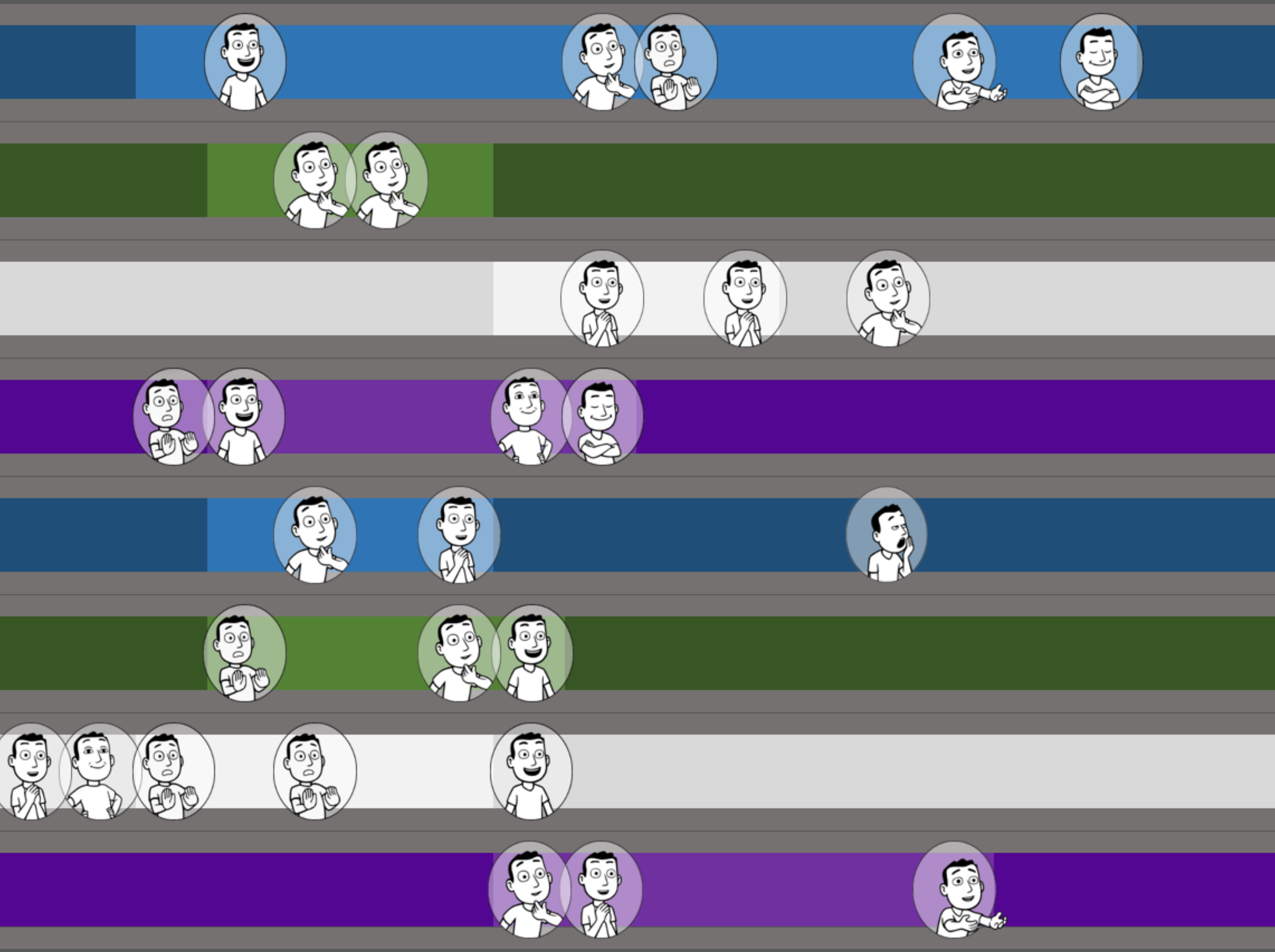
Master thesis, Design for Interaction

Responding to Micro-Emotions:

Towards neutral interactions between pedestrians and autonomous delivery vehicles



July 2020

Wietse Bosch

TU Delft

During my study I discovered the power of ADHD and dyslexia.

Although that wasn't easy, I'm now more confident than I was ever before.

For everyone who is prepared to support studying in a different way:

"Hello, you may not know me but do you want to join my party?"
- Buck van der Ploeg

I want to thank Zoltan and Jered for joining my party. All the way…

Responding to Micro-Emotions:
Towards neutral interactions between pedestrians and autonomous delivery vehicles

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Abstract

The way an autonomous delivery vehicle behaves during an encounter with a pedestrian evokes an experience comprised of many short-term emotions, influences which behaviour that person will use in reaction to the robot. In many cases, for both the negative and positive experiences, behaviour emerges that results in time-consuming encounters. This time could be used for deliveries but in order to have a neutral interaction a behavioural change is required.

Prior work by Desmet has mapped these ‘micro-emotions’ and described how they can be used to drive product design and shape product experience. As the sensing capacities and intelligence of our artefacts are increasing new opportunities arise. ***Could these micro-emotions also be used to shape the experience while a product is in use?***

We conducted a case study on an encounter between pedestrians and a small delivery robot. A clustering, based on people’s initial micro-emotions and experience, seemed to effectively capture how they would subsequently respond to the robot. We were able to design robot behaviour from these ‘emotion-clusters’ that helps to shape people’s response and experience according to achieve a time-efficient/neutral encounter. This concept opens up the exciting new design space of products that actively respond to micro-emotions.

1. Introduction

Our emotions play a key role in how we experience and react to the world around us. They can tempt us to throw a mobile device if interacting with it makes us sufficiently frustrated, or they might cause us to eagerly engage when we run into a robot on the street that makes us feel curious.

Last-mile delivery robots are more and more used throughout the world [ref], where these autonomous vehicles deliver orders to customers. For companies, this method of delivering brings low costs and at the same time it increases the time-efficiency of deliveries themselves. Because of these benefits for both companies and customers, we foresee a big increase in the number of robots that will join the sidewalks in the near future.




At this moment, delivery robots are designed first and foremost to interact with the main stakeholders: company employees, their customers and the people who intend to damage or steal from the robot. The robots are less designed for the secondary stakeholders: the pedestrians on the streets who encounter these robots without illegal or harmful intentions. Although most pedestrians behave similar to a robot as to other pedestrians, we noticed many recordings on open platforms, like YouTube, where pedestrians get curious or being playful and approach these delivery robots to interact with them (see Figure 1).

Figure 1: A pedestrian tries to steal from a delivery robots and teases it in the process (https://www.youtube.com/watch?v=UPZwnc_Lk2M) .

Pedestrians in these kinds of situations get triggered by the robot's behaviour, which in turn motivates them to start an interaction. These interactions are time consuming and therefore increase the robot's delivery time. Since the motivation of the pedestrian emerges from the robot's behaviour, it is the robot that makes it worse by repeating the same behaviour. The only solution robots have at the moment is to wait until the pedestrian loses interest and end the interaction. If the robots could detect and adapt to the pedestrian behaviour, they could influence the situation and therefore end it sooner, which would increase its own time-efficiency.

Table 1 shows the categories we created to order the different kinds of undesired pedestrian interactions which reduce the time-efficiency of the robot. These categories show that undesired pedestrian behaviour isn't always triggered by negative or illegal motivations. Because these interactions emerges from human behaviour, which is complex, there are many situations imaginable where a robot will end up in such a time consuming interaction. Because of this broad range of possible undesired pedestrian behaviours is the task of developing adaptive robot behaviour very complex. Every situation requires a specific, different robot behaviour in order to shape the pedestrian behaviour into a desired interaction.

1. Teasing pedestrians	2. Playful pedestrians	3. Unable pedestrians	4. Unaware pedestrians
			
Pedestrian engages a robot to see their reaction by actions like standing close to the robot or by running along with it. These actions emerge from this motivation and cause an obstacle for the robot. results in actions like blocking the road or running along. Because the pedestrian experiences some form of curiosity, it will behave this way until this feeling fades. https://www.youtube.com/watch?v=ujzjZuhE92g	An explorative child wants to play with the robot. The child in this situation gets more excited by every reaction from the robot because it seems like an invitation to play with it. The unpredictability of playful behaviour makes it difficult to predict if there will be a collision and, therefore, is the robot unable to just continue driving. https://www.youtube.com/watch?v=V1oG66fX2_4	People with limited capabilities to see or hear their environment have to communicate in different ways. For example, a blind person has to rely on hearing the robot in order to avoid a collision. From the perspective of the robot, this could seem like a human that behaves this way on purpose when the limitation isn’t detected.	People who are occupied and don’t noticed the robot, will block the robot’s path accidentally. In these situations, a robot makes pedestrians aware of its presence in such a way that they will be prepared to clear his path (which could become difficult if they get upset by the robot).

Table 1: Pedestrians have different activities and motivations to behave the way they do and although the good intentions of most of them, they still block the robot’s path.

When it isn’t possible to design suitable robot behaviour that fits all possible situations, we have to enable the robot to detect the specific situation and adapt to it. With current technology it’s possible to process behavioural data in the field (see Chapter 2), which leaves us with the question of how a delivery robot can detect specific undesired pedestrian behaviour. We did a research and created a concept that enables a robot to do this. In order to develop this concept, we combined our education (Design for Interaction) with our knowledge about autonomous vehicles.

