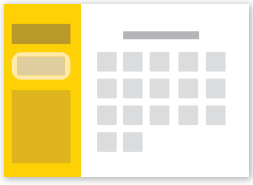
A mental model approach to design

The development of a framework on design for behavioural change

TUDelft | Graduation thesis | Ward van Hoeven



A mental model approach to design

The development of a new framework on design for behavioural change

Master thesis
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Executive summary

In a world with an ever-increasing overflow of information, what are we supposed to believe? Even credible sources are distrusted or no attention is paid to their communications at all. The RIVM (National Institute for Public Health and the Environment) is looking for new ways to communicate their findings in such a way that people do not only believe it, but also that they take it into account in their behaviour.

A new approach is proposed to find new compelling ways to communicate through design. In doing so, a new way to design for behavioural change in general is composed. The idea behind this approach is the following: People understand their world in a certain way. They have models in their mind about how all kinds of phenomena in this world work. These mental models help people to interpret and predict, which is fundamental to making choices on how to act. Therefore, if we could influence those mental models, we get a new handle on guiding behaviour. This project has explored exactly that handle as it investigates the questions:

How can we influence people's mental models through design? And how can those mental models influence behaviour optimally?

Many examples of mental models and designs that embody them were analysed thoroughly. This resulted in a wide range of types and dimensions of mental models and designs, which were collected in a framework. The framework offers strategies to compose, evaluate and refine mental models and designs that embody them.

The framework, translated into a toolkit format, was tested with students. Although still lacking validation, the framework seems to be a good basis for further steps:

• The framework and the initial toolkit as drafted in this project are a good start for developing a more usable toolkit. The initial test results suggest that the many handles that the framework offers for designing mental models and their embodiments are mostly useful.

• The framework offers future research a comprehensive palette for analysing mental models and designs that carry them.

The mental model approach as explored in this project is relevant not only for the design of specialized behavioural interventions, but also for design in general. It uncovers, and provides handles on, an element of design that is widely applicable since many designs and communications explain (or could explain) a mental model.

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0 Introduction

The notion of mental models was first postulated by Kenneth Craik (1943). He proposed that people carry "small scale models" of how the world works in their mind. People do so to understand the world in which they have to make decisions (Moore & Golledge, 1976). Because without an understanding, how would we know how to act?

The idea behind this graduation project is simple: If we could change people's mental models, we change the lens through which they interpret the world. This has a great potential to change their behaviour. Because certainly, some mental models lead to more desirable behaviour than others. While people interact with the world, they continually form mental models about things in it. Design, in the broadest sense, is a large supplier of the things people interact with, thus offers a way to influence mental models.

In this chapter we'll have a look at some examples of mental models and at the scope of this project.

0.1 Some mental models in the world

Let's start with some examples of mental models evoked by the designed world. Imagine driving towards a red traffic light. Some people may become agitated or even run a red light. However, there is a potential mental model that could mitigate this reaction: Most traffic lights in the Netherlands have a trigger in the road surface that senses whether a car is approaching. This data is input for scheduling the most efficient traffic flow. Knowing this (having a mental model that explains how it works) should make the system seem efficient and fair: You are not waiting for nothing. This should therefore create more acceptance and less negative emotions –and thus running less red lights.

The visible triggers in the road are the designed elements (figure 1) which evoke this mental model. As this example illustrates, the designed world influences people's mental models, though not always intentionally. This project uncovers that influence so that designers can be aware of it and it is not left to chance (and they can even use it to change behaviour).

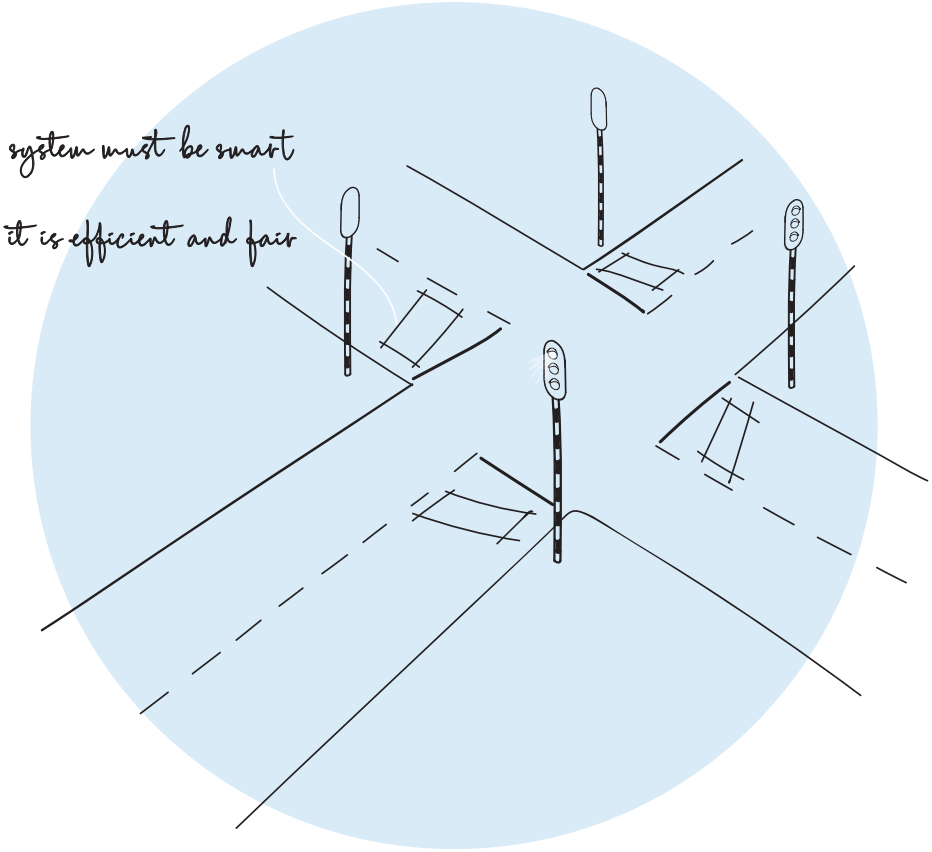

Figure 1 Street light sensor

An example of an intentionally mental model–inducing intervention aims to stimulate voting during the Dutch elections. Many people are demotivated to vote because they feel like one vote does not make any difference. In 2017 the government started a campaign to battle this through a TV advertisement (figure 2), in which each vote is represented as a balloon attached to a heavy weight ("Elke stem telt", 2019). It states:

> Think of your vote as a balloon. Alone, it doesn't seem to have much influence. But whether you are the first, thousandth or last one, thanks in part to you something starts moving. [Text from advertisement, translated]

2 Research question

At the moment there already are sources that intentionally communicate mental models. For example sites like the WWF ("How does plastic end up in the ocean?", 2019) and National Geographic ("What Happens to the Plastic We Throw Out", 2019) document how environmental effects work. The problem here is that this information is only accessed by people who already foster a positive attitude towards the environment and actively seek more information. Furthermore, even if the target group would see the information, they would likely not be very interested in such explicit sources which are clearly preaching

Figure 2 Balloon voting campaign

about how they should act. This supports asking the question whether design can provide an alternative by embodying* mental model communication in the world in a more natural and accessible way.

* The term embodiment stands for designs that have in them, and communicate, a certain mental model.

Research question: Is there potential for designers in changing mental models for behavioural change?

- Sub question 1: In what ways can mental models influence behaviour?
  - Guiding question: What types and dimensions of mental models exist?

- Sub question 2: In what ways can a mental model be embodied by design?
  - Guiding question: What makes an embodiment effective?

1.3 Practical relevance

The RIVM (National Institute for Public Health and the Environment) is connected as a client to this project. The RIVM conducts research into public and environmental health and has an advisory role for citizens, professionals and governments. However, their communication to citizens is not always effective. People are often not interested in the information, or they do not trust what they read ("Skepsis Congres 2017 – Risicocommunicatie", 2019). This may be due to the recent attention on fake news and an increased amount of media streams; anyone can put "information" online. Whilst perhaps more than ever, it is important that people listen and take action to create a sustainable world together.

The mental model approach may be suited for such a distrusting audience: It does not simply tell people what to believe and do, but it explains the 'why' behind it. It explains how things work, inciting people to form their own –yet inscribed by the designer– conclusions. Therefore, it should diminish the feeling of being told what to do. Furthermore, deciding on what to do through learning

about a potential mental model could be more engaging and fun than directly being told what to do. The mental model approach is also in line with the objective role of the RIVM; it works by building knowledge, not by coercing. In that way, autonomy is encouraged and reactance may be lower.

1.4 Goal of the project: A framework

The project has a research nature: It is about exploring the potential of mental models in design for behavioural change. To do so, a framework is developed. This framework offers a way of viewing the concept of mental models within design. Included in the framework are different types and dimensions of both mental models as well as designs that aim to stimulate them. It acts as a skeleton of mental models in design which can be used for further research and to create a toolkit for applying the framework. A rough version of such a toolkit translation is constructed. A more finalized version of this toolkit would be the tool for designers* to use the mental models approach to design for behavioural change. Such a finalized toolkit is the future objective of this project, making it applicable in practice. However, this step is outside of the current scope.

* Throughout this document the term designer is used to indicate the user of the toolkit. However, the toolkit is intended for anyone who aims to communicate mental models to provide people with a better understanding of how the world works, not only traditional designers.

The framework is based on many collected examples of mental models and designs. To find a place to collect them, a focus in the project was necessary. A topic was chosen that is relevant to the RIVM and promises to house interesting mental models: Plastics within the circular economy (more about this in chapter 3.1).

The original project brief (the official description of the project at the start) can be found in appendix A.

0.1 Two aspects of the framework

As reflected in the two sub research questions, the framework (this entire project, actually) consists of two parts: The first part (chapter 3) is on mental models and has a psychological nature. It is about what sorts of mental models exist and how they connect to behaviour. The second part (chapter 4) is design–related and is concerned with how a certain target mental model can be evoked in people through design.

It is good to note that the word design is meant in the broadest sense. A design can be a physical product, an app, a landscape, a service, and so on.

0.2 Disclaimer: Just a screwdriver

The approach developed in this project is not a holistic design method. It is a rather specific tool (like a screwdriver), which designers might add to their repertoire (their complete toolbox). It is suitable only in some situations and also when it is, it should be used in tandem with other methods. The mental model approach covers one new aspect of design and communication. There are other aspects which may be needed to create the desired behavioural change (for example making the behaviour easier, using a trigger, communicating the descriptive norm, and so on). However, within this project the focus is strictly on the mental model approach and exploring its potential. In that, it disregards other (already uncovered) mechanisms of design for behavioural change.

0.5 Reading guide

In chapter 1 we will have a look at what the literature has to say about mental models. Based on this, an operational definition is composed for the rest of the project.

The method is presented briefly in chapter 2 to give an overview of the steps taken in the following parts of this report.

The framework consists of two parts, of which the first is on mental models.

Chapter 3 explores what kinds of mental models exist and how they affect behaviour. It looks at how they can be evaluated and refined by designers.

The second part of the framework is concerned with how a chosen mental model can be embodied through design. In chapter 4, different strategies to embody mental models and ways to evaluate and refine those embodiments are proposed.

Next, the framework is evaluated in chapter 5, in which a small test with the framework among design students is described. For this purpose, the framework is translated into a rough version of a toolkit. Recommendations for further development of the toolkit are made here.

Finally, chapter 6 takes a step back and revisits the research questions. General recommendations and possibilities for further research are suggested.

1 Mental model definition

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What exactly is a mental model? How do different disciplines view them? And what is the operational definition for this project? Those are the questions that underly this chapter, for which answers are sought in the literature.

1.1 Mental models in the literature: Different definitions

The term mental models is used slightly differently in different scientific fields. For example, as a cognitive scientist Johnson–Laird (1980) analyses inferences such as: All A's are B and B=C, so A=C . In his research, each premise is a mental model. These types of inferences are termed logical problem–solving since they are executed in the mind, without coupling to an actual system (Moray, 1999). This coupling to a system is present in the more applied domain of human factors. Here, the context is operating a system such as a consumer product (Norman, 1986, 2013) or a highly dynamic system like an industrial plant (Doyle & Ford, 1998). Here, the mental model is about how the user thinks the system works. This is of interest in human factors because it influences usability.

However, the scopes that cognitive science as well as human factors attain are limited. The first one entails only mental models in logical problem–solving. Although the second one does include systems that are currently around and can give feedback, still the application is limited to products and industrial systems. Within this project, a broader scope is attained: One in which a mental model can be about anything, as long as it drives people's behaviour.

The Mental Models Approach to Risk Communication (MMARC; Morgan et al., 2002) is the basis for the method that the RIVM uses to measure and communicate risks (Greven et al., 2018). Within the field of risk communication, a mental model entails all beliefs about a risk. Morgan et al. state:

> "...assemble their fragmentary beliefs into a "mental model," which they will then use to reach their conclusions. This is not a model in a formal sense. It does not involve a strict mapping between things in the real world and elements in the model"

This is again a different way of seeing a mental model. It is broader than that of humans factors; it is not only about how something works but also about any other belief someone can have about the thing in question.

1.2 Mental models in non-scientific literature: A more general approach

A non–scientific community also talks about mental models (for example see

"Mental Models: The Best Way to Make Intelligent Decisions", 2019; "Mental Models: Learn How to Think Better and Gain a Mental Edge", 2019). They see them as practical ways of thinking about daily life. The premise is that each mental model is a new perspective on reality, a new way of (better) understanding it, which will lead to more effective actions in for example ones career or social life. These mental models are often general principles (e.g. reciprocity, anchoring, thinking experiments), not related to a specific problem or situation. This is an interesting notion: Certain general mental models are applicable (and thus influential) in many different domains.

"The chief enemy of good decisions is a lack of sufficient perspectives on a problem." - Alain de Botton

This community pursues having many different mental models. They state that since each mental model is another perspective on the same problem, having multiple perspectives gives a more holistic view, enriching one's understanding of it.

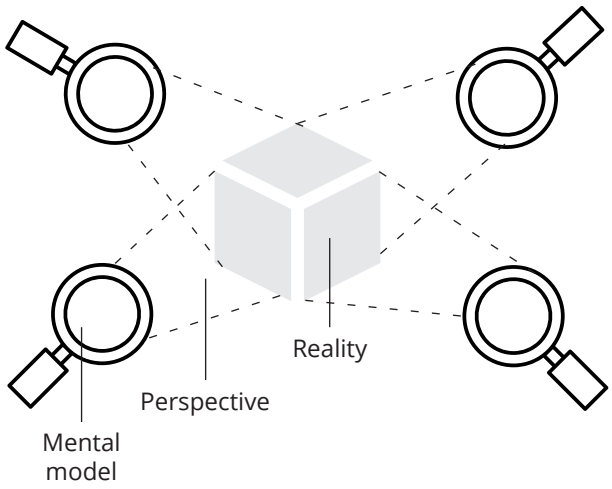

Figure 3 Mental models offering perspectives on reality

Each mental model can be seen as a lens through which someone sees another perspective of the same reality (figure 3). However, within the approach that is being developed in this project it is not about increasing the number of available perspectives. It is about evoking the right ones –those that promote the target behaviour.

1.3 Mental models in this project: A subset of beliefs (and knowledge)

As described in the literature, mental models are defined and used differently. In cognitive science and in risk communication a mental model is an assembly of all relevant beliefs. This is not the definition used within this project. This project's definition entails not all beliefs, but a subset of all beliefs and knowledge: Only the ones that describe how something works (see figure 4). This is more in line with the definition in human factors and in the non-scientific community discussed before. These mental models could change the other ("simple") beliefs. For example, knowing how global warming happens (by understanding the green-house effect) can create the belief that global warming is real.

