Ford. Retrieved February 09, 2021, from https://www.reliableplant.com/Read/3802/market-research-drives-product-development-at-ford

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5. Amabile, T. (2012). *Componential theory of creativity*. Boston: Harvard Business School

image / figure 2: Reference list

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

An overload of data is currently being gathered at Ford, consisting of both big and thick data. Ford is utilising this data in order to make data-driven decisions within multiple parts of the company. However, the use of data has not reached its full potential within the product development department yet, with the next step being the exploration of ways to trigger creativity during the design process. Currently, all data specific to the project that the team is working on at that moment is being analysed and interpreted, figuring out how and if to use the data along the way. The raw data is developed by the team itself or visualised using dashboards. These visualisations are the end results of the data analysis process and are used to steer the design process, analyse results and make informed decisions. However, they could fail to trigger creativity, as these dashboards filled colourful visualisations may not be enough to inspire the design process. This is possibly caused by the fact that these visualisations were designed to inform, not to trigger creativity, resulting in an excessive amount of data which makes it hard to filter out its relevance and a format that lacks physical interactivity. These assumptions and underlying issues will be some of the first research topics of the project.

Scope

Figure 1 illustrates the scope of this project. The figure shows that the integration of data plays an important role during the full design thinking process used by the design team, with most data analysis stages (acquisition, wrangling, analysis etc.) taking place during the 'Discover' and 'Define' phase of the design thinking process. Creativity needs to be triggered during the 'Develop' phase, where ideation takes place. What is missing to achieve this is a data analysis stage that transforms data visualisations into a format that does trigger creativity. This stage will be called 'data transformation' and will take place during the 'Develop' phase of the design thinking process. This phase which will therefore be the scope of this project (figure 1 between the black dotted lines). A global understanding of all other design thinking phases and data analysis stages will have to be used, but will not be the main focus.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Designing a Data Transformation methodology that transforms data into a format that triggers creativity in the multi-disciplinary design team within Ford, during the ideation phase of the design thinking process. The two main areas that will be researched in order to achieve this goal are the fundamentals of data and data visualisation and creativity during the design process.

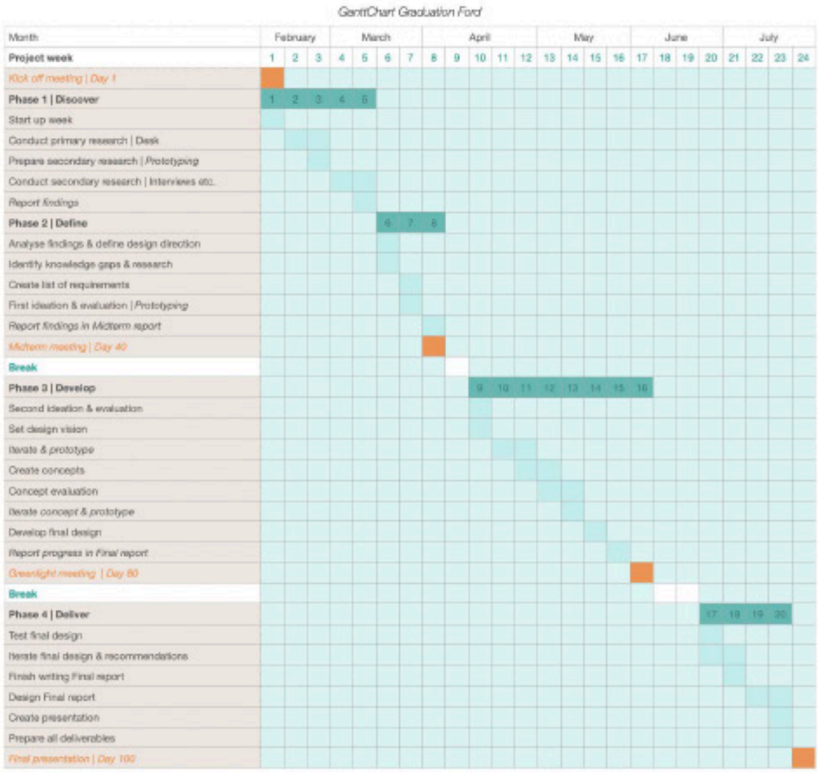
The expected solution is a methodology that transforms existing information graphics into material that triggers creativity during ideation. Important to keep in mind is that the methodology will be used by a design team that is already quite familiar with tapping into their creativity. In order to guarantee a solution that still triggers this target group, the main pillars of creativity are identified: expertise, creative-thinking skills and motivation (Amabile, T., 1998). These will be researched more in depth in a later stage but can already be used to shape the expected outcome. The solution should harbour the pillars of creativity by facilitating the use of the design team's existing expertise and stimulating new perspectives and motivation. Motivation can be enhanced by giving the user the opportunity to have an enjoyable experience of the solution, feel challenged or add a sense of novelty.