Designers use micro-emotions (short-term emotions mapped over time [10] (see Chapter 2)) to measure and shape a product experience [9]. Seeing that robots ends up in situations with complex human behaviour, made us think about how to enable delivery robots to create their own product experience that lead to the desired pedestrian behaviour. This provided the question in this thesis “*Could we shape pedestrian behaviour based on detected micro-emotions during an encounter with a delivery robot*?”. Figure 2 visualizes our envisioned concept.

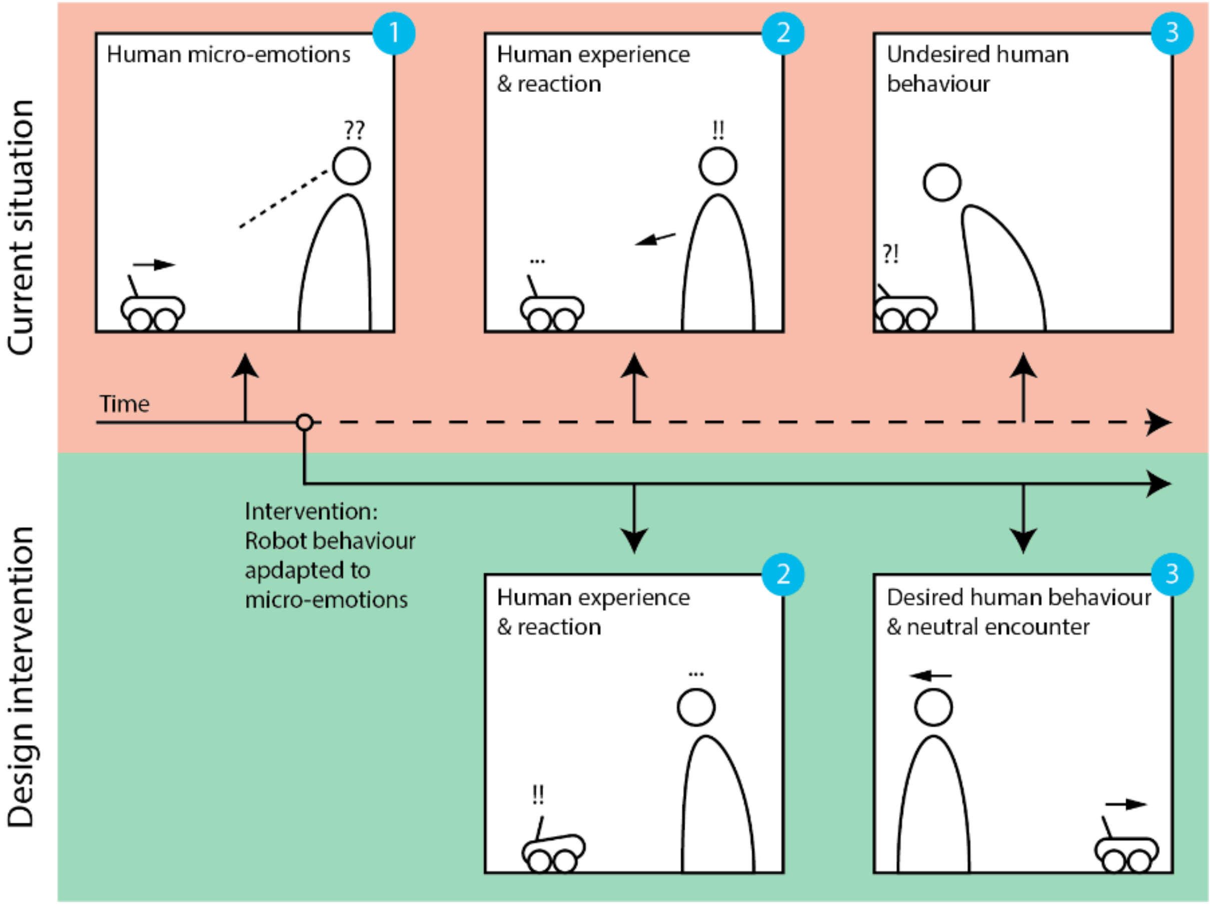


Figure 2: Current (undesired) interactions between delivery robots and pedestrians and the envisioned concept of adapting to micro-emotions to shape a pedestrian's experience to establish a neutral encounter.

Our research in this thesis is structured by: an exploration of the context in Chapter 1; the theoretical framework in Chapter 2; the developments of our methods included in the performed case study in Chapter 3; the insights from that case study are used to redesign adaptive robot behaviour in Chapter 4, which is evaluated in Chapter 5; and we finish with Chapter 6 where we discuss our findings, draw our conclusion and discuss our envisioned future developments.

In this chapter, we explore the context of a delivery robot on the sidewalk by an extended overview of the robot's, our observations to pedestrians who encounter autonomous robot's is used to define the scope and research questions of this project.

1.1. Benefits of using delivery robots

Delivery robots are used by companies to load their products and sent it, over the sidewalks, towards their customers (see Table 3) at any moment of the day. This approach, compared to traditional delivery methods, reduces delivery costs, improves delivery time and is easily extendable in terms of delivery capacity by adding more robots.

Table 2 shows some examples from companies that already use last-mile delivery robots to transport orders to their customers. For every company it shows the robot name, the company, the type of transport and what the primary motivation of the company to use this robot.

1. Starship	2. Kiwi	3. TeleRetail	4. Amazon Scout	5. Roxo
				
Company: Starship Technologies **Transport:** food **Motivation:** 'Instant delivery', 'lower costs' https://www.starship.xyz/	**Company:** KiwiBot **Transport:** food **Motivation:** 'Lower delivery costs', 'under an hour delivery' *https://www.kiwibot.com/*	**Company:** TeleRetail **Transport:** packages **Motivation:** 'Saving valuable time', 'reducing transport costs' *https://teleretail.com/*	**Company:** Amazon **Transport:** packages **Motivation:** 'A new delivery method that has the same qualities' *https://blog.aboutamazon.com/transportation/whats-next-for-amazon-scout*	**Company:** FedEx **Transport:** packages **Motivation:** 'Make deliveries flexible and convenient' *https://www.fedex.com/en-us/innovation/roxo-delivery-robot.html*

Table 2: Various delivery robots that drive autonomously through cities at the moment.

Based on this analysis to companies who use delivery robots, we can assume that the main benefits of this delivery method for companies and customers are the reduction of delivery costs, time and flexibility. These benefits are only achieved when their customers accept this delivery method as well. Customers who receive their order by a delivery robot have to trust that they protect their order during the travel and trust that they cause no physical harm. This can be seen in the current robot designs, which are focussed on demands from these, as we called it, main stakeholders. Every adjustment developed throughout our research must enable robots to meet these demands from the main stakeholders: the companies, their employees and their customers during an interaction.

1.2. Context of a delivery robot

Robot journey

Table 3 shows a robot journey, which contains main context of a delivery robot during a delivery. The journey starts with loading an order into the robot and sending it away; the robot travels the sidewalks towards the customer who receives the order and sends the robot back to the company.

1. Loading an order:	2. Driving to a customer:	3. Delivering the order:	4. Driving back:	5. Returning home:
				

Table 3: Robot journey of delivering an order: 1) loading an order, 2) driving towards the customer, 3) handing over the ordered items, 4) driving back to the company and 5) arriving back at the company.

The five phases described in Table 3 contain all people who interact with the delivery robot in use. Here the delivery robot picks up an order (1), drives on the sidewalk toward the delivery location (2), delivers the order (3) and then drives back (4) to the company (5).

During their travel on the sidewalks, robots meet different people, each of them experiencing the robot differently and, therefore, interacting differently. The robot therefore is required different kinds of behaviour during the different phases of delivery in order to optimize its time-efficiency.

All stakeholders the robot encounters during its use

The main stakeholders occur in the phases 1, 3 & 5. During the travel phases of the delivery (phases 2 & 4) occur different people – secondary stakeholders. We distinguished people who used the sidewalk as pedestrians and people who use the street as drivers. Table 4 shows an overview of all the stakeholders we consider relevant.

Stakeholder:	Journey phase:	Relevant robot interactions:	Encounter location:	Included:
1. Company employees	1,5	Sending robot with an order and receive the robot once its delivered	At the company itself	No
2. Pedestrians	2,4	Traveling with the robot: moving around it, walking next to it; walking behind it; etc.	On the sidewalk	Yes
3. Drivers	2,4	Encountering a robot that crosses the streets	On the streets	No
4. Company customers	3	Receiving the robot, taking their order and sending the robot back	At the delivery location	No

Table 4: All stakeholders who emerge throughout the robot-journey of a delivery robot in action.

Selecting relevant pedestrians for our research

Pedestrians occur alone, with their families or friends, hanging around, caring stuff or pulling a buggy and in many more variations. The combinations of these variations result in complex situations wherein a robot could end up. The robot should be able to deal with all of these situations in order to maintain its time-efficiency. To simplify the situation for our research its decided to create four groups of the main situations (see Table 5).

Single pedestrian	Groups of pedestrians	Sidewalk vehicles	Drivers (street-users)
			
An individual walks on the sidewalk towards his/her destination.	Young people enjoying free time, hanging besides the sidewalks.	A family walks around with a wagon or buggy.	Some pedestrians crossing the streets like the robot will do and encounter a car.