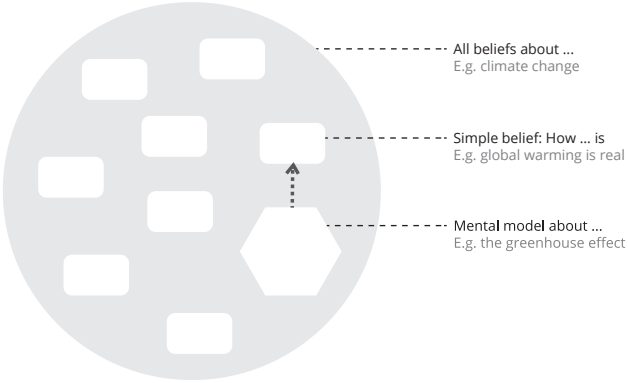

Figure 4 Mental models and simple beliefs

1.1 Beliefs versus knowledge

The distinction between beliefs and knowledge is whether it is verifyable to a reasonable degree ("Belief vs Knowledge | Scribespark", 2019). A belief is a claim which the owner feels is true. A claim about knowing something is a type of belief which is logical and backed by evidence. However regardless of it being veryfiable or not, the content of both types of claims can be the same. The research in this project is not concerned with whether a mental model can be verified. If it can, it doesn't mean that it will be accepted or be positively influential. And while some cannot be proven, they may still have a positive impact on people's behaviour. Therefore, from now on the term belief also entails knowledge.

A note for psychologists at the RIVM: According to the definition used in risk

communication, the project's definition should rather be termed a "sub-mental model" since it only communicates a subset of all beliefs about a topic -which in the MMARC is the mental model. However, the term mental model will be maintained because it fits to the definition in (human factors) design. The project's definition is elaborated on below.

.2 A chain of discourse

As mentioned, an important distinction is that between how things are (we could say simple beliefs), and how things work (dynamic beliefs). A good way to look at it is seeing a mental model as a model that can be run mentally (like an animated simulation) to depict change and predict outcomes (as formulated by Chi, 2008).

A mental model can be seen as describing a chain of discourse, containing the relationships between different elements. Someone's mental model about the green-house effect could look like this:

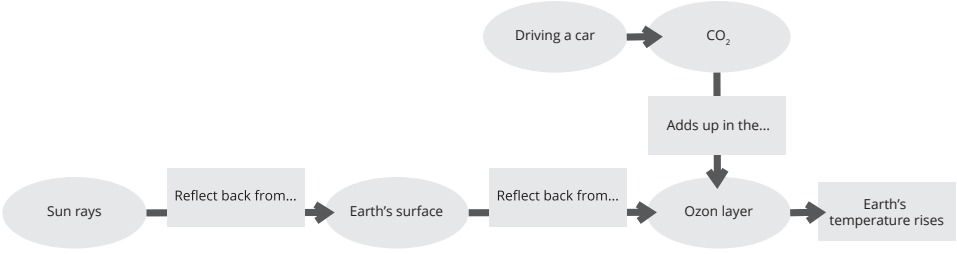

Figure 5 A possible mental model on the green-house effect

.3 Operational definition

The elements are depicted as either round or square. While working with (and writing down) many mental models, a distinction emerged: It respectively signifies an entity (an object or behaviour) or a process (a manipulation of an entity).

A mental model is a dynamic model people have about a process in reality. It entails how something works and it can be run mentally. Mental models are

used to explain and predict and it can be visualized as a chain of discourse. A mental model contains entities or processes (manipulations of entities) that interact. Mental models are a subset of all beliefs. A mental model is in the mind of people, in contrast to the phenomenon it describes which is in the world. It is a model of objective reality. Therefore, it can be wrong and/or incomplete (Jones et al., 2011) and vary interpersonally. A visual overview can be found in figure 6.

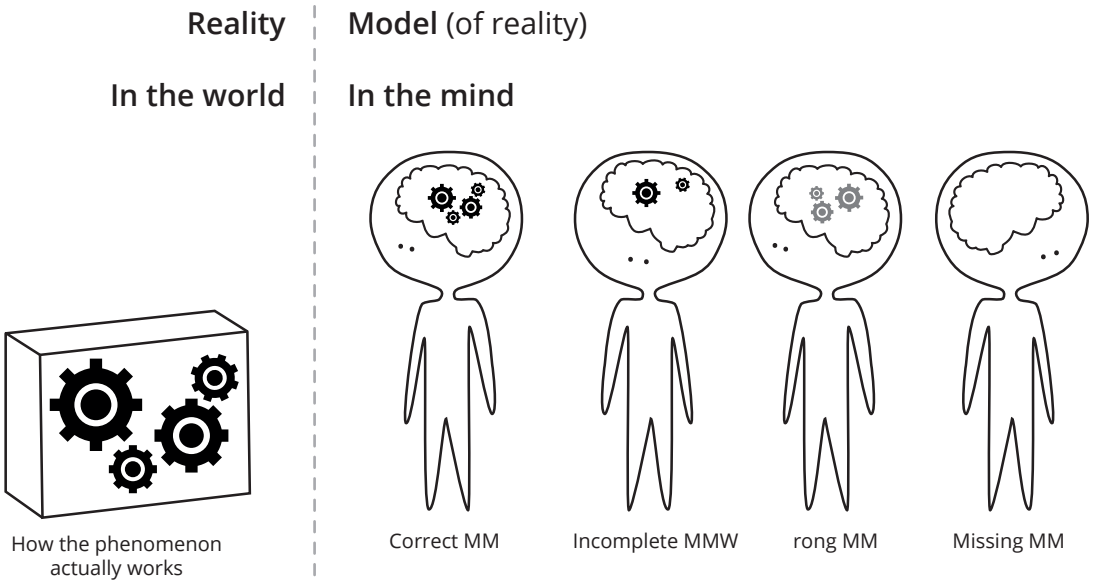

Figure 6 Phenomena versus mental models

In this chapter we've taken a look at what the literature has to say about mental models. There is not one clear existing definition which is suitable for this project. Therefore, an operational definition has been devised: They are a subset of all beliefs and they describe how something works.

In the next chapter the method for creating and testing the framework is described. After that, chapter 3 is about collecting and analysing mental models to form the mental model part of the framework.

2 Method of composing and testing the framework

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The method of composing and testing the framework is presented in this short chapter. It shows the different steps that were undertaken: From analysing the current situation, to collecting and clustering mental models and embodiments, to testing the contents of the framework.

Method

An overview of the steps taken to form the framework are displayed below. The order of these steps correspond with the order of the report.

• Collect relevant behaviours within the domain (both desirable and undesirable behaviour);

• Collect potential mental models that could influence these behaviours, by:

  – Mapping the phenomena (which may become target mental models) that play a role in the domain. This is based on the entire process from making to discarding plastics;

  – Interviewing circular economy experts (n=2);

  – Interviewing the public (n=5).

• Collect people's actual mental models by:

  – Composing interview setup based on found behaviours and potential mental models;

  – Administering in-depth interviews with a varied group of people (n=5).

• Cluster a varied selection of mental models to define types and dimensions in multiple iterations. The clusters are guided by literature.

• Collect and create embodiment ideas based on a high-variety selection of mental models by:

  – Designing for found potential mental models;

  – Hosting creative sessions with design students (3 sessions with 2 students);

  – Collect existing mental model-communicating designs.

• Cluster a selection of distinct embodiment ideas (n=51) to define possible ways to embody (n=21);

  – Analyse for each possible way to embody an accompanying embodiment on factors that make it effective;

• Test the framework by:

  – Translating it into a toolkit format;

  – Hosting a session with two design students.

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3 The mental model part of the framework

Before going into any designing in chapter 4, the current chapter has a psychological focus. It starts with discovering the desired behaviours within the domain of plastics in the circular economy and their (potential) underlying mental models. Furthermore, interviews and their results are described which show people's current beliefs (thus also mental models) and motivations with regards to phenomena and behaviours within the domain.

The mental model part of the framework is based on analyses of these collected mental models in combination with insights from literature. Different types and dimensions of mental models are defined and their application in designing with them is discussed.

3.1 Domain: Plastics in the circular economy

The domain functions as a focus to centre the research onto. In that, it provides a concrete context with examples of (potential) mental models and a set of current beliefs and attitudes.

The chosen domain is plastics in the circular economy (from a consumer perspective). For the RIVM, the circular economy is part of their Strategic Programme (SPR, Speerpunt in Dutch) for 2019. An SPR is a focal point of interest which the RIVM expects will have a big impact on society. An important area within this SPR is the circularity of plastics.

The domain of plastics within the circular economy is suitable as a focus for exploring the potential of mental models in design. Firstly, it encompasses a high variety of potential–mental models: About physical processes like recycling and climate change, about psychological processes on behaviour and about politics and business processes, to name a few. This allows for a broad analysis on the types and dimensions of mental models. Secondly, this domain has a relatively high variety of touchpoints: Physical or digital points (e.g. plastic products themselves, trash–bins and stores) with which the user may interact in their daily life to learn the target mental model. These touchpoints can be used to place an intervention (the embodiment). To research in what ways an embodiment can be designed, different touchpoints are required to be analysed.

As a final narrowing of the scope, the focus of plastic is specified to plastic packaging. Packaging is the largest stream of plastic waste (Plastics Europe, 2016) and consumers can have most impact there; options exist to reduce and recycle plastic packaging.

3.1.1 Relevant behaviours in domain

A mental model is not relevant in itself. It only becomes relevant through its influence on relevant behaviours. Therefore to find mental models, the relevant behaviours have to be mapped. For plastic packaging within the circular economy, the main behaviours are:

- Which product to choose;
  - Unpackaged, reusable, recycled, recyclable.

• Whether to reuse;
• How to dispose of packaging;
    – Recycling (correctly), no littering.

Closer inspection of these behaviours leads to a more specific list of environmentally good and bad behaviours. For example the general category of recycling correctly is specified into exactly what should and should not be put in the plastic recycling stream. These behaviours were mapped through an exploration of the information put online by recycling companies and by looking at different strategies (than recycling) to be circular (MacArthur, 2013).

.2 Potential Mental models

Once all the desirable behaviours were collected, potential mental models were sought which may have an influence on these. Such mental models do not have to be complete. They only have to contain the elements that make it possible for the "user" to choose a correct behaviour. This was done in several ways:

• Collecting a bulk of potential-Mental models, first the entire process that plastics go through was mapped. This starts with CO2 (hundreds of millions of years ago), passes the sub-processes of refining it, turning it into products, distributing them, discarding them, incinerating or recycling them or leaking them into nature. Also the process of what happens with it afterwards is relevant, such as the process of disintegration in the ocean. About all these processes people could have a mental model; the functioning of each process therefore is a potential mental model. These however do not necessarily have a positive influence on the desired behaviours. The next step is to filter out the ones that do not.

• Consulting experts (an assistant professor and a PhD student) with research topics about the circular economy were consulted as to what potential mental models could be stimulating for good circular behaviour.

• Interviewing the public helped to not only gain their current beliefs (explained in the next chapter) but also to uncover beneficial potential mental models.

3.3 Current beliefs and (de-)motivations

To determine which of the potential mental models would be influential, the current beliefs (including mental models) and (de−)motivations have to be considered. Firstly, the current beliefs are relevant in determining which potential mental model fits to it. Secondly, the current motivations will help in formulating mental models that play into this motivation, or counter a current de−motivation. These (de−)motivations can be caused by false beliefs (e.g. that global warming is not affected by humans) which are in turn fed by false or missing mental models (e.g. not having a correct mental model on the green−house effect).

To gather these current beliefs and (de−)motivations, five interviews were conducted with people from the city of Delft.

Interviews

The content of the interview was based on the analysis of the relevant behaviours and potential mental models within the domain. First, participants were asked open questions, simply: “Tell me about ...” to avoid reactivity. Next, more specific questions were asked to avoid missing any mental models. These specific questions were about inquiring the participant’s behaviour compared to the previously defined relevant behaviours and their beliefs about the collected potential mental models. See appendix C for the interview protocol.

In the Mental Models Approach to Risk Communication (Morgan et al., 2002) the researchers subsequently validated the measured mental models by administering a questionnaire to a bigger group. For the purpose in this project, that was not necessary.

> “As scientists who are interested in studying people’s mental models, we must [...] and discard our hopes of finding neat, elegant mental models, but instead learn to understand the messy, sloppy, incomplete, and indistinct structures that people actually have.” - Norman (1983):

Interview setup

Pen and paper was made available to draw for the participants to clarify themselves. The interviews took around 1 hour and were one on one to minimize social biases (Doyle et al., 1998).

Participants

The goal of the interviews is not to quantitively determine the current beliefs

and motivations of a specific target group. The purpose of the data is to get a sense of what exists, to enable making a well-rounded analysis. For this, a broad range of beliefs and motivations is most suitable. To find a broad range, an equally broad range of interviewees is required. Considering the cognitive nature of using mental models, an important characteristic of participants is their level of education. Furthermore, age and sex were varied to get a more balanced range (see table 1). The first three participants were recruited at the university. The other two were recruited on the street in front of a discount shop, using a flyer (see appendix B).

	Sex	Age	Educational level
#1	Female	23	Master university student (current)
#2	Female	25	Master university student (current)
#3	Male	19	Bachelor university student (current)
#4	Female	33	Secondary vocational education (MBO)
$5	Male	52	Secondary vocational education (MBO)

Table 1: Participant data

Limitations

There are some limitations in retrieving mental models in this way. For one, asking someone about their mental model makes them reflect on how the subject in question works. This can create a new (possibly transient) mental model which the participant did not actually have (Doyle et al., 1998). A quote from the interviews illustrates this:
Furthermore, the group of participants is not a balanced representation of the general population. Next to its small size, it consists of a disproportionate share of university students. However for the purpose of this project in which quantification is not required, the data is sufficient.

Interviewer: "Do you know how that works?"

Participant 2: "No I don't... I could guess... You could explain that it becomes dryer... O, right, I think I know. It becomes much warmer and then ..."

Results: mental model maps and (de-)motivations

See appendix D.1 for the insights per participant and appendix D.2 for the mental model map per participant. For example, see the mental model mapping of participant 1 in figure 7 on the following spread.

Some noteworthy results:

• Two participants are motivated by their mental model on the ripple-effect. This entails that good behaviour is perceived and copied by others and that it, in that way, spreads exponentially. A good behaviour therefore has a bigger impact than only its direct effect.

• Three participants think that businesses have a large impact but do too little. This feels unfair; consumers should not be the only ones making a sacrifice. Also the government should take more action. The potential mental model that explains that the recycling process is actually financed by packaging producers (who pay a fee for every package they distribute) may mitigate this demotivation. Instead, a feeling of mutual cooperation could be created.

• Three participants doubt whether recycling has a positive impact at all. One participant thinks that PMD (of which recyclable plastics are part) is combined with the regular trash after collection. A potential mental model could explain this was a hype in the media, whom always look for a controversial story. In reality, the PMD was combined only a short while and in a few recycling plants.

• One participant believes, since many smart people work on it, the recycling process must be effective. Any potential mental model which emphasises this can add to the positive attitude towards it.

• One participant does not believe climate change is affected by humans, but that it is a natural change. The potential mental model of the green-house effect could help in this case, explaining the mechanism through which people influence it.