The exact form of the methodology (eg. digital, physical, 3dimensional) will be defined in a later stage depending on performed research. A physical example of the specific outcome could be a 'data play room', with building blocks that represent visual objects like lines and points which can be used to recreate and play with graphs in a physical environment. However, with the current work situation in mind and working remotely being the new standard, a digital based example could be a tool designed to abstract data, which allows the target group to design and look at data from a different perspective.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 8 - 2 - 2021 20 - 7 - 2021 end date



As the Design thinking method is crucial during the project, I would like to structure my own process following the same phases, as indicated in the chart. The main activities are noted for each phase, however, more activities can be added or changed over the course of the project.
Important to note is that a lot of emphasis will be put on the final report regarding writing and visualizing. Therefore, each phase will be concluded with reporting findings or progress, including visualisations, in what will eventually be the final report.
Each phase will also involve a prototyping activity, inspired by the Research through Design methodology. Both research and prototyping are used to gain a better understanding of the context and behaviour of the target group within the process. Prototyping can vary from early idea prototyping to be used during interviews, to exploratory prototyping and finally creating a prototype that comes as close to the final design as possible.

A third methodology will be taken into account: Problem framing through metaphors. However, this methodology will not be used as a phase in the process, but rather as a technique to keep in mind during the full process. With data and creativity being quite abstract, complex fields to understand, metaphors can help clarify and frame the problem that will be solved during the project. At the same time metaphors are already being used to create data visualisations. Being aware of this and understanding where the used metaphors come from, helps creating new perspectives and eventually a new solution.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The short description of this project immediately sparked my interest as it touched upon multiple topics I felt connected to: creativity, visualisation and the design thinking process. These fields happened to be some of the expertise areas of the contact person of this assignment, dr. Goncalves, which increased my excitement. After diving deeper into the assignment I realised it offered the opportunity to develop my understanding and use of data to a more advanced level, of which I started to recognise the growing importance during previous projects executed in the pandemic.

This project offers the perfect combination of new challenges and previously earned skills. The main competences I will be developing are the understanding of data and creating visualisations. As data science is a huge, complex domain, the focus will be on the fundamentals of data science and data visualisation, which will be valuable in any future project as design and data become more interconnected than ever. Gaining these competences simultaneously offer a strong base to develop a broader skill set within data design.

As a designer coming from a multicultural background, with an interest in people and communication, I think I will be able to deliver most value by being the bridge between data scientists and the design team. During the last year I have been working as a concept designer for an event agency, mostly creating proposals for large, corporate clients using the design thinking process. My extensive experience with this approach will be an advantage when designing a solution to be used during a specific phase within this process. Hosting workshops both on- and offline and co-collaborating with clients could not only be valuable during the research phase, but also inspire the final result.

Personal ambitions

I will be striving to create an exciting, visually strong and proven concept, which will be challenged by the twenty-week time frame as the field of data is large and complex to understand. It will therefore be important to keep to strict personal deadlines and make sure not to drown in the sea of information by making the most out of contact moments with chair, mentor and experts.

This connects well to my personal goal of improved reporting and prototyping. In terms of reporting, I will focus on accompanying strong visualisations with well written, concise text in order to create a final report that excites readers and can be shared with other interested parties. As most of the testing and research will be performed online, I think it's important to create prototypes that come as close to the desired end result as possible.

Working remotely shouldn't be seen as a burden as it also offers the opportunity to use new digital tools. Therefore, I would like to focus on taking a creative approach to online meetings and include my recently acquired Ipad to help facilitate this. The iPad will also be used to improve visualisations and use visual thinking strategies during meetings.

Lastly, working for Ford and with the 'Ford graduation community' gives me the chance to work within an international environment which is valuable when aiming for an international career.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.