Table 5: An overview of all the different kind of the main groups of pedestrians that will encounter a delivery robot and could have an undesired interaction with it.

Our aim is to measure the influence of a robot on a pedestrian's behaviour. By complicating the situation of that pedestrian, we complicate our measurements, which could lead to wrong results and conclusions. To provide adequate results and conclusions we focus on the individual pedestrian.

1.3. Desired robot behaviour on sidewalks

Previously we discussed what is expected from a delivery robot and how pedestrian behaviour emerges. In this section we elaborate how we envision an idealistic encounter between robots and pedestrians, how pedestrian experiences relate to micro-emotions and what the possibilities are for robots to influence pedestrians throughout an interaction.

Neutral sidewalk encounters

When humans encounter each other on sidewalks, they effectively communicate about how they will pass each other. At least most of them. In a moment, it is clear for both parties that communication is needed to avoid walking into each other. This communication consists of non-verbal (or textual) communication like eye-contact (connection), pre-sorting (movement) or changing posture (body language/ hierarchical-status) to share intentions. This behaviour provides feedback to the other, who can react accordingly. In most cases this results in an encounter where both pedestrians keep their walk velocity (if there aren't any obstacles to prevent this). This method of passing each other on the sidewalk is most neutral and most time-efficient for all parties.

Just like an encounter with another human on the sidewalk, an encounter with a delivery robot requires a form of communication about who moves where to pass each other. In most encounters with a delivery robot, communication is established and the encounter results in the desired (neutral) interaction, but in some cases, pedestrians experience a trigger to start a time-consuming interaction.

Pedestrian emotions, experiences and behavioural reactions

Unfortunately for the delivery robot their current behaviour motivates some pedestrians to behave non-neutral which results in the undesired/time-consuming interactions. In these cases, their path gets blocked which forces them to slow down or to stop completely until the pedestrian decides to step aside. To understand why pedestrians might act this way, we asked ourselves what motivates a pedestrian to behave the way they do.

Every interaction is influenced by the behaviour of all involved parties. All human behaviour has an internal trigger upfront and so do pedestrians have. Every human behaviour is triggered by an experience from the situation around them. In the field of designing these situations are influenced by the product interactions. To adequately design product interactions, designers evaluate every individual event where a user could experience something that is called a micro-emotion. Combining all events shows how the total experience that is constructed. With the overview of all the micro-emotions is it possible to redesign the smaller parts that evoke the undesired micro-emotions and improve the whole experience (see Figure 3).

Interaction <- Behaviour <- Experience <- Micro-emotions

Figure 3: Build-up from human behaviour that will influence interactions with delivery robots.

If an experience can be reflected afterwards, it should be possible to predict what experience will follow by measuring and combining micro-emotions. For this reason we asked ourselves the questions: "W*hat micro-emotions emerge at the beginning of an (undesired) encounter?*" and "*Which aspect of the robot could influence those micro-emotions?*".

The robot's influence on neutral encounters

By researching possible patterns between micro-emotions and pedestrian behaviour, we intend to improve the delivery time and therefore not only improve the benefits for companies and customers who use these robots but also improve the communication between robots and pedestrians on the sidewalks.

So, why not build a robot that stands up a bit and gives strong opinions to increase its time-efficiency? Why should we only create nice interactions where robots look like the animated robot Wall-E? Well, although enabling a robot to stand-up for itself would help to improve its time-efficiency, but it would also negatively influence the experience from pedestrians who are encountered, which will finally (in extreme) lead to a terminator-like robot that forces its way to your house to bring food. Besides that I'm personally not happy to encounter such robot on the sidewalks or on my front door, I wouldn't like a company that uses this robots (and what if competitor robots get in a conflict?). So when we don't want terminator-robots on the sidewalks and Wall-E-robots are too kind to be time-efficient, we have to provide the robot with different behaviour to enable it to establish neutral encounters.

Figure 4: Different kind of robot designs we know from the movies (left Wall-E and right Terminator) which show how robot behaviour can be interpreted differently.

Human behaviour isn't always nice, but it serves a purpose. When people want to avoid contact or time-consuming interactions, they will communicate this by performing defensive behaviour that could prevent an encounter completely. A delivery robot as sidewalk-user will experience comparable situations where it should, in order to keep the same time-efficiency, prevent or reduce the required time for that specific situation. Delivery robots should therefore, just like humans, perform some form of defensive behaviour.

1.4. Main research questions

In this chapter we explored the context of a delivery robot which provided us the research questions to answer the main question: "*Could we shape pedestrian behaviour based on detected micro-emotions during an encounter with a delivery robot?*". In order to answer this question in Chapter 6, we have to answer the following sub-questions:

1. "*What micro-emotions emerge at the beginning of an (undesired) encounter?*"
See Chapter 3 for our case study where a participant encounters a seemingly autonomous robot and reflects on the experience and micro-emotions, which are explained in Chapter 2.

2. "How do micro-emotions lead to certain pedestrian behaviour?"
See Chapter 3 for the analyses of the results from the case study where we have clustered the results and explored patterns in the behaviours.

3. "*Which robot-aspects could influence those (undesired) micro-emotions?*"
See Chapter 4 where we redesigned the robot behaviour in order to adapt to the measured behaviour. In Chapter 5 we evaluated our redesigns with an online test with the same participants to get an indication from the relevance.

2. Theoretical framework

The introduced concept of improving the time-efficiency of delivery robots by looking at micro-emotions is based on existing research in areas like human-robot-interactions, social signal processing, social cues detection and processing and society design. In this chapter, we connect existing literature and research that explores a similar idea or supports our concept and enabled us to measure pedestrian micro-emotions and experiences. To be sure that our concept is feasible for a real-life situation, we explored the feasibility as well. With all this information, we conducted a case study which can be found in the Chapter 3.

2.1. Observing human behaviour around autonomous robots

To get a better understanding of the 'how' and 'why' behind the behaviour that pedestrians show around delivery robots, we drove around with a robot that seemed to be autonomous to observe the reactions and participated in an experiment that explored human reactions towards an autonomous robot. From these experiences, we collected many insights (see appendix) and we selected the most relevant ones for the research in Table 6. Visuals are added to show the context (and not to connect an insight to a specific observation).

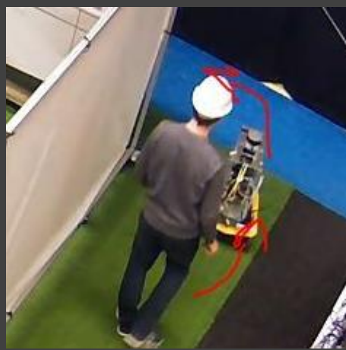
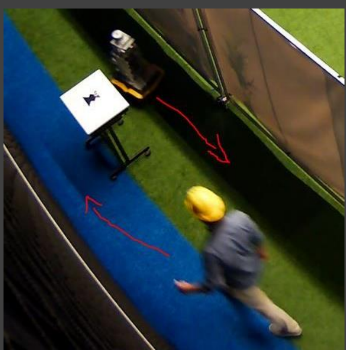
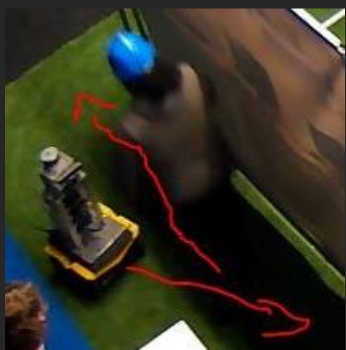
Keeping a distance	Evoked interest	Scary robot movements	Frustratingly slow robot
			
Because of the lack of space during an over taking this person preferred to hold on to the table in order to avoid any contact with the robot.	Autonomous robots evoke interest and some form of challenge by some pedestrians who get stimmulated to test the robot on it reactions.	By sudden changes in the robot's driving pattern it scared the people who walked behind him.	This person could not move around the robot when it drove slower. In reaction, the person got frustrated.
Clear communication	**Dominant human behaviour**	**Intentions in body language**	**Frustrating surprise**
			
By detecting the robot this person decided to move to the left side of the table. Both the robot and the pedestrian could continue.	The more this person got familiar to the robot, the more dominant he behaved. At this moment, the robot had to wait in order to continue.	By moving his shoulders in the direction he was heading, this person communicated on what side he intended to pass the robot.	The person waited for the robot, who stopped suddenly. This evoked frustration by the person who's path got blocked by the robot.

Table 6: Insights gained from our experiences with robot interactions and observation of putting a robot in a crowed.

2.2. Processing micro-emotions

Human behaviour and experience, including emotions, shapes product experience and can be shaped by it, but how can products be designed with this in mind? Micro-emotions have been introduced by Desmet to try and capture the emotional aspects of an interaction such that they can inform the design of products and their behaviour [11]. His work describes micro-emotions as internally experienced "short-term emotions", evoked by an event (such as an aspect of a product or its behaviour). Throughout an interaction, these micro-emotions together from an experience, which then motivates people in their reaction. This framing is used to capture and reflect on a design from the user's perspective, resulting in an overview of events and micro-emotions over time that provides insights and helps evaluate the product experience.