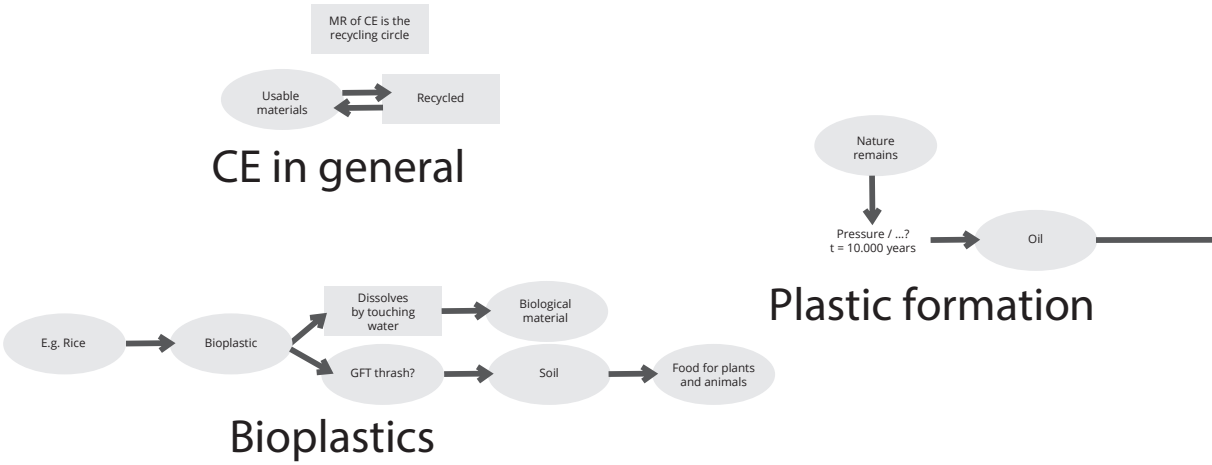
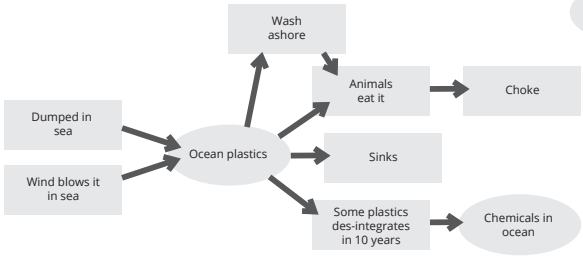
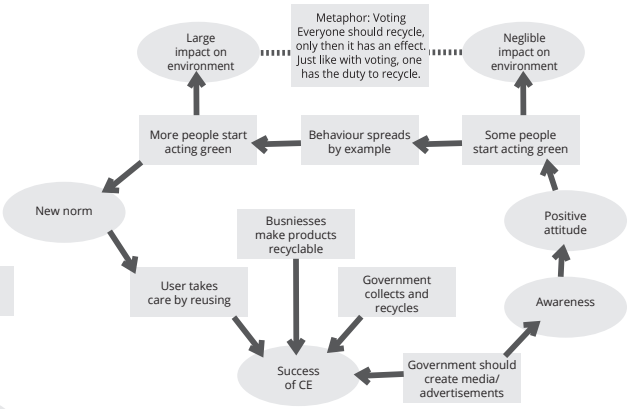


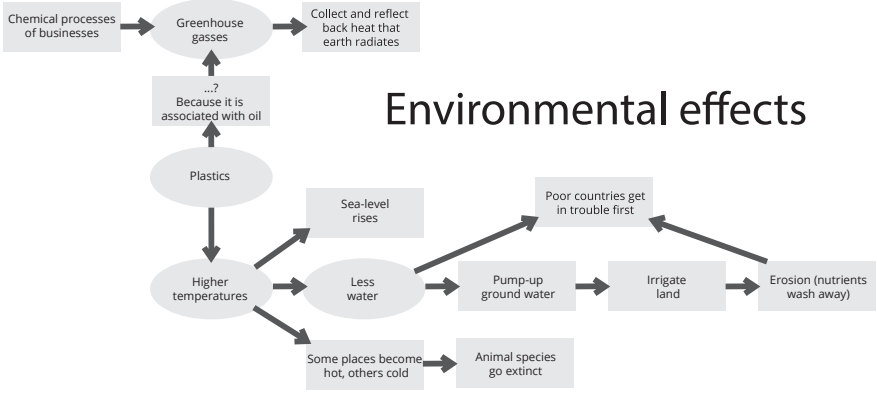
Figure 7 Mental model map participant 1 (on spread)



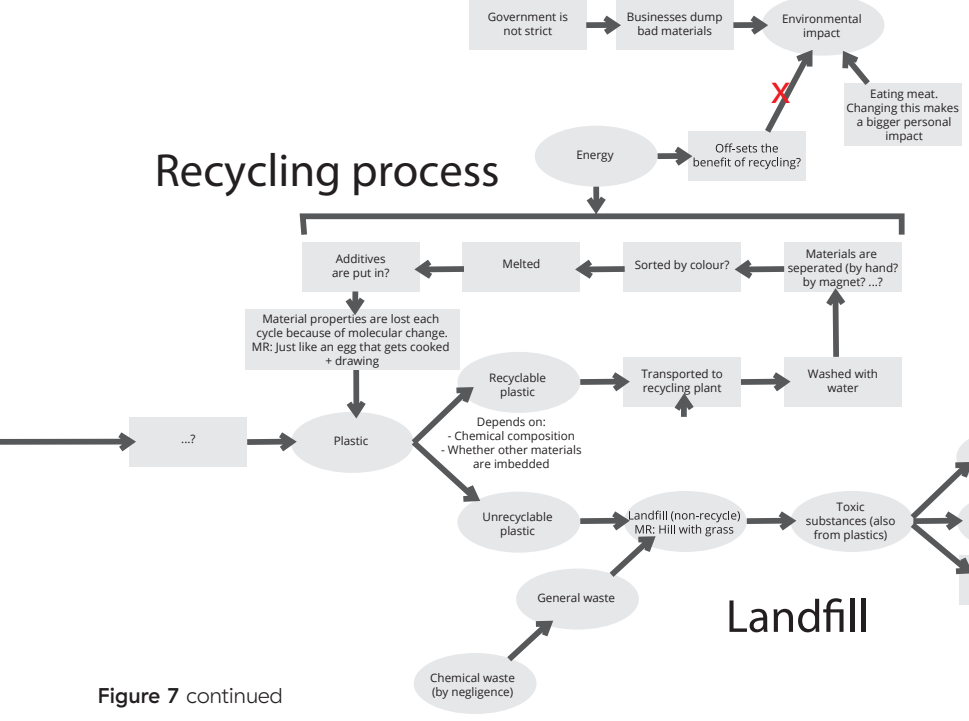
Ocean plastics



Who is resposible for circular economy?



Environmental effects



Recycling process

Landfill

Figure 7 continued

3.2 Mental model clustering: Types and dimensions

The hypothesis was that there are different types of– and dimensions within mental models. By clustering a selection of all potential mental models, these types and dimensions were explored. This is the basis for formulating the mental model part of the framework. The clusterings served to find underlying types and dimensions. These types and dimensions are of interest since they can provide a handle on picking an effective mental model and refining it.

The selection used for clustering consists of 28 potential mental models. These originated from a larger pool of potential mental models (from chapter 3.1). The selection was made intuitively based on the criterium of variety and impact. Multiple clusters were formed (see appendix E). The most relevant ones became part of the framework and are discussed in more detail below.

Structure of coming chapters
Chapter 3.3 and 3.4 (the mental model part) and chapter 4 (the embodiment part) explain the framework and how it was developed. The framework consists of two parts, each divided again in two sections (see figure 8 on the right). Additionally to the theory parts of the framework (eight in total), also three checklist cards were developed. These are intended for designers who might use the framework. They contain criteria to make choices about potenti–al–mental models and embodiment ideas. All elements are discussed below.

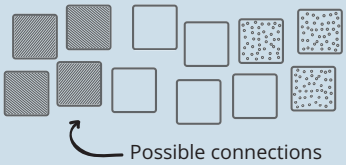
3.3 Part 1A: Mental model collection & evaluation

Part one of the framework is concerned with the theoretical part on mental models. The first section of that (1A) is about collecting and evaluating them and consists of three theory sheets and one checklist. The first of those sheets is displayed on the following spread. All sheets are displayed on a full spread (two facing pages), after which they are discussed one page later.

Phase 1: Mental models

1A: Collection & evaluation

Connection to action
How can mental models influence behaviour?



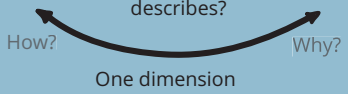
Relation to current beliefs
How does the mental model relate to existing beliefs of the target group?

Mental model openness
Is the mental model a general principle or a proving mechanism? And to how many behaviours is it applicable?

1B: Refinement

Mental model complexity
How detailed is the mental model?

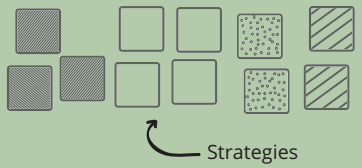
Explanatory emphasis
What is it exactly that the mental model describes?



Phase 2: Embodiments

2A: Generation & evaluation

Ways to embody
In what ways can a mental model be embodied into something in the world?



Embodiment explicitness
How how aware are people about the intervention, and how explicitly is the mental model stated?

2B: Refinement

Embodiment refinement
Which factors of the intervention are important for the interaction with the embodiment and the subsequent internalization and application of the mental model.

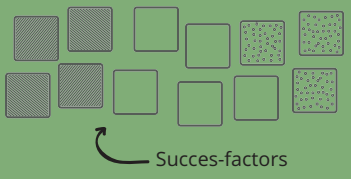


Figure 8 Contents of the framework

CONNECTION TO ACTION

The key to picking the right mental model is finding one that is likely to influence behaviour. This part of the framework shows the different ways in which a mental model can have an influence on behaviour. In other words; the connection from mental model to action. Use it to formulate or to evaluate already found potential mental models.

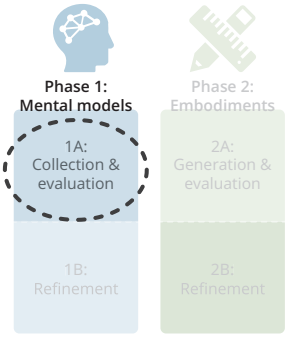
There are three main ways in which a mental model can connect to action (behaviour):

1. Firstly, a mental model can enable someone to execute a behaviour which they already wanted to do, but were unable. For example, we could explain the concept of the circular economy. This knowledge enables people to choose the more energy efficient option of reusing over recycling.

2. Secondly, a mental model can change ones attitude towards the target behaviour. Within this category, there are multiple ways. For example, someone can feel like businesses should take more environmental action instead of consumers. This creates a negative attitude towards, for example, recycling. In that case a good target mental model would be knowing that businesses have to pay a fee for every package they distribute, which finances the entire recycling process.

3. Thirdly, a mental model could imply a social norm. This can happen when the mental model discloses multiple options, of which one is perceived as being the norm. For example, toilets have two buttons to flush; a small and a large button. The resulting mental model is that either a little or a lot of water is used. The fact that this option exists implies water-saving behaviour as the injunctive norm.

Note that for the target behaviour the target group may have a weak link. For example having the right attitude, but not being able. Then, it is clear which main way is most suitable. You can use this sheet as a way to formulate influential potential mental models. Also, it can act as a way to evaluate already found mental models. Be aware that more mechanisms must exist, so feel free to add and combine.



Overview of connection to action

(Sub-)strategies of connecting to action

1. ENABLING TARGET BEHAVIOUR

ENABLING

There sometimes is an existing motivation, but people are (or feel) unable to exhibit the behaviour. In that case, a mental model could provide how-to knowledge.

For example: Explaining that recycling requires energy enables people to understand that it is good to first try to reuse and prolong product lifetime (other strategies that also circulate resources).

PERSPECTIVE

A mental model can put a situation in perspective. This can create feelings of kinship and trust.

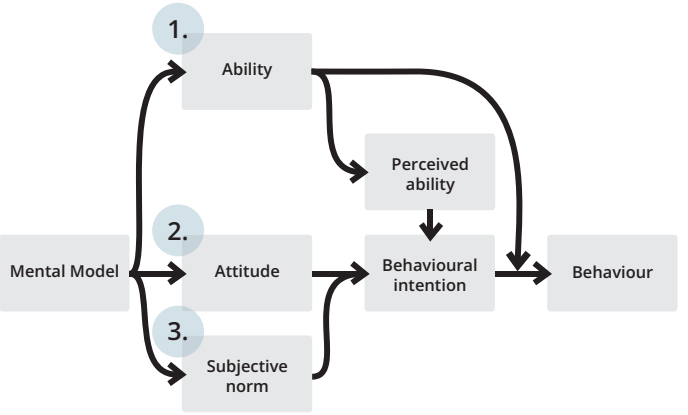
For example: The entire recycling process is financed by the businesses that distribute packages; they are obligated by law. Having this mental model creates a sense of alliance; everyone is working together on a common goal.

EXPOSE BIASES

People's beliefs can be biased. A mental model can expose the negative biases.

For example: People may start using much more plastic once they start recycling. They feel like they are acting green since they picked up recycling. Although recycling is better than putting it in the general waste, the rebound-effect makes for a netto negative effect because they buy much more.

Figure 9 Connection to action sheet



2. CHANGING ATTITUDE TOWARDS TARGET BEHAVIOUR

MOTIVATING

PERCEIVED EFFECT
People can feel like their good behaviour has no effect. A mental model can explain in what way it does.

For example:
If someone does a selfless (green) behaviour, other people tend to copy it. This happens like a ripple in the water, growing wider and wider. Having this as a mental model, people can know that their behavioural impact is much bigger than just it's direct effect.

ASSOCIATION
A mental model can expose a link between the target subject and something else. Through association, the (positive or negative) attitude can be transcribed.

For example:
Explaining that plastic is made from petroleum, just as gasoline, can create a similarly negative attitude to plastics as is already present for gasoline.

SHOW OR PROOF CONSEQUENCES
A mental model can provide insight into how a certain behaviour has a negative (or positive) effect on the world. Also, in case people know but disbelief the consequences, the mental model of how it works may convince them; it acts as proof.

For example:
For people who don't believe in climate change and it's consequences, a valuable mental model could be explaining how the green-house effect works.

EXTRINSIC BENEFIT
If people don't care much about (e.g. environmental) consequences, a mental model can explain how certain behaviour also has a personal (extrinsic) benefit.

For example:
A mental model can explain how products that last longer will in the long run also be cheaper.

DISTANT
↕
PROXIMATE
(spatial, temporal, probabilistic, social)
Consider psychological proximity; people feel proximate consequences more.

3. CHANGE SUBJECTIVE NORM TO TARGET BEHAVIOUR

IMPLY NORM
A mental model can indicate a choice to be made, and simultaneously the injunctive norm to choose one option over the other.

For example:
A thrash bin with seperate compartments for plastic and paper show that thrash can be recycled by collecting it seperately. This implies the norm to do so.

Connection to action (on previous spread)
The Connection to action sheet connects to the constructs of the Theory of Planned Behaviour (Ajzen, 1991) as seen at the top of the sheet. The three elements from the ToPB (perceived ability, attitude and subjective norm) are represented in the Connection to action and provide the literary backing for the claim that mental models influence behavioural intention. However compared to the perceived ability in the ToPB, in Connection to action there is a more prominent focus on changing the actual ability. As illustrated by the six connections focussing on attitude, most connections a mental model can have to action use attitude as a mediator.

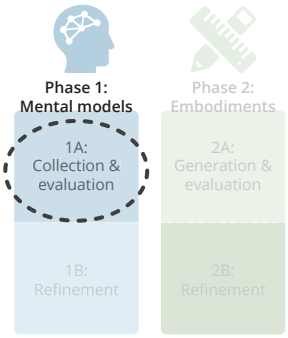
Within the cluster Show or proof consequences, psychological proximity to an environmental effect influences how much it affects consumers (Magnier et al., 2017). Effects perceived as more proximal are perceived as more concrete. There are four dimensions of psychological distance: Spatial, temporal, probabi-listic (perceived likeliness of affecting you) and social (perceived difference between you and the affected social group). Some mental models communicate an effect (e.g. on the environment). In this case, it should be more proximal to have a bigger effect.

This cluster Perspective was inspired by the overview-effect (Yaden et al., 2016). This effect is seen in astronauts who view the earth from space. Getting this new perspective makes them change their attitude towards earth and its inhabitants. They feel part of a bigger whole and gain a sense of respect, accompanied by concordant behaviour.

Some examples

The ripple–effect (good behaviour spreading exponentially) mentioned earlier (page 31) falls within the category of changing attitude by increasing the perceived effect of behaviour.

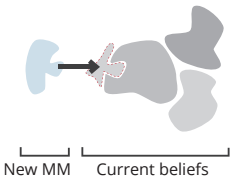
Another noteworthy finding from the interviews was that people are demotivated to recycle because they feel like companies take too little responsibility compared to consumers. Combined with this feeling, some people also believe collected recyclable trash is combined with the regular trash due to a lack of financing. The target mental model that for each package a fee is paid by the producer tackles both demotivations. It fits to the category of putting a situation in perspective.



RELATION TO CURRENT BELIEFS

A potential mental model is not simply suitable or unsuitable in itself. This depends on the recipient's current beliefs. There are five possible relations between a potential mental model and current beliefs. Use this part of the framework to evaluate which potential mental model is most likely to be adopted.

Five ways exist in which a potential mental model can relate to the target group's current beliefs. A potential mental model can be expected to be more likely to be adopted, the more it is in line with current beliefs. If it contradicts someone's current beliefs, there will likely be more resistance to accept incoming information.



SUBSTITUTE

A new mental model can replace an existing, incorrect one. It is contradictory, so expect resistance.

For example:
If someone believes all recyclable plastic is incincerated anyway, it will be difficult to convince them it is actually mostly recycled.

COMPLEMENT

A new mental model provides an addition to existing beliefs. It is non-contradictory so should be easier to add.

For example:
If people already know recycling is a rather sophisticated process, they are receptive for how it is exactly that it works.

Figure 10 Relation to current beliefs sheet

CONNECT

People may already have a (on an abstract level) comparable mental model. It only has to be connected to the situation.

For example:
If someone already knows the formula for Volume, all that remains is connecting it to the domain of packaging to realize that bigger packages are more material-efficient.

ACTIVATE

The desired mental model may already be present, but inactive. In this case, it only has to be re-activated.

For example:
People may have known, but forgotten why some colours of plastic cannot be recycled.

USE

In some cases, people already have a useful mental model (which is ideal!). Now, it is a matter of putting it to use as effectively as possible.

For example:
If people already believe that their recycling behaviour is copied by others, it is a matter of making their behaviour (seem) visible.

Relation to current beliefs sheet (on previous spread)
There is a relation to someone's current beliefs for all new information, thus also for a potential mental model. This relation is relevant because people filter information based on whether it is congruent with their existing beliefs (Jones et al., 2011). Dissonant evidence may be rejected. However, in some cases it may be worthwhile going against current beliefs. For example the target mental model about how producers pay for the recycling process does this and by doing so removes the demotivations accompanied by the previous (false) beliefs.

On the other end of the spectrum, exploiting the ripple-effect makes use of an existing mental model (for some people, at least). Even if people currently do not use it, it is likely that they may have heard about it already. In that case, it only has to be activated or connected to the current situation.

Mental model openness sheet (on following spread)
The dimension of openness (and particular domain openness) may be a very important one for the mental model method. A domain open mental model (coined a general principle) is applicable to many different contexts. The ripple effect is such an open target mental model, both in its focus on a domain and on its applicability to multiple behaviours. This type of mental model is not dependent on a certain context, it can be applied regardless of any specific setting and time.

On the other hand, explaining how producers pay a recycling fee can lead to a very specific mental model; it is applicable only in the domain of recycling and has an influence only on the behaviour of recycling. Yet still, it can be effective in changing a persistent false belief (that all thrash is combined, for the example of the recycling fee) which has a strong demotivating effect on the target behaviour. This type of mental model is coined a proving mechanism. It could be more effective in changing persistent false beliefs because it facilitates an understanding of the situation, proving why their belief should be revised. This could be more efficient than simply 'telling' people what they should believe, which may create more reactance.

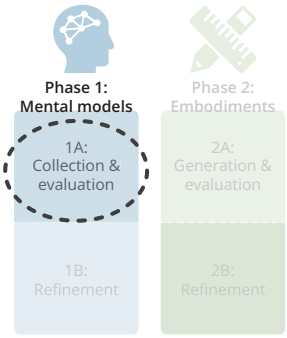
MENTAL MODEL OPENNESS

One of the strong suits of using mental models is that they can be open in nature. This means that they are applicable (and therefore influential) in many situations. Use this part of the framework to evaluate the openness of the potential mental models.

There are two dimensions within the openness of a mental model. The first dimensions is the domain in which the mental model is located. An example of an open-domain mental model is about the ripple-effect. This mental model describes a mechanism of behaviour, which is applicable to many domains (from recycling, to littering, to helping the elderly, etc.). On the other hand, a mental model that describes the green-house effect is very specific in its domain; it is solely about the physical process of the green-house effect.

The second dimension is openness in behaviour. Although it correlates, it is a distinct dimensions from openness of domain. Openness in behaviour entails that a mental model can be applicable to either few or many behaviours. A mental model with a high behavioural openness could describe the green-house effect, since it is applicable to a lot of behaviours; any behaviour that leads to green-house gasses is potentially affected.

The advantage of an open mental model should be clear. However, it also has a drawback: Due to its unspecificity, people may not always be triggered by a specific situation to remember and apply it.



DOMAIN OPEN:

Applicable to multiple domains

For example:
The phenomenon of the ripple-effect entails that people copy each other's good behaviour. This can be in the domain of sustainability, but also on not littering, helping the elderly, etc. It is applicable to many different domains.

BEHAVIOUR SPECIFIC:

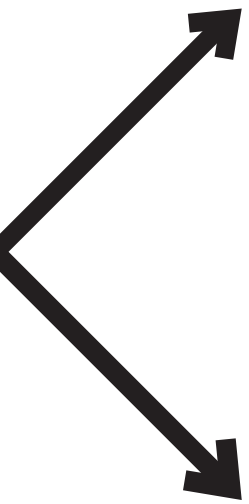
Applicable to only few desireable behaviours

For example:
The mental model that explains that black plastics cannot be recycled is very behaviour-specific. This knowledge can only be applied to the behaviour of disposing of black plastic packages.

Figure 11 Mental model openness sheet

BEHAVIOUR OPEN:
Applicable to multiple desireable behaviours

For example:
A mental model about the green-house effect is behaviour-open. It is applicable to the many behaviours that affect emission.



DOMAIN SPECIFIC:
Applicable to only few domains

For example:
The green-house effect is, although it can be applied to many behaviours, very domain specific: It is solely about the physical process of the green-house effect.

Checklist 1A: Mental model evaluation

Mental model:

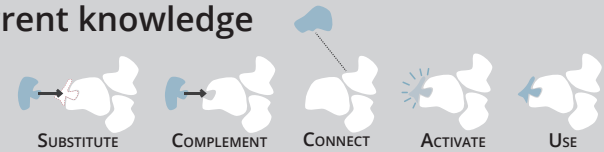
Connection(s) to action: _____

_____

Relation to current knowledge

Whether a mental model is adopted and what its effect will be is determined by the knowledge that is already present.

How likely is it that the target group will adopt this mental model?



SUBSTITUTE	COMPLEMENT	CONNECT	ACTIVATE	USE
☐	☐	☐	☐	☐
01		23		4

NotS	omewhat	Quite	Very
☐	☐	☐	☐
0	12		3

MM openness

A more domain-abstract mental model is applicable to different systems (and more robust in changing times). A behaviour-open one is applicable to many (desired) behaviours.

OPEN DOMAIN: APPLICABLE TO MULTIPLE DOMAINS ☐ 1

OPEN BEHAVIOUR: APPLICABLE TO MANY GREEN BEHAVIOURS ☐ 1

SPECIFIC BEHAVIOUR: APPLICABLE TO ONLY SPECIFIC GREEN BEHAVIOURS ☐ 0

SPECIFIC DOMAIN: APPLICABLE TO ONLY ONE DOMAIN ☐ 0

Shareability

Is it likely that people share (and thus spread) the mental model? Is it fun to tell others?

NotS	omewhat	Quite	Very
☐	☐	☐	☐
01		23	

Behavioural influence

How big will the influence of this mental model be on behaviour? Does it fit their motivations and concerns?

NotS	omewhat	Quite	Very
☐	☐	☐	☐
01		23	

Embody-ability

How easily could the mental model be embodied? Briefly check 'Ways of Embodying' (phase 2A).

Not	Somewhat	Quite	Very
☐	☐	☐	☐
01		23	

\+

Total: .....

Figure 12 Contents of the framework

Checklist card 1A
The first checklist card (figure 12) aims to guide designers using the framework in using the first part (1A) of the framework to choose a suitable target mental model.

The designer fills in the checklist card for a number of intuitively chosen potential mental models. While filling out the card, a total score for the potential mental model is accumulated. A choice should however not be based solely on the score; it solely functions to make the designer's intuition aware of the relevant factors.

Besides the criteria that correspond with the framework (connection to action, relation to current beliefs and mental model openness) some more criteria are added:

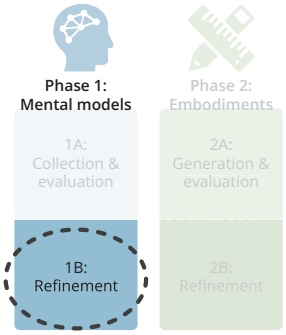
• Shareability: A mental model is not only communicated through an embodiment, it also happens socially. Some potential–mental models are more likely to be shared. For example, a very surprising mental model is much more fun to tell others about than a boring one;

• Behavioural influence: The estimated degree to which a potential mental model will be effective in changing the target group's behaviour;

• Embody–ability: The estimated ease with which the potential mental model could be embodied.

4 Part 1B: mental model refinement

The first section of part 1 of the framework functions to help designers choose a suitable target mental model. The next part (1B) is centred around refining that target mental model.



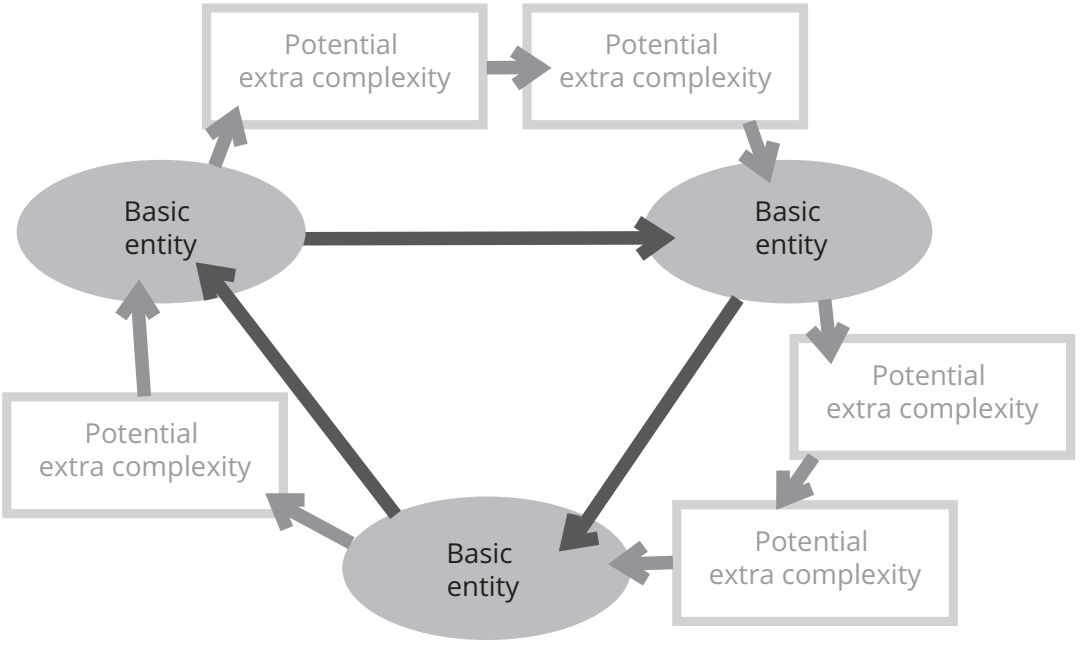
MENTAL MODEL COMPLEXITY

A mental model can explain something superficially, or highly in-depth. This complexity is another dimension of mental models.

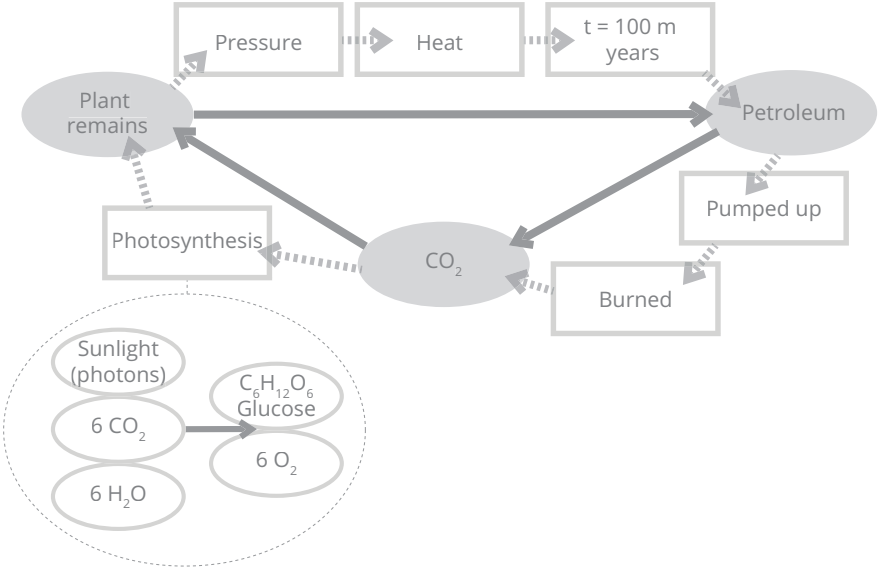
On the lower end of the spectrum, a mental model can explain something very briefly. This may be suited for people who don't have the time or capacity to process a more complex mental model. However, it may then lack power. For example, when people's existing knowledge is contradictory, more complexity may be needed to convince them.

Ask yourself this: Would a higher complexity increase the mental model's effect? Or could the same effect be achieved by a lower complexity? Which parts of the mental model are crucial?

Figure 13 Mental model complexity sheet



FOR EXAMPLE: The formation of petroleum



Mental model complexity sheet (on previous spread)
A mental model is never complete due to a limited cognitive processing power (Miller, 1956). To prevent mental load, irrelevant aspect are omitted (Forrester, 1961). This suggests that a target mental model have a limited complexity to be understood, remembered and applied.

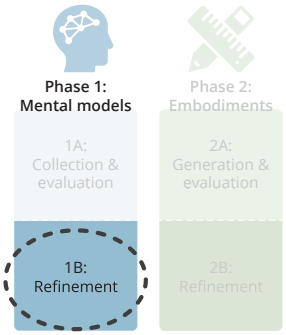
- "Essentially, all models are wrong, but some are useful" (Box, 2005).