Rich-experiences and general-experiences – Rich-experiences are a combination between a positive and a negative emotion [15]. By experiencing both at the same time, it results in rich experience. We approach an general-experience as a combination of emotions, but we keep the option open to have all possible combinations for each emotion to be positive and negative.

Measuring micro-emotions – In current design practise, micro-emotions are commonly measured by tools like the PrEmo-tool (see Figure 5) or the emotion scan [10] – where a designer observes a user, documents event that evoke emotions and end with an interview where the user reflects on the events.

We used both of these tools to develop our own tool to enable users to reflect on specific events of their behaviour. An interviewer asks participants to reflect on their event-experiences by selecting from a set of illustrations from the PrEmo tool that expresses their feeling best and grading the intensity level they experienced it. This tool is used to measure micro-emotions in our case study (see Chapter 3).

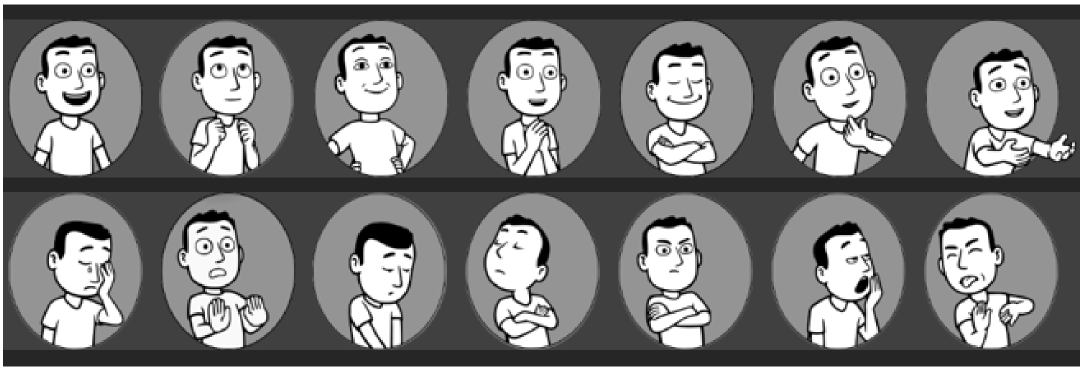


Figure 5: All used PrEmo illustrations with seven positive emotions on top and seven negative emotions at the bottom.

Though micro-emotions have a strong subjective quality – emotions are internally experienced – it is worth noting that they are also reflected in body language and facial expressions [12]. They can also be measured 'from the outside' as well, though doing so will, of course, be less rich than the aforementioned qualitative methods.

Automatic detection of social cues – Recent work in social signal processing [1][2] and affective computing [6][13] has made significant progress in the automatic detection/interpretation of social cues like body language and facial expressions. Examples range from detecting interpersonal attraction from wearable sensors [3] to the detection of subjective perception of a robot's behaviour from posture [8].

Those findings cannot directly be applied to the detection/interpretation of micro-emotions, as current work is commonly more focused on emotion-concepts rooted in psychology, not design. Crucially, a key difference is that micro-emotions flash by (much) quicker; this will put novel demands on the frequency and speed with which detections are to take place to be effective. Albeit, again, not directly from a micro-emotion perspective, work is already being undertaken in this direction, e.g. to handle data collected in the wild at a reasonable speed [4][16].

Overall, this suggests, that, while doing so will still bring its own challenges, it should be feasible to start working towards systems that might detect micro-emotions. Or, at least, towards systems that detect the outward cues that signal the inward experience of micro-emotions.

2.3. Delivery robots

Various companies are already deploying delivery robots on sidewalks, including both established companies that depend on package delivery, e.g. Amazon Scout, FedEx Roxo, and younger tech start-ups, e.g. Starship and KiwiBot (see Table 2). These robots all depend on sophisticated navigational capacities to fulfil their purpose of being a "safe, polite and quick" alternatives for (last-mile) delivery. (twitter.com/EmilyEAckerman/status/1186363305851576321)

Such robots encounter a broad variety of encounters were pedestrians who approach them. These approaches can be disturbing for both the pedestrian and the robot. Though such disturbances can be very obvious, e.g. someone exploring how to steal the contents of a delivery robot (see Figure 1) they could also be much more muted – people may spend a few seconds trying to initiate an interaction out of curiosity, or they may give the robot an uncomfortably wide berth. For this reason, we asked ourselves the question of "*Can the behaviour of delivery robots be designed that they better handle these different reactions in all their rich variety?*".

Desired and undesired interactions – Delivery robots should, of course, be time-efficient, as that is at the core of their functionality, but as they have to share the sidewalk and will serve a representative function, they should also fit-in without causing undue discomfort. Looking at human-to-human sidewalk encounters for comparison, communication is minimal (natural and non-verbal, e.g. eye-contact [5]) and collisions are still avoided effectively most of the time.

Ideally, people would respond in much the same way to a delivery robot. Neither being (overly) disrupted by it, nor being (overly) engaged by it. In other words, the aim should be for a delivery robot to behave such that it manages to achieve a neutral encounter between itself and all pedestrians.

Neutral encounters between pedestrians and delivery robots – Recent approaches in human-robot interaction [14], such as affective grounding [6], quoted below, have started to see emotion as something that emerges from the interaction.

> "In order to the develop the understanding necessary for enabling robots to successfully participate in social interaction we need to view emotion and emotion regulation as something that takes shape in between interaction participants." [6]

A similar position can be taken towards neutral encounters. Rather than aiming for the robot's behaviour to be neutral by itself – as that may well be what evoked the reactions mentioned above – the aim could be for the robot to shape the encounter as a whole to be more neutral. By anticipating micro-emotions to shape human behaviour [7], this affective ground can be established.

2.4. Our concept/hypotheses

Based on the existing research presented in this chapter, we know that:

- We may soon be able to detect the social cues indicative of micro-emotions
- A robot experience is based on a collection of micro-emotions, like all product experiences
- Human behaviour is motivated by their experiences, which can be influenced

These conclusions together forms our envisioned model (Figure 3). It suggests that a delivery robot can evoke more neutral encounters by deploying behaviours that are designed to be used in reaction to detected micro-emotions.

3. Case study: Pedestrians encounter a delivery robot

Now that we have established that pedestrian's micro-emotions do exist and can be measured, by designers as outsiders, in order to design a product experience, we intend to answer the questions of "**Which micro-emotions emerge at the beginning of an encounter?**" and "**How do these micro-emotions lead to (undesired) pedestrian behaviour?**". We did this by conducting a case study with participants who encounter a small delivery robot. The experiment we created simulated a sidewalk were participants encounter a delivery robot and reflect on their micro-emotions and experiences. From this data, we gained insights into what combinations of micro-emotions triggers undesired (time-consuming) behaviour. These insights are used in the next chapter to find patterns in micro-emotions and behaviour (which should enable a robot to anticipate pedestrian behaviour to establish a (more) neutral encounter).

3.1. Measuring pedestrian experiences in 'Pedestrians of the Future'

Most valuable insights come from realistic encounters where participants behave natural and reflect afterwards on their micro-emotions. Participating in an experiment influences the bias of the participant, therefore, we edited the setup to set their expectations away from delivery robots. Table 7 shows the overview of the whole test setup which we explained in detail in this section.

	Participant	Moderator
1. Preparation	(not present)	- Prepares evaluation tools (micro-emotion cards, overview emotions, etc.) - Prepares location (camera's, robot, screens, etc.) - Prepares Arduino and related software
2. Set-up	- Asks potential questions - Signs consent form	- Explains the setup and what is expected - Explains the measurement tools - Presents and explains the consent form - Starts central recording
3. Study (3 rounds total)	- Goes through the sidewalk simulation - Reflects on the overall experience - Selects most relevant events for the whole experience & fills in an emotion card for each event	- Observes participant behaviour - Informs about the whole experience & micro-emotions - Guides the participant by the reflection - During the 3th round: manually controlles the robot during the encounter
4. Wrap-up	- Optionally asks questions	- Stops recording - Rounds up the session - Answers optional questions

Table 7: Steps taken throughout the test 'Pedestrians of the future' where participants got trained with reflecting on their experience by looking to occurring micro-emotions. These reflections were used to reflect on the encounter with a prototyped delivery robot. This overview shows what actions every step required for both participant and moderator.

Selecting an encounter situation – Our goal was to measure micro-emotions and behaviour by a pedestrian during a robot encounter. In order to make comparing between different results more easy, we used a method to structure reflections overtime where participants learn to reflect on their micro-emotions. From our observations (see Chapter 2) we collected the most interesting encounter situations where we saw that pedestrians had the strongest experiences, which are shown in Table 8.

In order to get consistent measurements during our case study, we needed a robot encounter situation which could be repeated easily for all participants where the micro-emotions got evoked in a similar way, without biasing participants to have the same experience. Situation 3 in Table 8 is the most spontaneous situation where participants have a strong experience, which could easily be repeated without influencing our participants. For this reason, we selected this situation for our case study.