Seeing a mental model as a chain of causes and effects, the simplest mental model imaginable would be only one cause (input) and one effect (output), with an undefined black box in between. However, this should not be considered a real mental model since it does not actually explain how the system works. This remains hidden in the black box, which is why the benefits of the mental model approach would not apply –it loses its convincing power.

Explanatory emphasis sheet (on following spread)
In the field of human factors Moray (1990) distinguishes four levels on which a user may explain what he sees:

> "...when considering a switch causing a pump to operate, he (the operator) may consider; A formal cause (because it is in the 'on' position), a material cause (because it closes a pair of contacts), an efficient cause (because it allows current to flow through the pump), or a final cause (because cooling is required)."

Although Moray's levels are not applicable one-to-one to the type of mental models within this project, they did inspire to come up with the dimensions of explanatory emphasis which states that an essentially identical potential mental model can differ in exactly what it explains: How something works versus the why behind it.



EXPLANATORY EMPHASIS: HOW VS. WHY

The emphasis of what a mental model explains can differ. In its explanation it can focus on how something happens, or why (or both!).

Most things happen for a reason. Knowing this reason may make the entire mental model more believable. For example, this may be an evolutionairy reason (see the why of the second example). Likewise, when people understand more fully how exactly it is that it works, it becomes more plausible. This would explain how the why happens -for example physically (see the how of the second example).

The applicability of this dimension is not straight-forward. One is not better than the other. It depends on the situation; which mental model it is and who should adopt it. Also, the how and the why are not exclusive (hence the curved axis) and for some mental models there may be only one.

Example 1:

EMPHASIS ON HOW?

People see each other's green behaviour, creating a social norm.

People follow each other's example of green behaviour.

EMPHASIS ON WHY?

People are relucatant to act green, selflessly. They feel like they would be stupid to make a sacrifice while others don't. Yet, when they see others do it, their relucatance is mitigated.

Figure 14 Explanatory emphasis sheet

Example 2:

Neural connections become stronger when used more often, enabling easier firing.

If you do something more often, it becomes easier; a habit.

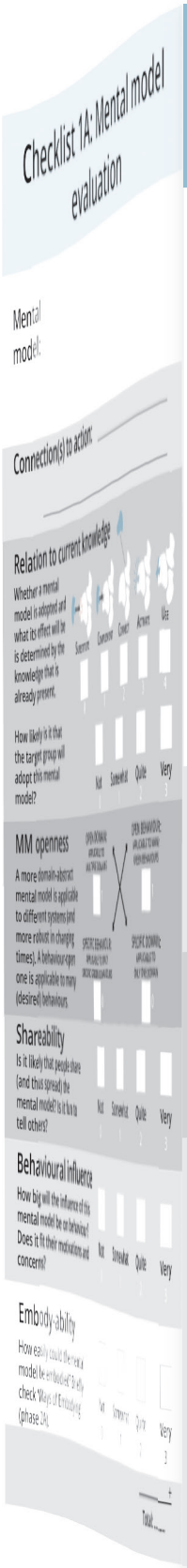
Habits are created to reduce mental processing load for repetitive tasks.

Example 3:

A magnet is used in the recycling process. In this case, people will easily infer the why.

Metal is seperated from other thrash in the recycling plant.

A magnet is used to seperate metal from mixed thrash. In this way, it can be melted down into usable material for new metal products.



Checklist 1B: Mental model refinement

Potential additional effect for this mental model:

Check Connection to Action

Example: Let's say a potential mental model gives perspective and therefore changes attitude. Additionally, this same mental model (with some small refinements) may for example enable people as well.

Refine the potential mental model's complexity

Which parts of the mental model are crucial? Could you leave some out?

Or would a higher complexity be more convincing?

Refine the how versus the why emphasis

A mental model can vary in the degree to which it explains how some-things works versus why it does. Both can add to believability, but may not always be necessary.

Refined MM:

Figure 15 Checklist card 1B (folding out from checklist card 1A)

Checklist card 1B

The second checklist card (see figure 15) functions as a guide to go through part 1B. It is printed on the same piece of paper as checklist card 1A (folding out), making sure that the previous analysis of the mental model is not forgotten. After using the checklist a refined target mental model is defined by the designers.

In this chapter we've looked at which behaviours in the domain are desirable and which mental models underly them. Those collected mental models were then analysed through clustering (with some help of the literature) into the first part of the framework. To complete the framework, its second part (about embodiments) is discussed in the next chapter.

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4 The embodiment part of the framework

Mental models can be influenced in several ways. From the perspective of human factors, this would be by interacting with a product. However, this point of view is only concerned with how the product itself works. From the perspective of risk communication (Morgan et al., 2002) mental models can be influenced by external information like websites or flyers. However as discussed before, both perspectives are limited and explicit communications like flyers may create reactance or not reach the target group. Therefore, the following part of the framework (part 2A and 2B) focusses on in what (other) ways a target mental model can be communicated.

Generative sessions
To explore the different ways in which a target mental model can be embodied, three sessions were held with industrial design master students (Design for Interaction master track). In teams of two, they got the objective to generate as many design ideas as they could that embodied the given target mental models:

• In a recycling plant, an infrared scanner is used to separate the trash. However, black plastics (black surfaces in general) do not reflect light and can therefore not be separated, and recycled.

> – With this knowledge, people know black plastics should not be disposed in the PMD (plastic) bin. They may even avoid buying it altogether.

• Recycling waste saves resources, but it does require energy.

> – Knowing this, people may try to minimize use, re–use or repair instead of recycling (directly).

• The ripple effect: People tend to follow your good example. So, doing something for the greater good makes other people do the same: The impact grows exponentially.

> – With this mental model, people may become more willing to display selfless (sustainable) behaviour, even if others do not yet.

In addition to embodiments of these three target mental models, also embodiments ideas containing other target mental models and existing designs that embody a mental model were collected throughout this project.

Touchpoints
As defined earlier, touchpoints are physical or digital points with which the user may interact in their daily life to learn the target mental model. These touchpoints can be used as a place for the embodiment.
In the sessions the participants were instructed to first map all the touchpoints they could think of. During slow moments in the sessions, they were encouraged to take a look at the touchpoints as a starting point for ideation.

1 Part 2A: Embodiment generation & evaluation

The main question of part 2A of the framework was: In what ways can a target mental model be embodied in a design?

To find an answer on this question, the collected embodiment ideas were clustered in several iterations into what is now part 2A of the FW: Ways to embody and Embodiment explicitness.

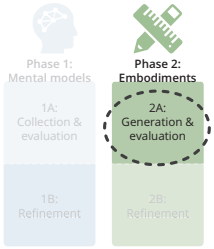
WAYS TO EMBODY

In using mental models to influence behaviour, it is crucial that the target group adopts the target mental model. This part of the framework contains different strategies to create embodiments; designs that embody the target mental model.

Globally, there are four categories of embodying. The first two are most obvious; showing either the system itself or its output. When both of these options are not possible (for example because the system is too far away or the output is invisible) the latter two options can be tried. All four categories have more concrete strategies listed below.

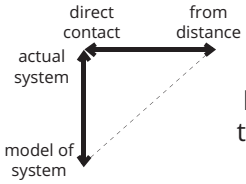
Not all strategies, and certainly not every category will be suited for every mental model. This has to do with the system and its potential touchpoints; the physical (or digital) points at which the target group may come into contact with any part of the target mental model. Before starting to design, map all the potential touchpoints. These will prove useful during ideation by offering potential places in the world to put the design.

Be aware that the list of strategies on this page is not defenitive and complete. So feel free to use your own strategies and intuition!



SHOW SYSTEM

In essence, a mental model explains the working of a system. Most obvious then, is to show this system. This can also be rather convincing; seeing the system (in action) is pretty good proof of it.



As seen in the axes on the left, there are more options than directly interacting with the actual (target) system.

To show the system, could you ...

... bring people to the system?

Example: Organize a school trip to a recycling plant.

... show the journey "through" the system?

Example: App that allows people to follow their thrash using cameras in the recycling plant, when they scan a QR code on the waste container.

... make the system more visible?

by making the system transparant

Example: Give recycling plant a glass facade

by putting the system on a visible location

Example: Put recycling plant next to a busy highway

... bring the system to people?

by creating a demo installation

Example: Put a mini recycling plant line on the city square

by creating a game

Example: "SimCity Edu"; A game in which you learn about the complexity of building a sustainable city.

by showing the system's blueprint

Example: Put a picture of the recycling line on a PMD container.

by showing what the system sees

Example: A sensor above the supermarket conveyor belt can mimick a part of the process in a reyclcing plant. Consumers directly see why certain things (like black plastics) can not be recycled.

Figure 16 Ways to embody sheet

SHOW IN-/OUTPUT: AN INSTANCE OF THE SYSTEM

In some cases it is not possible to show the system itself. In those cases, next best may be to show the in-/output of the system. This can be highly convincing since the output essentially is proof of the mental model.

A system processes input into output. Understanding the input - output relation can facilitate inferring how the system works.

Could you show output when ...

... plant a seed?

Example: Explain the mental model explicitly, and put a symbol of it on one's keychain. Being reminded of it often, they may keep it in mind at a moment in which there is natural proof of the MM in their daily experience.

... behaviour is good?

Example: If people should understand what can be recycled in PMD, an embodiment could be a bench on the street, with the recycled products it is made of still visible. 'Good behaviour' = recycling correctly.

... behaviour is bad?

Example: "CoraLog"; a computer screensaver that displays a coral reef which deteriorates during stand-by time.

For example, by ...

by imposing a choice on people

Example: A recycling bin on the street has multiple compartments. The choice communicates the mental model of recycling, and implies the social norm.

by tracking and feeding back user behaviour

Example: The effect of buying a plastic bag can be displayed on a receipt; the cost split into material and production energy cost.

by creating the circumstances to form the mental model

Example: Without actually communicating the mental model , the embodiment can facilitate people forming the mental model themselves. For example, the mental model of the ripple-effect can be facilitated by placing recycling containers on visible locations.

by using a token (if output is intangible)

Example: In light of the target mental model on the ripple-effect; The copying of behaviour can be signified using a ribbon as a token.

USE METAPHOR

For some mental models, both the system and the output are so intangible that they cannot be used.

In this case, we might use a metaphor containing a similar mental model which is easier to explain or which people already know.

Could you link ...

... existing knowledge to the system?

Example: Imagine this advertisement: People drive to work (in the town of "Circuvillage") and upon arrival put their car in a shredder, recycling the car. It concludes with a picture of a plastic bag and the text "Why not reuse?"

... an experience to the system?

Example: Tell people to try this game: Cross your arms, look up, or make any other distinct movement and see that people subconsiously copy your moves. This is metaphor for green behaviours; people copy each other.

COIN NEW TERM

Some languages have words which cannot be translated. They allow people to think about concepts which would otherwise remain illusive (hypercognition).

This principle can also be used to communicate a mental model.

Could you ...

... think of a term that implies the mental model?

Example: The word "Appended product energy" can be used on receipts. It communicates that not only resources, but also energy is appended in a product.

... find an existing term describing the mental model?

Example: The "confirmating bias" is an existing term that means that people tend to overlook information that contradicts their beliefs and overvalue info that confirms it. If that is the taget mental model, using this existing term may increase credibility.

Ways to embody sheet (on previous spread)
In an unfamiliar domain people use a seemingly similar domain which they understand (Collins and Gentner, 1987). Furthermore, intangible things (like behaviour and sustainability) are explained by analogy (Rickheit and Sichelschmidt 1999). This is the basis for the Use metaphor cluster.

Levy (1973) coined the term hypocognition, meaning the lack of a word to describe a concept. He studied Tahitians and found that they do not have a word for sorrow. They would report feeling sick instead of sad and they didn't have any ritual around grieving. Still, they did experience the emotion and this is hypothesized to be connected to the higher suicide rate in Tahiti. The cluster Coin new term is inspired by this notion that a (new) word can communicate a new concept to use in thinking.

Some examples:
The ripple-effect, embodied
The mental model of the ripple-effect can be embodied by making people feel seen in their good behaviour. Related to recycling, this can be done by placing recycling containers on crowded locations, in which people know each other. To further increase the action's visibility, a lamppost (connected to a proximity sensor) illuminates the container. To show the user what others are seeing (them, while recycling) the hatch of the container is made of a reflective material (see figure 17).

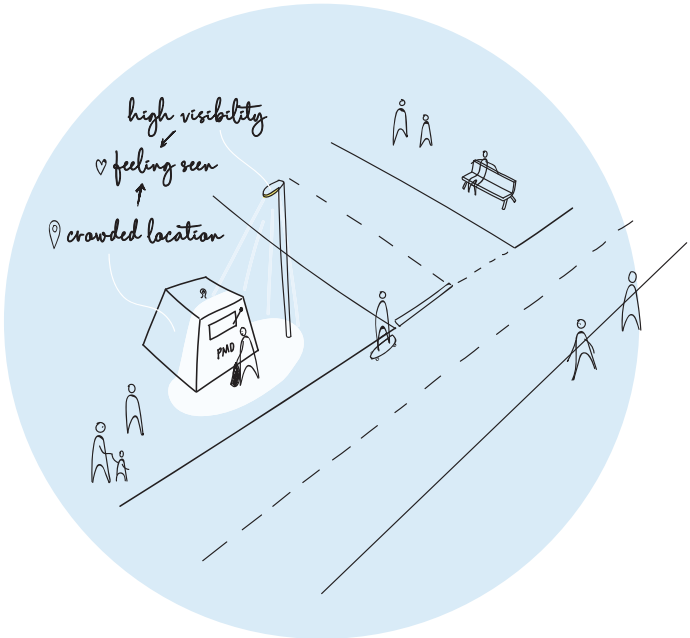


Figure 17 The ripple-effect, embodied

This intervention increases the feeling of being seen while doing a good behaviour. It increases the motivation of people who already have the mental model of the ripple-effect (which suggested by interviews are quite a few). Furthermore, it facilitates the circumstances for people to internalize the target mental model.

Besides motivating people to recycle, the openness of the mental model makes that it can spill-over to other domains of life: Any context where good (or bad) behaviour is thought-to-be perceived by others whom are believed to follow a given example.

The recycling fee, embodied

There is a persistent false belief that collected recyclable trash is combined with the regular trash due to a lack of capacity and financing. This clearly is a strong demotivator for recycling. Furthermore, many people feel like companies do too little, while they are big polluters. People feel like the consumer gets an disproportionate share of the responsibility.

In reality, recyclable trash was only for a short period of time and in an obvious minority of recycling plants combined with regular trash due to a technical shortcoming. Also, companies do take a part of responsibility: They finance the entire recycling process by paying a fee for each package they bring to the market. The target mental model that producers pay a fee for each package's recycling can remove both demotivations to recycle: First, the false belief that

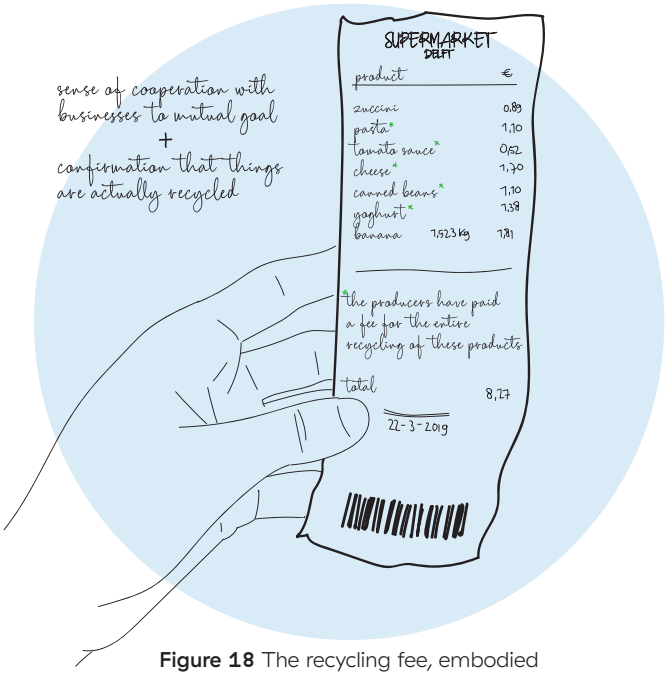


Figure 18 The recycling fee, embodied

all trash is combined is abated, because knowing how the recycling process is financed confirms that it actually happens. Secondly, the feeling that companies take too little responsibility is mitigated by the target mental model which shows their effort. Instead of a sense of iniquity, one of cooperation is created.

The target mental model can be embodied in a simple way: On supermarket receipts it is marked with asterisks for which products a fee has been paid (see figure 18). A short explanatory text describes that producers have already paid the fee.

Social leasing as an embodiment

A very different way of communicating a mental model is through a new business model for leasing. From the perspective of the circular economy leasing can be a more sustainable option than personally owning products. However, people may be demotivated to lease because they feel like they just have to pay more: A share of the money has to go to the leasing company. However, people are not aware of the fact that the same product can be used by multiple people if it is shared. This makes that if a product is used by 20 people, it is still ten times as cheap as buying it for yourself –even if the leasing company takes 50% of the revenue.

Giving people this mental model could be done through the business model of the company. Much like your utility bill, the rate would be dependent on the usage. In this case, the price will be the company's costs, divided by the

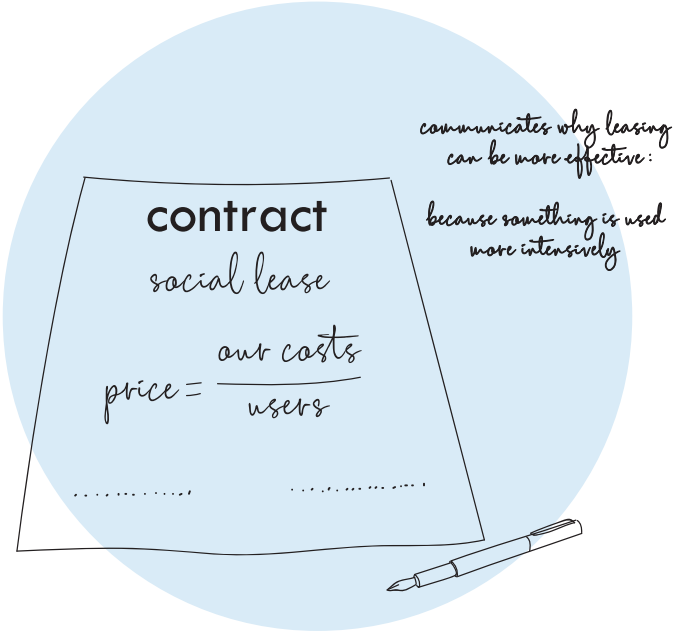


Figure 19 Social leasing, embodied

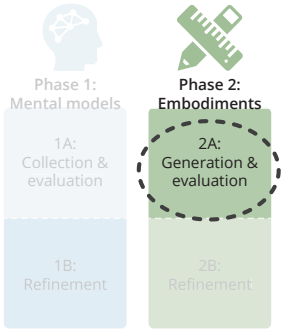
total use (by multiple people). This arrangement communicates that, and how, leasing can actually be cheaper (see figure 19).

Favouring cyclists in the rain

The Netherlands is a country of cyclists. At the same time it is quite rainy, which is not the best combination. To cater to the needs of cyclists that still choose the bicycle over a car, the city of Enschede installed rain–sensors to the traffic lights ("Regensensor op verkeerslicht geeft sneller groen voor fietsers bij regen", 2019). If it rains, they get a green light more often than cars do. Luckily the designers didn't forget to make sure to communicate how this system works: The mental model is embodied by an additional light which lights up when the sensor is triggered (see figure 20). Without this there probably would be little positive effect.

Image source:
(Kohartog, 2017)

Figure 20 Favouring cyclists, embodied



EMBODIMENT IMPLICITNESS

The implicitness of an embodiment influences reactance on- and the sense of ownership of new information.

Embodiment implicitness has two dimensions which are related but not dependent.

1. Explicitness of statement. An embodiment can either (explicitly) tell what the situation is or it can show it (without words).

2. Awareness of intervention. Regardless of the explicitness of statement, the design can be clearly manipulating or more subtly woven into the daily life of the user.

A lower explicitness of statement can be more convincing and a low awareness of the intervention decreases reactivity.

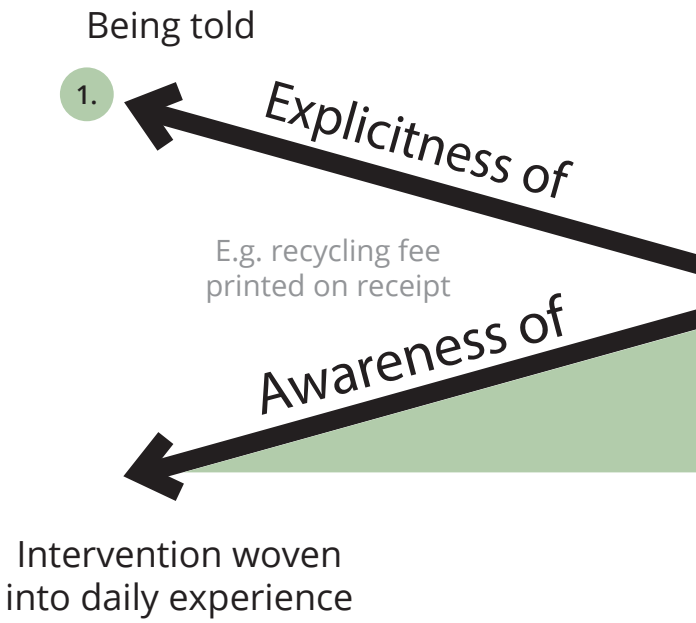
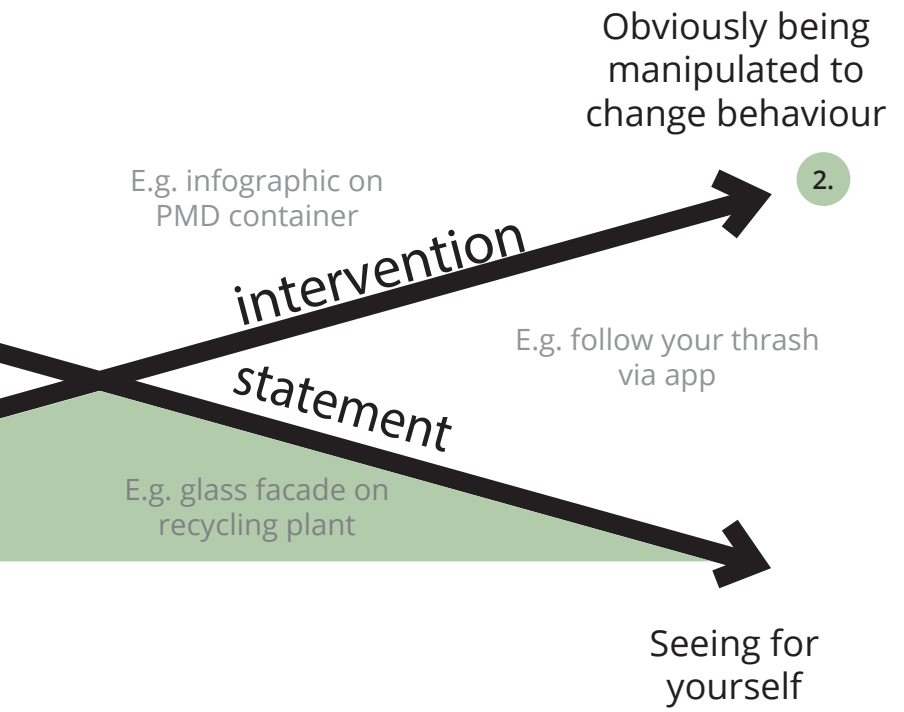


Figure 21 Embodiment explicitness sheet


Obviously being manipulated to change behaviour
2.
E.g. infographic on PMD container
intervention
E.g. follow your thrash via app
statement
E.g. glass facade on recycling plant
Seeing for yourself

4

Embodiment implicitness sheet (on previous spread)
The implicitness of the embodiment can be used to evaluate the generated embodiment ideas. Generally, an embodiment that is more implicit will be more convincing and trustworthy, but less easy to see the embodied mental model.

The embodiment of the ripple–effect (making the behaviour seem perceived by others) is on both dimensions on the implicit side of the spectrum. People will mostly not be aware of the intervention trying to influence their thinking and behaviour. The explicitness of the statement is especially low; it is not stated whatsoever. This removes reactance from the equation, but does diminish the likeliness that the target mental model is thought of. Therefore it cannot be stated that a higher implicitness is always better.

Checklist card 2A
This checklist (see figure 22) helps designers in choosing an embodiment idea. Like the previous checklist cards, it reminds the designer of the key aspects of an embodiment.

.2

Part 2B: Embodiment refinement

In the first iteration of the framework, the assumption was that people would make an effort to interact with an embodiment and to understand its mental model. However, this assumption is naive. People follow the route of least resistance unless there is a reason to do otherwise. That's where *refining the embodiment: Three levels of stimulation* (figure 23 on the next spread) comes in. In it, three steps in the process of obtaining and using a mental model are defined. For each level, success–factors (accompanied by strategies to achieve them) are proposed. These factors are defined by evaluating the collected embodiment ideas on their apparent strengths and weaknesses.

Checklist 2A: Embodiment evaluation

Embodiment idea:

Does this embodiment contain the correct mental model?

☐ Yes

Who?

Who will interact with the embodiment? Is this the right target group? Should their behaviour be changed?

☐ Yes

Interaction

Is the interaction with the embodiment automatic (vs. needing people to exert extra effort)? Do people have enough time and energy at this moment?

☐ Yes

MM internalization

Are they likely to internalize the mental model? Does the embodiment have a good level of implicitness?

☐ Yes

Behaviour change

Are they likely to change their behaviour? Take into account their concerns, motivations and abilities.

☐ Yes

Timing

Do people see the embodiment at the right moment? If not, will they remember the mental model at the right moment?

☐ Yes

Realizable

Is the embodiment feasible? Are potential conflicting interests between stakeholders surmountable?

☐ Yes

Figure 22 Checklist card 2A

REFINING THE EMBODIMENT: 3 LEVELS OF STIMULATION

Now that there is a rough embodiment idea, there are some things to keep into account. There are three stages in the process of an embodiment being effective: Interaction with the embodiment, internalization of the target mental model and application of the mental model. This part of the framework provides cues to make each stage succesful.

This part of the framework can be considered as a checklist. The three steps it covers are:

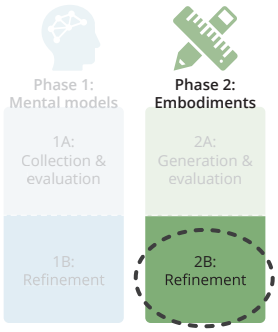
1. nteraction with the embodiment. For any target mental model to be potentially transmitted by an embodiment, people have to interact with it. For this step, interaction should be stimulated.

2. nternalisation of the target mental model. Once people interact with an embodiment, it has to stimulate people to internalize the embodied target mental model. Displayed on this sheet are several factors that influence the likeliness of internalisation.

3. Application of the mental model. Once someone has the right mental model the goal is not yet reached. They still have to apply it in order for behaviour to change.

All three above steps should be stimulated. The principle of the weakest link is applicable here.

Note that not all cues will be relevant for every embodiment + target mental model combination.



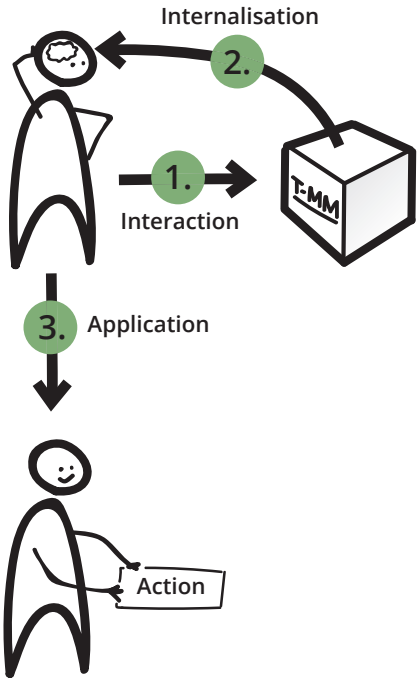


Figure 23 Refining the embodiment sheet: 3 levels of stimulation

1. how to stimulate **interaction**

- make it automatic → put embodiment on existing touchpoint
- activate using emotion → e.g. curiosity

2. how to stimulate **internali-sation**

- facilitate repetition of exposure
- make more believable → show credible source
- make it relevant for the target group → use personal data for explaining the target mental model
- let the target group apply the found mental model to strengthen the internalization

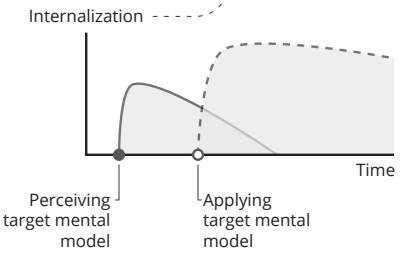
both

- increase self-efficacy → encorporate tips for mental model congruent behaviour
- increase self-efficacy → let people interact with demo-feature, increasing perceived ability to have an influence

3. how to stimulate **application**

- make memorable → provide visuals to enable a mental representation
- decrease distance between embodiment and target behaviour (the 'just in time' principle)

A mental representation is the image people "see" when thinking about something that is not actually around.



Refining the embodiment sheet (on previous spread)
It was investigated in what ways design for emotion (Desmet, 2012) can be a handle on the three levels of stimulation. First, an emotion can be evoked by the embodiment, leading to people becoming interested in interacting with it. For example curiosity may be used to stimulate interaction. Secondly, the content of the mental model itself can evoke an emotion, leading to a certain action-tendency. For example, knowing the curious fact why black plastic cannot be recycled (because black surfaces do not reflect the light of the scanner) may give a micro-kick, making people remember it better and apply it more.

Most of the success-factors originate from analysing the collected embodiment ideas. Examples for embodiments for each strategy can be found in appendix F. However, some were found in literature. Lakoff (2004, p. 25) suggest that repetition is key for establishing a frame. For mental models this likely also is a success-factor for internalization. Furthermore, credibility of the source is conducive to attitude change and behavioural persuasion (Pornpitakpan, 2004). The strategy of applying a mental model soon after learning about is to increase internalization is based on the finding that applying knowledge boosts internalization (Tsai & Lee, 2006). Additionally, incorporating tips on how to do the (implied) target behaviour increases self-efficacy (and actual ability) and through that the occurrence of the behaviour (Staats et al., 2004). Lastly, letting people interact with a demo-feature can make complex interrelations tangible and therefore malleable (Bendor, 2018) which should increase people's self-efficacy.

Additional behavioural change mechanisms
Besides the mental model approach, other design for behavioural change mechanisms should be incorporated while designing. For example think about the recycle-fee printed on a receipt. It states that the fee has been paid by the producer before any effort (putting it in the recycling bin) is asked from the consumer. The reciprocity effect (Cialdini, 2001) works in parallel with the mental model; consumers may become more inclined to cooperate after "receiving" something first. Likewise, other persuasive strategies can and should be applied while also using the mental model approach.