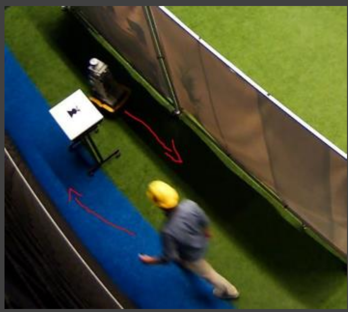
1. Overtaking of the robot	2. Frontal encounter in a wide area	3. Encounter around the corner	4. Frontal encounter in a small area
			
A pedestrian approaches a robot from behind. The robot drives slower and the pedestrian intends to overtake the robot.	A pedestrian walks in opposite direction from a robot and it isn't clear who moves what side in order to pass each other.	A pedestrian comes around the corner and is confronted with a robot which intends to make the same turn in opposite direction.	A pedestrian encounters a robot which drives in opposite direction. One has to wait for the other because of the limited space.

Table 8: Situation for an encounter between a pedestrian and a robot that evokes the strongest pedestrian-experiences.

Achieving a realistic encounter in a test environment – Because the influences of a test environment prevents a participant to get a realistic experience we have chosen to distract our participants to set their expectations away from the robot before they encountered the robot itself. Keeping this distraction close to the environment of the robot encounter, we made sure that participants experienced the robot without being influenced by something else. We decided to do this distraction with LED-lightning where we asked participants to reflect on their experiences. How this is done is explained later in this chapter.

Experimental set-up – To create a, as realistic as possible, sidewalk experience, we had to find a the location that contained the main elements of a sidewalk-situation, enabled us to repeat the test consistent and it should provide similar participant experiences. To do this, we gave the room the same width as a normal sidewalk and to simulate a situation that is comparable with the familiar situations outside, we gave participants a travelling goal.

Although this setup should enable participants to have a (close to) realistic sidewalk experience, our goal was to measure micro-emotions and experiences and as for most test setups, experiences become more consistent in a controlled environment. For these reasons, we decided to locate the experiment on the IDE-faculty in a sidewalk inside which has comparable dimensions as a real sidewalk and enabled us at the same time to conduct a repeatable experiment. Figure 6 shows an overview of the setup of 'Pedestrians of the future'.

Figure 6 shows the steps taken during every round: 1) start the experiment, 2) enter the setup, 3) detecting/observing changing LED's (distraction method), 4) encountering delivery robot (in the third round) and 5) leaving the setup and reflect on experiences with the moderator.

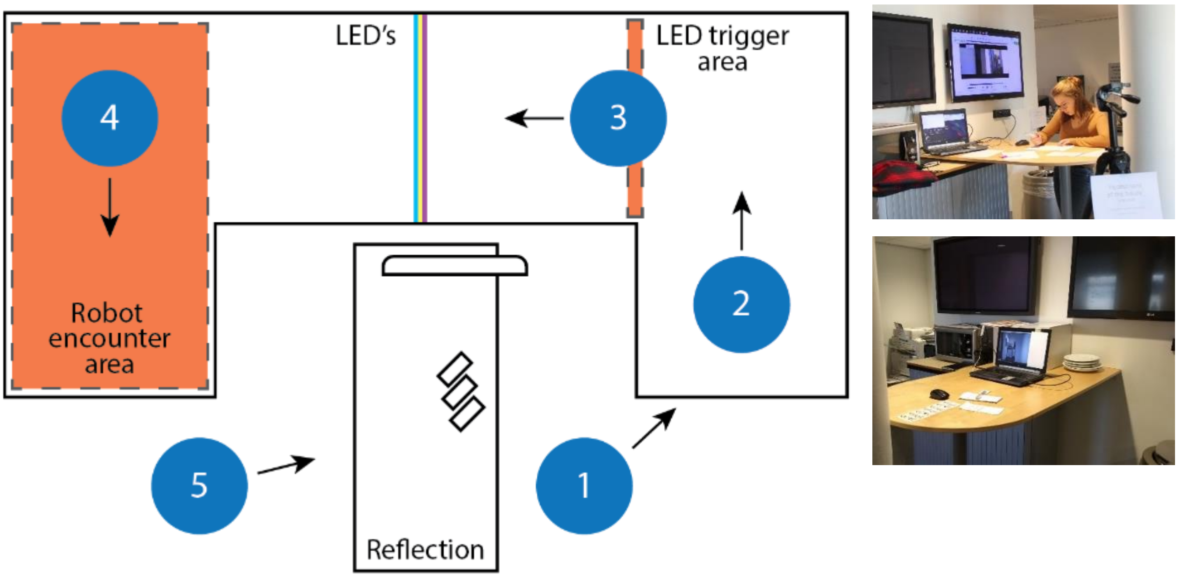


Figure 6: A top-view of our sidewalk simulation that shaped expectations away from encountering a robot to establish a natural/unexpected encounter. The numbers indicate the positions from a participant that walked through the setup.

Recording the participants experiences – In order to records micro-emotions by participants, we installed two cameras in position 4 (see Figure 6) to record all activities inside the setup without indicating their main purpose of recording the encounter with the robot. Both cameras are positioned to record the facial expression and body language of participants during their performance inside the simulation. These recordings are used by the participants to review what they experienced and by us to analyses the results.

The recordings made by the cameras inside the simulation record the participants actions inside the setup per round. These videos where shared afterwards to the participant (see Figure 7). The clock in the top-left corner is included in the recordings to prevent confusions in future editing when we determined the exact moment of the events.

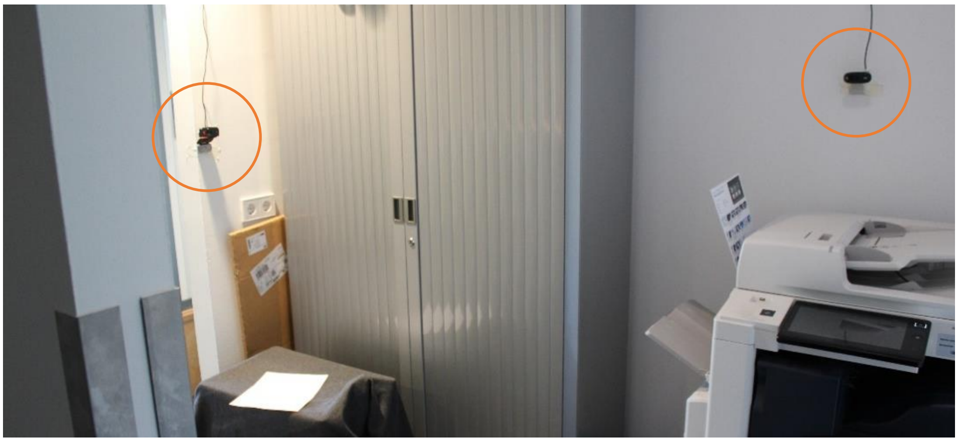


Figure 7: two cameras are placed at the end of the test setup (position 4 in Figure 6) to record participants when they are inside the sidewalk simulation.

Our initial plan was to locate the encounter opposite side of the simulation (see step 2 in Figure 6). But because of some complains about privacy form the people who worked around the test location, we had to relocate the cameras. By changing the positions of the cameras was the angle towards participants different and was the robot itself cut off of all recordings. Although we could reconstruct the robot's behaviour, it was planned to include it in the recordings.

Simulating an autonomous delivery robot

The robot we used for this case study had to provide the participant with the impression to drive autonomously and had to look like a delivery robot. We used the robot the Jackal from CLEARPATH (see Figure 8), which is designed to prototype with an autonomous robot and has a joystick to enable manual driving.

Figure 8: the autonomously driving robot 'the Jackal' (from CLEARPATH) which can be driven manually and is used in our case study to encounter participants.

To make the robot look like a delivery robot added we a blue crate on top where normally the order would be placed and now functioned as storage for technology and other elements that could be added in a potential redesign (see Figure 9).

Figure 9: The prototype used in our case study: the Jackal with a (for the Netherlands) recognizable crate from the grocery store to communicate its purpose.

Setting expectations

In general expectations are set once a pattern is detected and confirmed. For our test this means that participant needed to get familiar with the setup, detects a pattern and get a confirmation of these predictions. To simulate a realistic sidewalk simulation, we developed a setup where participants walked through a sidewalk simulation and experienced the encounter corner where it could be possible to encounter other people, like it could happen on a real sidewalk.

Because expectations are set in three phase, we decided to have three rounds per session:

1) Participants gets familiar with the simulation
2) A pattern emerges based on the repetition from the previous round
3) Participants expect to experience that the pattern continues

Once the expectations are set in the 3th round, an encounter will be unexpected and therefore realistic. Because of the limited time the moderator had to let the robot enter the setup, we covered it on the positions it was entering the setup (step 4 in Figure 6). The robot was covered with a blanket with a paper on top. The blanket was taped to the wall and felt away when the robot started to drive. This construction enabled the moderator to enter the robot at the correct moment. Figure 10 shows what participants saw throughout the first two rounds and the 'uncovering' from the robot.

Figure 10: The test delivery robot was covered (under a blanket and a sheet of paper on top) during the first two rounds (were expectations were set). The image on top shows the covered robot from the perspective of the participants.

Like explained in Chapter 2, participants need to train with reflecting on their micro-emotions in order to reflect without help from the moderator when they reflect on the encounter with the delivery robot. By reflecting two rounds on their experiences with the lights, reflecting on micro-emotions is practised while the moderator was able to provide support when needed. This way, participants were prepared to reflect on their own after they encountered to robot.