We've started off this chapter by looking at the collecting of embodiments. Next, similarly as in the part on mental models, the collected embodiments were analysed through clustering -inspired by insights from the literature. It consists of different ways a mental model may be embodied, how the embodiment can be evaluated and subsequently how it could be refined.

Now that the framework is complete, it should be tested. Is its content actually useful for designers? We'll have a closer look at this question in the next chapter.

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5 Testing the framework

Does the framework help designers in embodying mental models? Which parts work and which parts do not? And do designers even understand the concept of mental models?

These questions were the basis for this chapter. The (theoretical) framework is translated into a (more practically usable) toolkit that was tested by design students. We'll look at the test results of- and recommendations for the toolkit.

To investigate the framework's usefulness it was tested with design students. The goal of the test is to determine whether the framework in general, and specifically which parts, are helpful in choosing and refining a mental model (part 1) and translating it into an embodiment and refining this embodiment (part 2). There are two aspects that influence the usefulness of the framework:

• First, the usability of the framework can form a barrier. It may be confusing how to use it and unclear what the different terms mean;

• The second component is the content of the framework. There it is about whether the different elements of the framework are useful in their corresponding steps of the process.

1 From framework to toolkit

The framework is very theoretical. Solely the abstract content of the framework would not directly be usable by designers. For this reason, it was translated into a toolkit. The content is the same, only the level of explanation and guidance is higher. In this translation from framework to a toolkit, the following adaptations were made:

• A clear order in which the different parts can be used was constructed (parts 1A–2B);

• A guide talks the designers through the process;

• The checklist cards were added to aid the designer in going through the theory parts of the framework;

• Each part is accompanied by concrete examples for inspiration.

The toolkit is what was presented earlier in the report as the framework because while the content is identical, the toolkit contains more explanation and examples –making it suitable to explain the underlying framework.

The purpose of this version of the toolkit was to be able to test which parts of the framework are useful for designers. Therefore, each part of the framework was included into the (intentionally overly extensive) toolkit.

6.2 Test setup

The scope of the test is almost as it would be in real life. However, the first part of collecting the current beliefs and motivations and the potential mental models would take too much time. Therefore, the test speeds up this process by providing a shortlist. It contains a persona which includes current beliefs and motivations (see appendix G.1). This persona is based on the interviews described in chapter G.2. Next to the persona, the shortlist includes a fact-sheet with potential mental models. The fact-list also contains non-mental model facts. This functions as a small test, to see whether the participants understand what defines a potential mental model.

Two master design students acted as participants. The test started with an explanation on mental models and the toolkit. Next, instead of providing them with a written guide, the more time-efficient and flexible option was chosen to let this report's author act as the guide personally. In that way, explanation could focus on the specific questions of the participant at the moment they arise. The moderator guide can be found in appendix H.

The test took 4 hours and was concluded by a lunch during which the workshop was discussed.

6.3 Test results

Below, the concept developed during the test is discussed, after which the test results are discussed per part of the toolkit.

Concept developed by participants

The participants chose the target mental model of the circularity of trash: It is sorted, transported to a recycling plant, processed to a usable resource and made into new products, which eventually become trash again. This mental model connects to action by increasing the perceived effect of recycling. It shows that recyclable materials are actually being recycled (instead of, as many people believe, being combined with regular trash) and that they are valuable input for new products (which many people also do not believe). The concept developed in the test is Loop-a-Loop: A playground design for children that communicates the entire process of recycling, from trash to new product (see figure 24).

This concept is characteristic to a large portion of initial embodiment ideas generated during this project: A mental model is forced into a design quite literally. The system that the mental model describes is transcribed directly to a design in the world. This makes for a quite unnatural intervention: It is highly explicit in its intention, very circuitous (and therefore often also inviable) and it requires a lot of effort to interact with. This can be partly ascribed to the test being very short (especially the design part: 2A and 2B), allowing few design iterations to improve it. However, it is also an inherent difficulty of the mental model approach in design (see chapter 5.5).

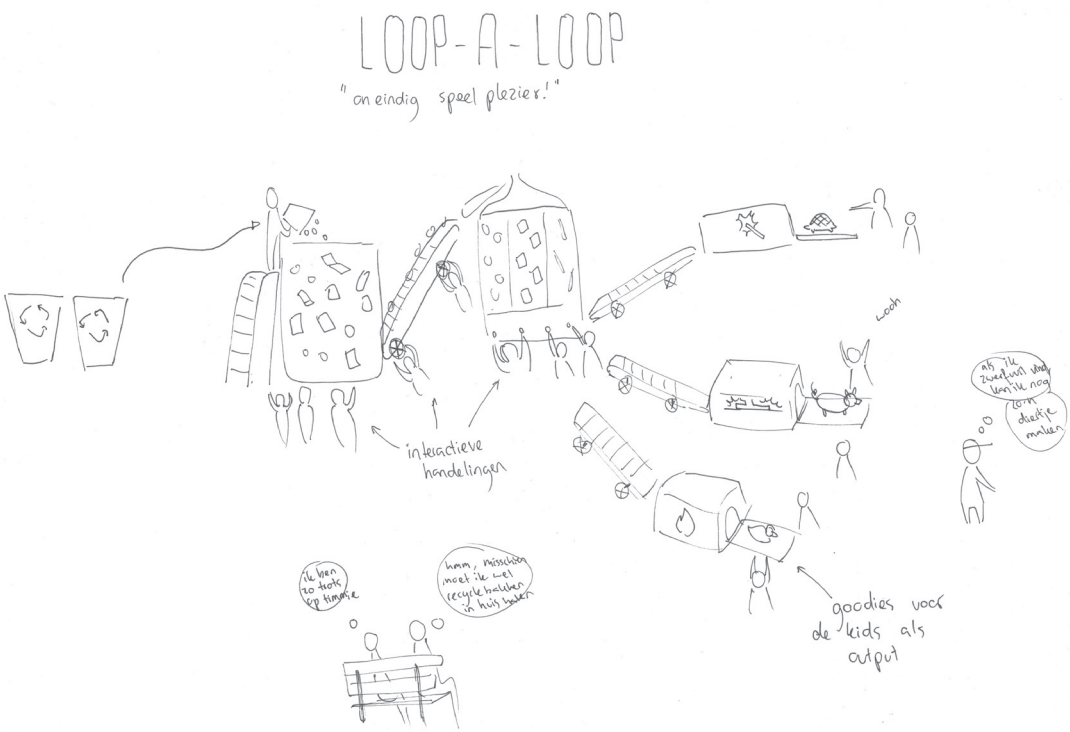

Figure 24 Concept developed during test: Loop-a-Loop

Part 1A: Mental model collection & evaluation
First of all, the explanation about what a mental model is exactly was unclear. This was also manifested in an uncertainty in identifying mental models from the fact-sheet provided. During part 1 (both A and B) this blurriness complicated the process. In discussing the definition together with the participants, key elements for them to understand it emerged, serving as input for a revised explanation (see chapter 5.4 Mental model explanation for a separate section on this).

The first sheet of part 1A (Connection to action) was perceived as most difficult. It is a very complex piece of information and it is too much to give at once, on one sheet. The examples accompanying the different strategies are not all described in enough detail. However, once the different strategies were explained more by the guide, they made sense to the participants and they could identify to which category each potential mental model belongs.

Relation to current beliefs and Mental model openness were clear. Only the distinction between behavioural- and domain openness were not clear without an additional explanation.

The checklist card was perceived as helpful, guiding the participants through the different elements of part 1A. The scoring was seen as a helpful way to compare them and the participants reported that the higher score aligned with their intuitive preference.

Part 1B: Mental model refinement
The Mental model complexity sheet was clear directly. This was expected since it is a rather simple element: It is about only one dimension of a target mental model. The Explanatory emphasis: How vs. Why is a bit less simple and therefore also needed some more explanation in the form of the examples on the sheet in order for the participants to get a feel for what this dimension entails.

Checklist card 1B was also seen as helpful, although it was deemed as less necessary than in the more information-dense part 1A.

Part 2A: Embodiment generation & evaluation
At the part of creating embodiments the participants came into their element: Designing. This part of the toolkit was perceived as much more clear. However,

the quantity of strategies presented at once in both part 2A and B was again overwhelming.

The created embodiment ideas were mostly very close to the example of each strategy provided in the toolkit. This means that they are helpful in creating the ideas, yet also that it may hinder generating truly creative ideas that are optimally fitting to the design situation. The tight coupling can also be partly ascribed to both the test-case and the examples in the toolkit being about recycling or sustainability.

Checklist card 2A was necessary: The participants did not intuitively know how to decide on an embodiment idea. At the same time, it was a bit too time consuming for this relatively short session. After going through the card once, the participants got a better sense of the requirements an embodiment should meet and they were able to pick one.

The sheet Embodiment explicitness was added only after the test, so was not included.

Part 2B: Embodiment refinement

Like some of the other more crowded sheets, Embodiment refinement was a bit too much at once to comprehend. The participants had to deliberately make sure to stop and think a while about each sub-strategy to understand them.

The toolkit in general

For some of the sheets (Connection to action, Ways to embody and Refining the embodiment) there was too much information at once. It was overwhelming in this form and it was too much for such a relatively short test. The checklist cards however were appreciated by the participants for providing a handle on the more theoretical parts of the toolkit.

The process of going through the toolkit was experienced as strictly linear. Therefore, new insights (e.g. that a certain mental model is difficult to embody) did not lead to a step back and a revised choice.

At all parts of the toolkit there were some unclear strategies, which have been clarified.

4 Recommendation for toolkit

For the toolkit to be applicable for designers it has to be iterated on and tested further, probably multiple cycli. Two main problems emerged during the test: First, the concept of mental models was not completely clear. A new explanation has been devised, as described in the next sub-chapter. Secondly, the toolkit was overwhelmingly complex. The next iteration should be simplified. It would have to be more compact, only containing the key elements. Perhaps in long-term projects complexity can be added back in, but this should happen gradually and only once the designer has become familiar with the basics. The key elements which should be included in a next iteration of the toolkit are:

• Connection to action. This is the basis for the mental model approach to design for behavioural change: The mechanism through which a mental model can influence behaviour.

• Mental model openness. An important benefit of using mental models is that it can be applicable to many behaviours and in different domains. However, these two dimensions of openness may be simplified into one; general openness.

• Mental model complexity is intuitive and easy to understand, so this can be included without adding much strain.

• Ways to embody clearly is crucial to the mental model approach, just as Connection to action. Without strategies to embody the mental model, the approach is of no use for designers.

• Embodiment explicitness (of which the sheet was added after the test) has turned out to be an important factor for the quality of the embodiment and should be included in a next iteration of the toolkit.

• Refining the embodiment. It is an important step to refine a rough idea into a more well-rounded concept.

Furthermore, a more suitable format for the crowded sheets (Connection to action, Ways to embody and Refining the embodiment) may be cards. Using separate cards instead of a big sheet, the designer can focus on one strategy at a time instead of being presented with all of them at once. For Ways to embody, if the example for each strategy would be on the back of each card, designers may be less likely to literally transcribe the example to their situation and thus more likely to create a solution truly fitting to their context.

To prevent the embodiment concept becoming circuitous and highly explicit there should be:

• A more prominent focus on existing touchpoints in which the embodiment can be incorporated more naturally;

• More attention for an embodiment idea's viability and implicitness before choosing on a concept;

• More time reserved for iteration.

Finally, a more iterative way of going through the toolkit should be stimulated: New insights should lead to adapting choices made earlier in the process.

Mental model explanation
Since the concept of mental models has to be explained more clearly, the input from discussions during the tests was used to formulate a new explanation. Next, tests were executed with design students to refine the explanation by letting participants read the 400 words of explanation. After three iterations, an understandable explanation was composed (see appendix I).

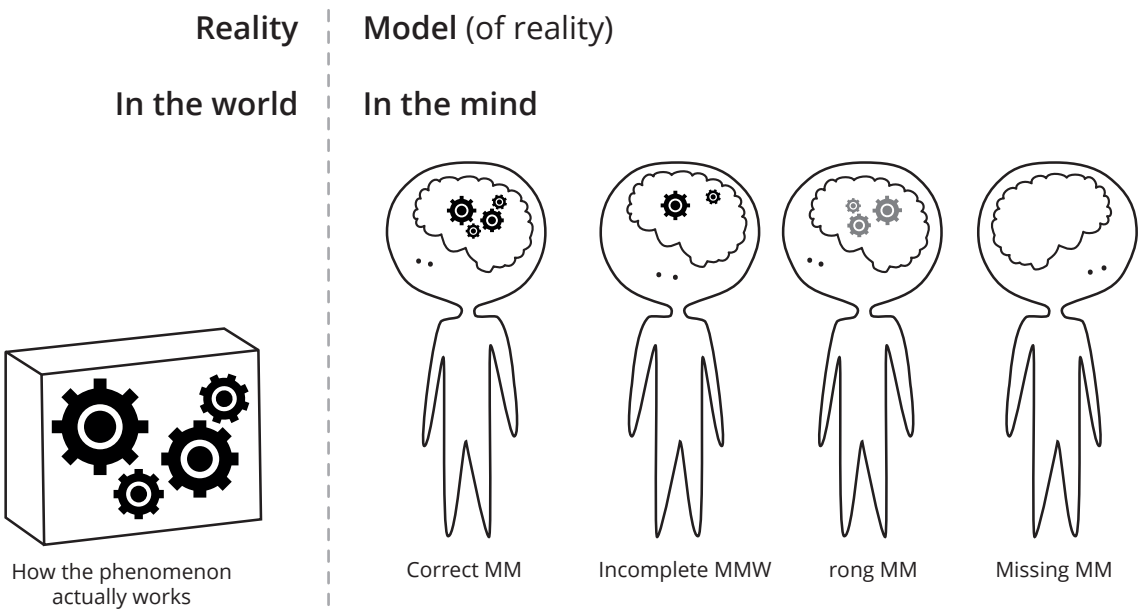

Figure 25 Mental model explanation visualized

The elements in this explanation that seem to work for designers (see figure 25) are:

• There is a distinction between phenomena and models of them;

• Phenomena are in the world, while mental models are in the mind;

• Phenomena are the objective reality, while mental models of it may be false, incomplete or missing and differ between people;

• A mental model can be seen as a chain of discourse, describing the elements that make up this chain and how these relate to each other;

• A mental model explains how things work, which explains why things are as they are.

5 Pitfalls of the mental model approach in design

As mentioned in the test results, there are some pitfalls in using the mental model approach. In many initial embodiment ideas generated during this project a mental model is forced into a design quite literally. The system (which the mental model describes) is transcribed directly to a design in the world. This creates some pitfalls:

• The system that the mental model describes is literally transcribed to a design. For example, the Loop-a-Loop circular playground developed by students in the toolkit test is one of these kind of translations. Such a forceful way of designing leads to unnatural, circuitous interventions:

> – The intervention becomes infeasible. For example, communicating how a recycling plant works by putting the plant itself on a prominent location and making the façade from glass may theoretically work, but has a disproportionate cost.

– The intervention requires a lot of effort and initiative from the target group. For example for the same mental model as mentioned above, we could put cameras in the entire plant. There is a QR code on each trash–bag, which people can scan with an app. In this way, they get a live–stream of their trash being processed into new resources. Although this could be a highly engaging way of explaining the mental model, it requires people to download an app, scan a code and watch a stream –which is not likely to happen.

• Another pitfall is that the embodiment ideas become very explicit. Mental models are much more easily conveyed explicitly –explaining it with text, diagrams or video. However, this takes away much of the benefit of the mental model approach: It may remain unnoticed, not trusted or lead to reactance.