This construction of distracting participants raises some ethical questions. Therefore, we went through the ethics application from the TU-Delft and got a confirmation. Of course, we explained our intentions afterwards. See the appendix for the consent form. After the participants knew about our intentions, the moderator told them the following: "*The robot is part of the test. I research how people react to service robots on the street. By not sharing this upfront is your reaction unbiased and most realistic compared to a real-life situation. Hopefully, you are alright with this. From now on, there will be no more surprises*".

A coloured room as distraction method – To gain valuable insights into micro-emotions during an encounter, an experiment needed a participant to experience an encounter with a delivery robot as realistic as possible. A realistic encounter emerges when a pedestrian doesn't expect the encounter. Table 9 shows our brainstorm to different distraction methods.

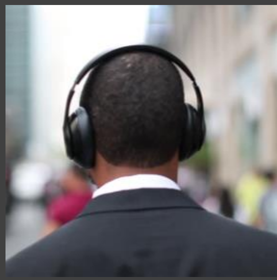
1. Lighted room	2. Encounter people	3. Guided tour	4. Playing sounds
			
Lighting up the room to create different settings easily.	Encountering someone like it happens on a sidewalk.	Placing objects like a guided tour to get the participants attention.	Playing sounds inside the setup to simulate different locations (nature, city, etc.).
[+] Unrelated to robot [+] Enabels practicing with refecting.	[+] Good to practise reflecting the sidewalk context. [-] Too close to encountering a robot.	[+] Clear path for participants to follow. [-] Could be time-consuming once object distract too well.	[+] Easy subject to reflect on and unrelated to robots. [-] The robots sound could be covered by other sound, which interfares too much.

Table 9: The considered (and relevant) distraction methods to set expectations away from encountering a robot, but still extends the experience of a sidewalk simulation.

From these options, the lightning of the room (option 1) required the least amount of time to experience and stimulated participants to continue walking inside the simulation, which enabled participants to have a realistic sidewalk experience. Because the first rounds didn't provided any relevant insights for this study, we could, with this method, minimise the required time. For these reasons, we decided to use lighting as dictation method.

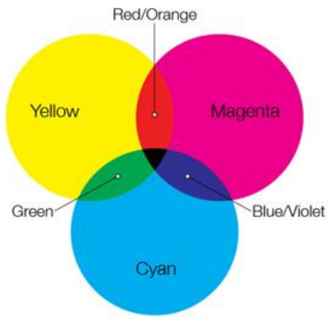


Figure 11: Secondary colours (yellow, Magenta & Cyan) are the least used colours in a sidewalk context and can therefore function a plausible subject for an experiment like ours.

The used distraction method should be believable for the participant in order to avoid suspicion to the real goal of the experiment. It also should be connected to the context where a robot encounter could happen. The secondary lights shown in Table 9 (nr.1) aren't used on sidewalks as the primary colours do. Therefore, these colours are suitable for both the distraction method and the required context of a robot encounter.

We iterated with the location of the LED's and the material to find the best way to colour the room. To improve the strength of the light, we covered some lights but we made sure that the robot was perfectly visible for the participants. Figure 11 shows the placements of the LED's on the simulation and some iterations with transparent materials.

Figure 12: Prototyping with different cover materials and LED-locations to diffuse the light enough to light up most of the room.

The LED's are controlled by an Arduino (see appendix for the code), which is controlled by the moderator who turned it on or off on the correct moments. To prevent any influence from the order that the lights are presented to participants is this order for every test randomized by the Arduino code (included in the appendix).

Measuring experiences & micro-emotions

Participants were asked, after every round, to reflect on their experience in general and after that by looking through the recordings and to select the moments that were most important in defining that experience. By viewing their own behaviour, they were enabled to remember what they felt before. Besides supporting participants, this method of reviewing provided us with insights because the micro-emotions got linked to specific moments in the video and therefore they could be used to find patterns between behaviour and micro-emotions.

Directly after going through the simulation, we asked participants about their whole experience before they saw the recording. This experience is used as guidance to select the most relevant moments.

To easily reflect on an emerged micro-emotion during an event, we developed emotion-cards (see Figure 13). These cards are designed with a structure to guide participants through the reflection process.

Figure 13: The emotion card for a single event where participants 1) select the most suiting illustration to their feeling, 2) give one word for the emotion and 3) describe what made them feel this.

Reflections are structured in micro-emotion-cards we designed for this test. Here is every moment individually described by participants by 1) selecting an illustration from the PrEmo-tool, 2) give a one-word description of what the illustration represents for them and 3) write a short description of why this moment is important for their experience (this to create the connection towards the overall experience).

Moderating participants – As discussed in Chapter 2, a person has to practice with reflecting on his or her micro-emotions in order to use it properly. Because of our goal to only measure micro-emotions during the third round the moderator was enabled in the rounds before to practice our tools with the participants which enabled them to reflect on their own after the thirds round.

In order to make the test as consistent as possible a cheat sheet for the moderator was developed with all required steps and the text that had to be communicated. (See appendix).

Securing recorded data – Every participant signed a consent form before the test started. In here, we told them about what was going to be recorded and where it is being used. After the test, the moderator made sure that they knew that they could retrieve their data at any moment and without a reason. Just like all recordings made during this test are the consent forms stored on the IDE-faculty in a save location.

Experiment location – The test location had multiple requirements to enable to conduct a consistent test for all participants and where the whole test could be conducted again after the results from the first test had been processed into a redesign of the robot behaviour. We collected the main test-demands with all considered locations in Table 10 in an overview. Based on this overview, the IDE-faculty hallway showed to be most suitable and is therefore selected as location.

A location should enable us to:	1. Sidewalk on the campus	2. IDE-faculty lunch room	3. IDE-faculty hallway	4. IDE-faculty closed room
1. Record the whole test freely:	- - -	-	+ +	+ + +
2. Repeat the experiment again with a redesign:	+ +	+ +	+ +	+ +
3. Test multiple times with consistent environmental influences:	- - -	- -	+ + +	+ + +
4. Make a sidewalk experience for the participants:	+ + +	-	+	- -
5. Distract participants:	- -	- - -	+ + +	+
6. Reflect on micro-emotions with participants in a quite area:	- - -	- -	+	+ + +

Table 10: All considered locations and how well they suit the test-demands.

Insights afterwards

GoPro recordings during the case study – During the first test, we tried to record the perspective the robot as well by adding a GoPro on top of it, but unfortunately this camera got stuck once it entered the setup and felt down by most of the encounters. For this reason, we haven’t enough recordings to make a valuable comparing between the participants micro-emotions and the perspective of the robot. Although this didn’t prevent us from getting our findings, it would have helped to show our envisioned developments afterwards.

Consequences of testing in a controlled environment – Because the experiment is conducted in a controlled environment and not a real sidewalk, we had planned to drive around with the Jackal’s slightly bigger brother the Husky on a private terrain where we were allowed to drive around to observe the reactions from the people walking around. With these observations we could have reflected the differences in behaviour between in the different locations. Unfortunately, due to Covid19, we were unable to do this.

3.2. Test results

Driving the robot was harder than expected. Although the moderator of the case study practiced with driving the robot manually, the lack of eye-sight required to make the robot seemingly autonomous, made it difficult to react to the situation. In the future this could be improved by having a life GoPro on top of the robot that provides the driver with a life vision of the situation and therefore enable him or her to react better to the situation.

Validating results

In order for data to be valid an encounter has to be as natural as possible. We have set two criteria to validate data: 1) participants should not know upfront that they are going to encounter a robot and 2) participants have to have the impression they encounter an autonomous robot (and not driven manually). From the moment that a participant knew one of these aspects, is the data excluded from this research.

All participants didn't know when the robot would encounter, but they all discovered the driver at a different point in time. All recordings after the point of discovering the driver are excluded from this research. For this reason, all pilot participants and participant 12 are removed completely because it was known upfront that the robot was driven manually.

Structuring data

Our aim was to find patterns between pedestrian behaviour and robot behaviour. We started to review by putting the pedestrian behaviour (see Figure 14) against the on the robot behaviour in individual actions. Because the robot was manually driven differs the pedestrian behaviours as well. By clustering behaviour as much as possible, without losing the original value, we could simplify this overview later to compare the behaviours more easily.

				participant behavior						
seq	PP	Time	Action	Walking	Move aside	Move back	Look at Robot	First robot sound	Know who drives	Touching robot
1	4	02.74	Begin First Encounter	x				x		
2	4	03.94	First visual contact	x						
3	4	04.62	Robot drives straight towards pedestrian				x			
4	4	05.00	Pedestrian making space for the robot		x		x			
5	4	06.40	Paths are no longer blocked		x		x			
6	4	06.94	End First Encounter	x						
7	4	07.81	End Interaction + Discover driver	x					x	
1	5	03.34	Begin First Encounter	x				x		
2	5	04.27	First visual contact				x			
3	5	05.82	Pedestrian awaits reaction from robot				x			
4	5	08.59	Robot drives straight towards pedestrian		x		x			
5	5	19.25	End First Encounter	x						
6	5	22.85	End Interaction + Discover driver	x					x	

Figure 14: Our first attempt (not the final one!) of reviewing participant behavioural (right) related to robot behaviour (left).

To our surprise, despite big personal differences in timing and experienced emotions, all participants went through similar phases were they: 1) heard the robot; 2) saw the robot; 3) stopped walking; 4) stepped aside; 5) let the robot pass (see Figure 15). Because some participants approached the robot after they passed it already three time-stamps are added to indicate the behavioural processes:

- 6) *End encounter* – the time-stamp where participants passed the robot (some participants approached the robot afterwards)
- 7) *End interaction* – the time-stamp where participants decided to leave the robot alone to leave the simulation setup.
- 8) *Discover driver* – the time-stamp where participants discovered the driver and became aware that the robot wasn't driving autonomously.

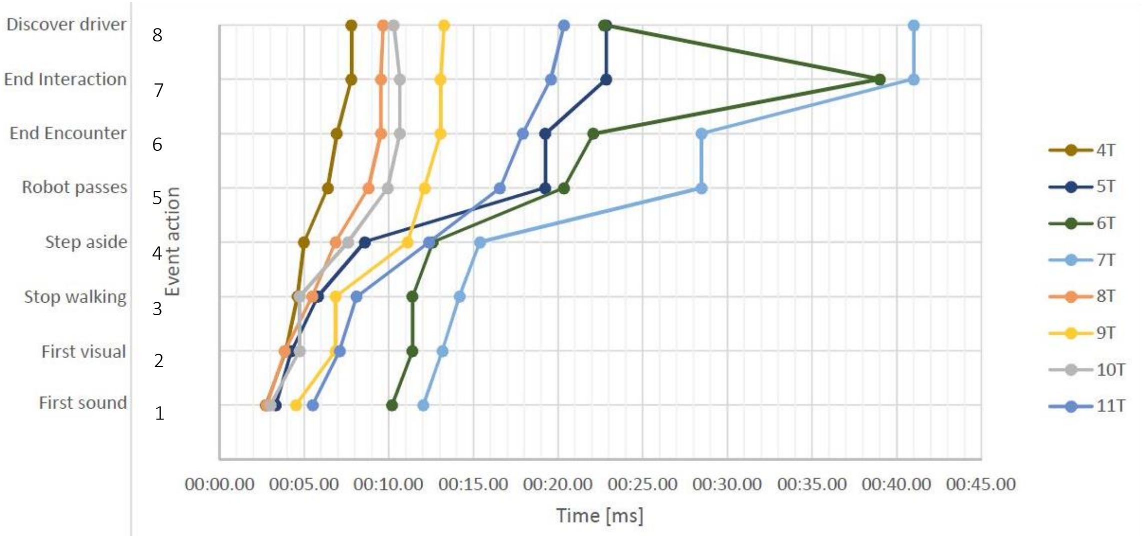


Figure 15: Behavioural patterns emerging from every participant throughout the test.

In order to compare the encounters based on their time consumption the time between the moment that a person stopped walking and the moment that he or she continued was defined for the encounters as time-consuming. This definition allowed us to simplify the pedestrian behaviour during the encounters to 3 phases: 1) First sound; 3) Stop walking; 5) Robot passes (see Figure 16).

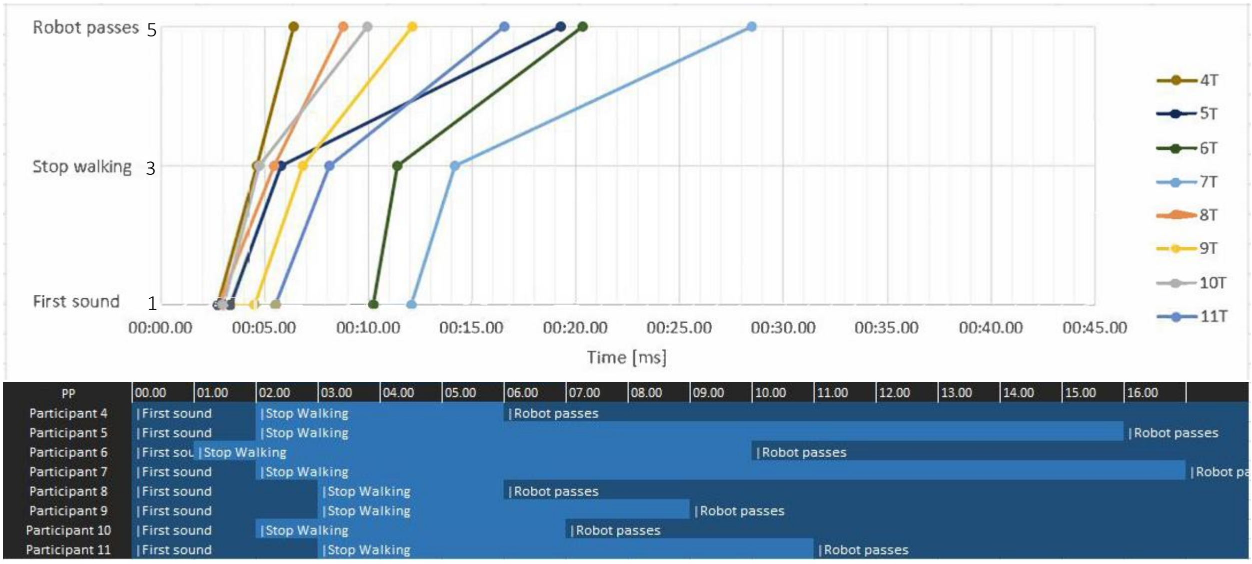


Figure 16: The three most relevant phases all participants performed at the begin of their encounter with the delivery robot, which indicates how long the robot had to wait before it could continue. The top part shows the graph relative from each other and the bottom part a more static representation.

Final data representation – We iterated on the data presentation to highlight only the most relevant data to compare results correctly. We started mapping micro-emotions over time, based on the intensity level, like the original tools to. This provided us a nice overview of how the robot was experienced, but we still weren't able to compare results correctly because of the intensity that was motivated differently per participants (see Figure 17).

The behavioural patterns we found were added to see what micro-emotion related to certain behaviour. Although these relations told us the relations, they didn't clarify what behaviour related to the time consumption in these interaction.

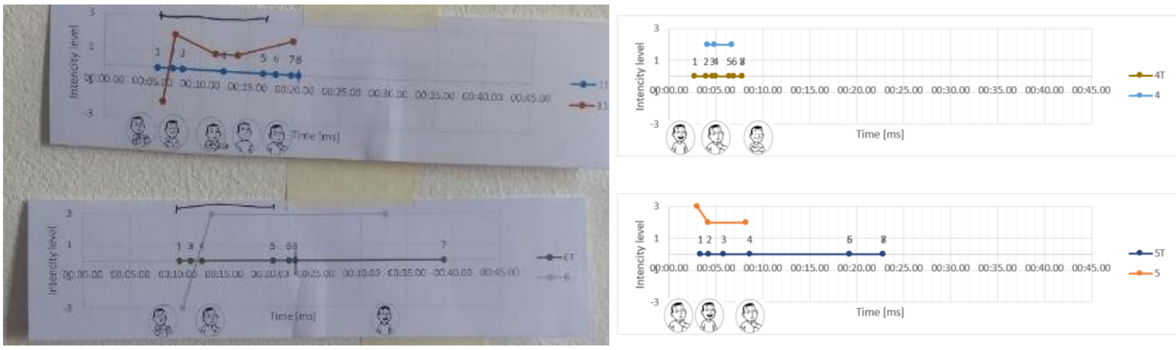


Figure 17: plotting the data based on the intensity levels like it originally is done to provide an product experience.

Because the motivations were more important than the intensity level, we decided to place the micro-emotions central and the intensity level above or below. Figure 18 shows the prototyped version of this process which is used for the final graph for the obtained data in the case study.

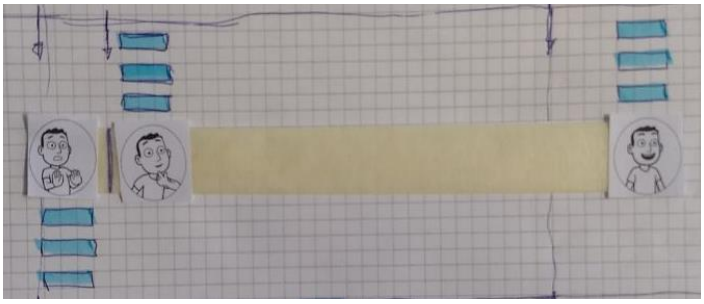


Figure 18: The graph prototype of putting micro-emotions central and adjusting the timelines (with arrow on top) to contain the time consumption of the interaction created a clear overview of what motivations occurred during the case study.

Overview of all valid data

Figure 19 shows an overview of all included data in the final version we developed to enable comparing and analysing, which we explained in the next section.