• Yet, when not explaining the mental model explicitly there is the risk that people may not get it. Some embodiment ideas require a high inductive attentiveness from the target group. For example, consider communicating the mental model that recycling (while it does save resources) costs energy (and therefore making preventing or prolonging use better). An embodiment idea is to print on a plastic supermarket bag “40% material, 60% energy”. However, inducting the corresponding mental model may require more attentiveness than present.

The pitfalls in the concept created in the test can be partly ascribed to the test being very short, allowing few design iterations. And although it is also an inherent difficulty of the mental model approach, patient designers should be able to overcome them by critically evaluating initial ideas and iterating on them thoroughly.

As expected, the toolkit was not completely usable. First of all, the concept of mental models was not entirely clear to the participants. To tackle this issue, a new explanation was devised and tested. Furthermore, some parts of the toolkit were overwhelming in the amount of information presented at once and the toolkit in its entirety was too complex for a first encountering with it. However, looking forward, these issues can be overcome as discussed in the recommendations.

Finally, some pitfalls that the mental model approach in general is susceptible to are discussed. In the next chapter, we will discuss the results while revisiting the research questions.

6 Discussion & Conclusions

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The framework developed has been tested (although briefly) in the previous chapter, and throughout chapters 3 and 4 we have gathered quite a few mental models and embodiments. What answers can these provide on the research questions? And what should happen next?

6.1 Discussion

Before answering the main research question, let's take a look at the sub questions:

Sub question: In what ways can mental models influence behaviour?

Eight mechanisms were found through which a mental model can influence behaviour. For example by enabling performing the target behaviour, putting a situation in perspective or increasing a good behaviour's perceived effect (as defined in Connection to action, chapter 3.3). Furthermore, mental models have a fundamental effect on behaviour since they guide people's reasoning. Compared to other interventions that aim at changing only the symptoms (e.g. putting healthy snacks at eye height in a supermarket), the mental model approach may have a more transformative effect.

This answer points in the direction that there may be potential for mental models in design for behavioural change. If they can be influenced by design, that is. Which leads us to the next sub question:

Sub question: In what ways can a mental model be communicated through design?

As presented in Ways to embody (chapter 4.1), 21 ways were found in which a designer may convey a mental model. This involves not only product design, but also that of surroundings, buildings, services, apps, ads, policy, etcetera. In short: Anything that designers can manipulate to give people a certain mental model.

However, many of the first iterations of generated embodiment ideas are not suitable. There are some pitfalls that initial embodiment ideas are prone to, as discussed in chapter 5.5. Yet, these pitfalls certainly do not always occur. The examples presented (such as the recycle fee on the receipt, the visible PMD container, the lease contract, the traffic light trigger and the rain sensor for cyclists) manage to elude them.

These answers suggest that, although there are some pitfalls, there is potential in a mental model approach to design for behavioural change. The guiding questions may shine a light on how big this potential is.

Guiding question: What types and dimensions of mental models exist?

There are five types and dimensions of mental models (constituting part 1 of the framework), such as a potential mental model's openness and its relation to current beliefs. These can help designers in choosing a target mental model and subsequently tweaking it for an optimal effect on behaviour. For example, the dimension of openness led to two types of mental models: General principles and Proving mechanisms (chapter 3.4). A general principle (e.g. about the ripple effect) is applicable to different domains of life, potentially having a broad impact on behaviour. On the other hand, a proving mechanism is specific (e.g. about the recycling fee for producers). This type of mental model is suitable to target behaviours which are currently inhibited by persistent false beliefs.

Guiding question: What makes a mental model design effective?

Ten factors have been identified (see chapter 4.1 and 4.2) which may increase the success of an embodiment and overcome the pitfalls of the mental model approach as discussed in chapter 5.5. For example, interaction with an embodiment may be made automatic by putting it on an existing touchpoint. Another example is the distance between the embodiment and the target behaviour, which should be decreased as much as possible to minimize relying on memory.

Although the framework has been subjected to a small test on its usability and potential to help designers generate embodiment ideas, it has not yet been validated whether the embodiments are effective in changing mental models and (subsequently) behaviour (see figure 26). Using literature (and common sense) it has been made plausible that the mental model approach can be effective for behavioural change, yet validation lacks.

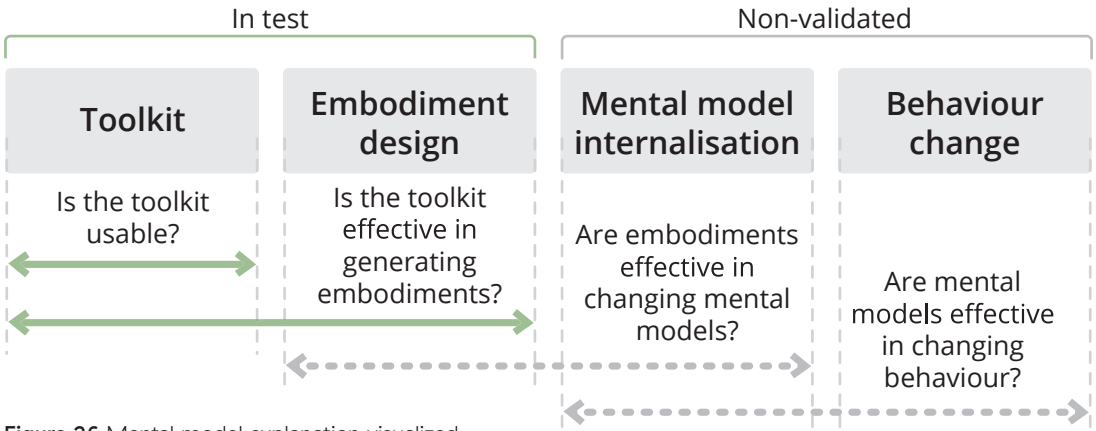

Figure 26 Mental model explanation visualized

6.2 Conclusion

Now, on to the main research question:

Is there potential for designers in changing mental models for behavioural change?

The answers on the sub– and guiding questions suggest there is potential to stimulate behavioural change by designing mental model embodiments: A wide range of handles is uncovered for designers to work with. These handles support the designer in composing, evaluating and refining a target mental model and its embodiment.

That doesn't mean that it is easy to design an effective embodiment. It takes a persistent designer to keep on iterating to circumvent the pitfalls prone to the mental model approach. Also, further research has yet to validate the causations of embodiment to mental model and mental model to target behaviour.

The framework seems to be a good basis for exploring mental models and designs that carry them in future research. Furthermore, the framework and the initial toolkit as drafted in this project provide a good starting point for developing a more usable toolkit.

The mental model approach can be considered limited in the sense that it should be used in tandem with other elements of design for behavioural change. However at the same time it is broadly applicable: Not only in the field of designing specialized behavioural interventions, but also for design in general. It uncovers and provides handles on a universal element of design: Many designs explain, or could potentially explain, a mental model. The mental model approach offers a way of making this omnipresent element of design explicit. And although the term mental model was already present in the design field of human factors, this project has demonstrated that it can be applied with a drastically wider scope: The mental model approach goes far beyond usability and user interfaces, as the mental models it helps create can be about anything in the world and the embodiments can take any shape.

The theoretical content of the framework itself has some limitations:

• The framework is based on a selection of mental models and embodiments, which were analysed by only one researcher. Although literature was used to guide the analysis where possible, the process of analysing by clustering is

subjective. As mentioned before, the strategies resulting from the clustering should be validated on their effectiveness.

• Also, the selection of mental models and embodiments used is not exhaustive. It is limited by both the amount of data used as well as the scope of the project: Plastics in the circular economy. It is unclear to what degree it is complete and whether it is applicable in different domains. However it certainly offers an elaborate basis for further research to iterate on and complement.

5.3 Recommendations

• First of all, the assumption that embodiments lead to target mental model internalization and that this predictably stimulates a target behaviour should be validated experimentally. Such an experiment could be set up pretending to be about something else to avoid that people interact with the embodiment more consciously than they would in daily life. During the fake task, half of the participants interact with the embodiment. After the task there is the possibility to display the target behaviour. This behaviour could for example be properly (as explained through the embodiment) disposing of a coffee cup they were offered before the experiment. Furthermore, a post–experiment questionnaire should inquire the participant's mental model. In this way, a change in the mental model and behaviour that is expected to be associated with it can be measured.

• The toolkit should be refined into a practical and understandable (probably highly simplified) tool. See chapter 5.4 for specific directions.

• The framework is based almost entirely on examples in the domain of circular plastics. Different contexts may require different strategies. Therefore, its applicability in other domains should be tested and the framework should be supplemented to be more generally applicable if needed. For example the domains of healthy eating, nuclear energy, vaccination and happiness may lend themselves for a mental model approach because they contain interesting underlying phenomena which are not yet well understood. A potential mental model about food could for example explain how sugar (e.g. versus fat) is

processed by the body and how it affects metabolism. An example of an embodiment in the domain of vaccination is described on page 94–95, and in the following paragraph the application of the mental model approach in the domain of happiness is discussed.

• The intention for the framework as developed was to have an influence on behaviour. However, it may also have an influence on subjective well–being, without necessarily changing someone's behaviour. Therefore, the domain of Design for happiness may be an interesting one to explore with the mental model approach. This domain will be explored further below.

The mind is its own place and in itself, can make a Heaven of Hell, a Hell of Heaven - John Milton

Happiness is for a big part determined by our minds, instead of (only) by the circumstances. So why not try and give our minds some new ways? Seeing (by understanding) things differently can have a great impact.

– For example consider this metaphor for the human mind: The mind can be seen as the combination of a rider on an elephant (Haidt, 2006). This indicates a dichotomy in humans: The rider is the conscious, rational part which tries to steer the much bigger and stronger elephant (which behaves without awareness, led by habits and emotions). The implication of this is that our conscious thinking (the rider) cannot forcefully dictate our habit– and emotion–driven behaving (the elephant). It can only nudge the elephant and train it. Having this mental model should give people a different relati–onship to (or perspective on) their own thinking and behaviour, resulting in a different (more positive) experience with it. It may also enable them to create more effective strategies in changing their own behaviour to reach their goals.

– Another concept in positive psychology (and positive design) is hedonic adaptation. It states that (to some degree) we adapt to the circumstances in our lives, returning back to our individual happiness set–point. Particularly positive feelings related to material possessions are short–lived since we get used to the new objects quickly when interacting with them becomes habitual. Experiences on the other hand (e.g. a holiday with a friend or a hike in nature) are much less prone to becoming a habit; they are finite in nature and we usually have a higher awareness about them. Furthermore,

they can increase relatedness to others who participate. Knowing how this works (having a mental model on it) can increase happiness by enabling people to make better choices about how they spend their time and money.

Many more examples of (hypothesized) happiness-increasing mental models exist, originating from (positive) psychology (e.g. about the workings of savouring, the paradox of choice or adversity and its often surprisingly beneficial effects). These will however be difficult to embody naturally since the systems they explain are not visible in the world, but exist in our minds. Additional strategies to compose and embody these would have to be developed, yet the framework (mainly parts 1B, 2A and 2B) should offer a good start.

• Besides testing the effect of an embodiment on one specific behaviour, also the open applicability of more general mental models (coined general principles in chapter 3.1) should be tested. These general principles can be applied to different domains of life. However, there will be a (probably temporal and contextual) limit to the likeliness of application of such a mental model. Where this limit lies and which factors influence it should be investigated.

• The mental model approach developed in this project is aimed at designing for behavioural change. However, some of the mental model dimensions and the strategies to embody could also be applicable in the field of human factors. As discussed in chapter 1.1, mental models are considered within the field of usability. However, few concrete handles are provided on how to design (with) them. Human factors research could draw from the framework developed here to get a better understanding on how to design (for) target mental models.

• The discussed benefits of using the mental model approach may also apply to traditional (explicit) communication interventions: It could make them more credible and interesting and facilitate a sense of autonomy, leading to a higher adoption of the message and behavioural intention.

– For example, think about the target mental model of vaccination. A significant percentage of parents refuse to vaccinate their children "unnecessarily". Unvaccinated children not getting sick is proof for them that it is not needed. A video ad (see figure 27) could show one person walking the street blindfolded. Others get out of his way as to not bump into him. The next shot, everyone is blindfolded which creates all sorts of collisions. This

metaphor (Haenen, n.d.) represents how viruses spread: It is dependent on the vaccination (non-blindfolded) coverage.

• The cognitive focus of this project lays heavily on conscious system 2 (Kahneman, 2011) processing. This means that the information that an embodiment provides is assumed to catch someone's attention, leading to a mental model which is used in reasoning. The reflexive system 1 on the other hand is characterized as making quick decisions based on little information. The degree to which Kahneman's fast and automatic system 1 is receptive to embodiments and makes decisions based on mental models is assumed to be low, but this is not verified. Future research may look into this, since this has implications for the way embodiments should be set up.

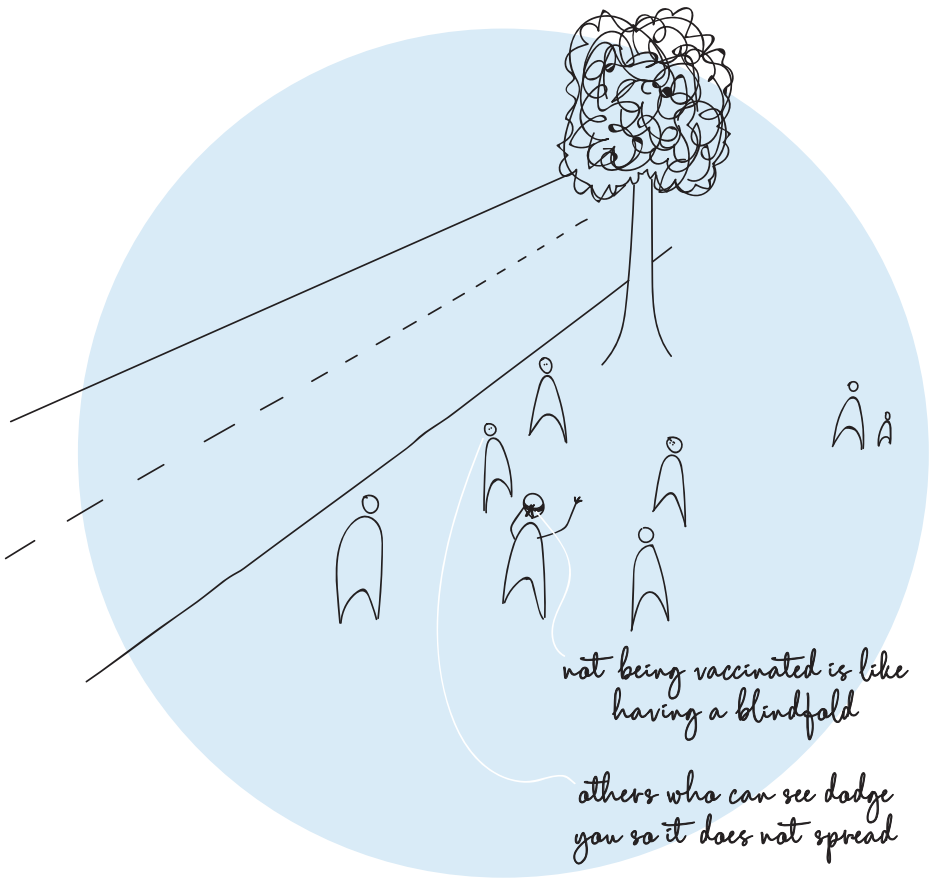

Figure 27 Mental model explanation visualized

We've reflected on the results and we drew conclusions. The framework and the initial results from the test helped to concretize an answer on the research question:

Yes, there seems to be potential in the mental model approach to design for behavioural change. It will require more exploration, but the framework and the lessons learned in this project should provide a good basis.

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