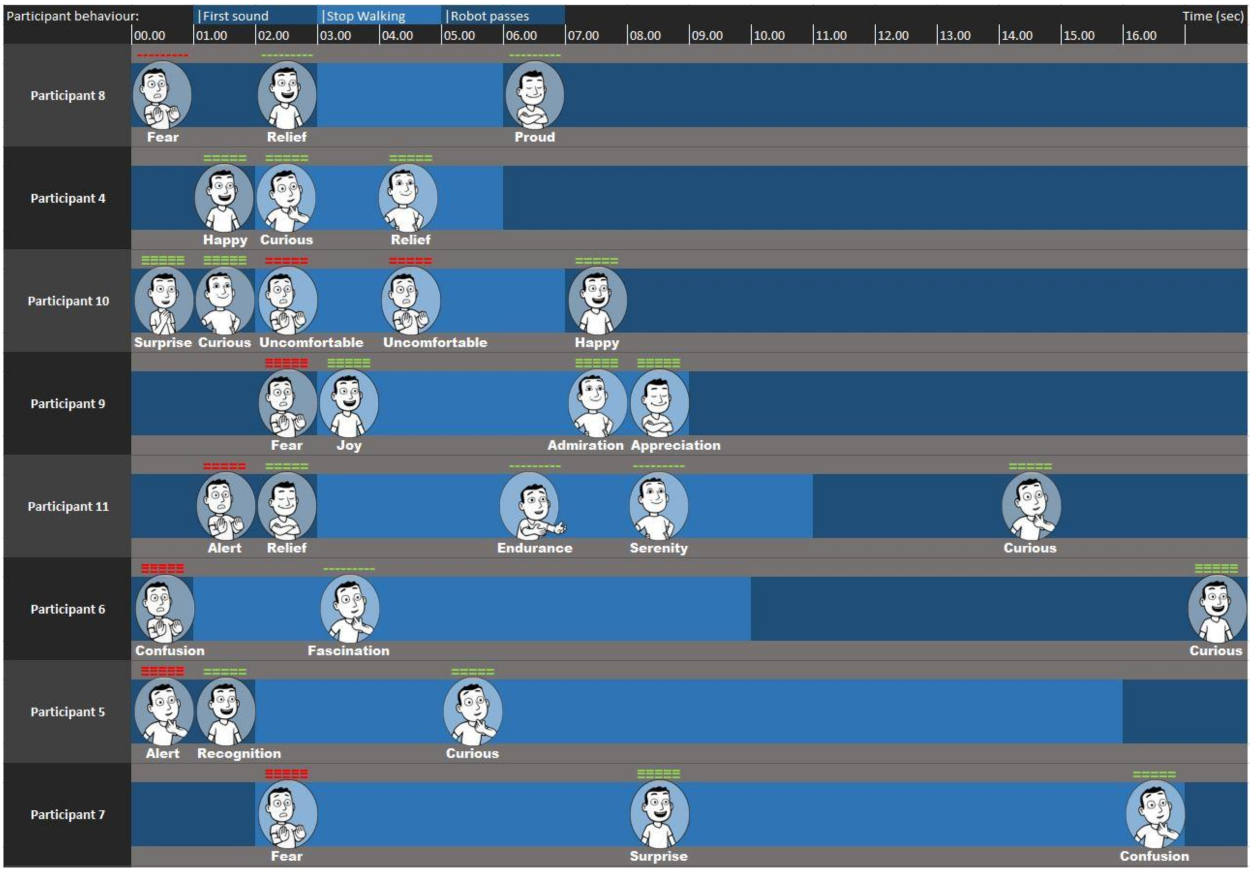


Figure 19: Overview of the behaviours of our participants on individual time lines, together with their self-reported micro-emotions and accompanying quotes. All time lines have been set with the moment where the sounds of the robot first were audible as 0:00. The behaviour of each of our participants followed a similar pattern, with them stopping for the robot and then moving out of its way to allow it to continue its path sometime later – we have indicated these behaviours with, respectively, the start and end of the bar on the timelines. Encounters are sorted by how long it took before the robot could continue its path. The number of lines above each of the micro-emotion symbols indicates their reported intensity, while their colour indicates if the emotion was experienced as positive or negative by the participant.

3.3. Patterns between micro-emotions and behaviour

Like we showed in the previous section the measured micro-emotions do relate to the measured behaviour. In this section we present our explorations to the patterns between these relations and what causes them to be time-consuming or not.

An experience is build-up from multiple micro-emotions that influence each other (see Chapter 2). An experience triggers/motivates people to behave in a specific way. By finding patterns in the relations between micro-emotions and behaviour, we have adjusted the robot behaviour that aims to evoke different micro-emotions and, accordingly, different human behaviour (see next chapter).

Cluster 'Interaction duration'

Our goal is to increase the robot's time-efficiency and we started with clusters based on the longest interaction duration (8 to 15 seconds) (see Figure 20) and based on the shortest interaction durations (3 to 6 seconds) (see Figure 21).

Figure 20: All results with the longest interaction duration before the robot could continue its path.

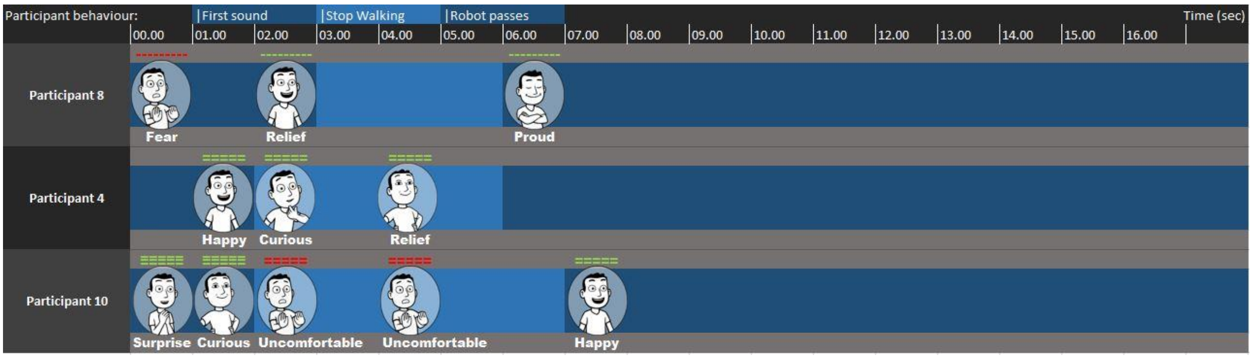


Figure 21: All results with the shortest interaction duration before the robot could continue its path.

In the cluster with the most time consuming interactions, all participants experienced a single negative micro-emotion in the beginning followed by only positive micro-emotions. Because these micro-emotions occur in different forms and combinations, we could not find a consistent pattern for why these interactions consumed this amount of time. In opposite to the previous cluster a short encounter doesn't have the pattern of occurring positive and negative micro-emotions.

Because these clusters lack any form of consistent pattern between micro-emotions, robot behaviour and encounter durations, we can conclude that there are different situations and motivation where pedestrians get triggered to engage in a time-consuming interaction.

Cluster ‘first micro-emotion’

The returning combination of positive and negative micro-emotions made us curious to see if a pattern emerged by clustering the first micro-emotions (see Figure 22). Because most participants expressed a negative micro-emotion, based on the unpredictability of the robot, we could combine these micro-emotions to a group we called ‘unease’.

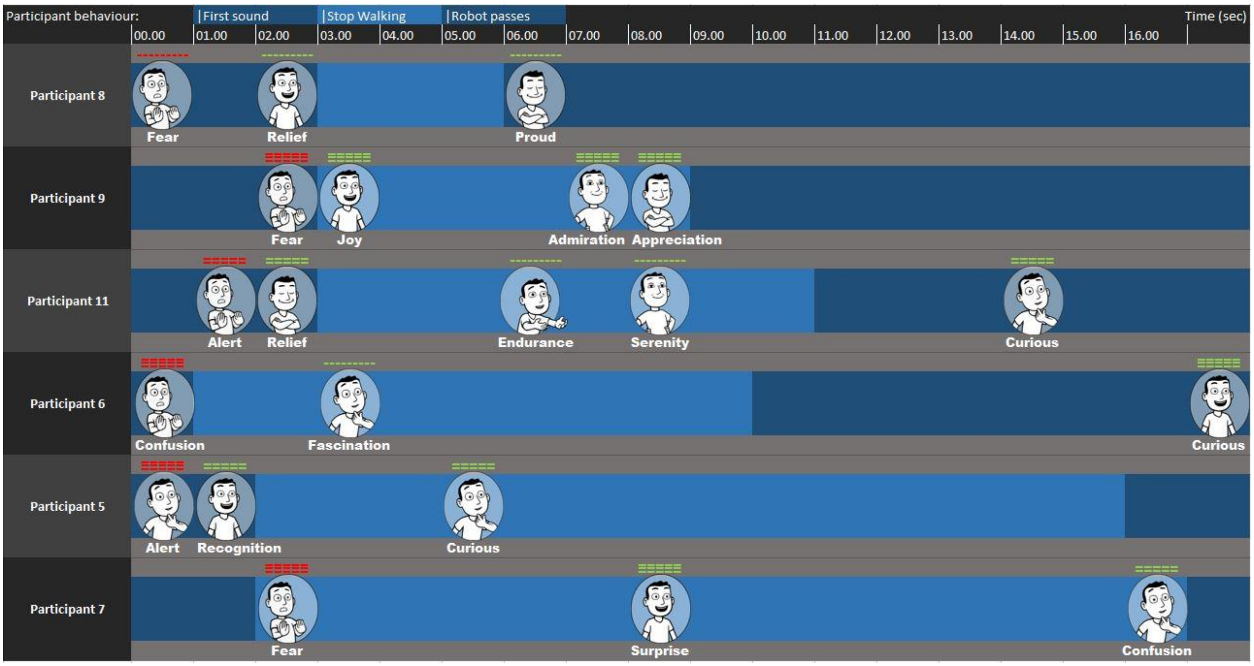


Figure 22: Results cluster ‘unease’ as first micro-emotion.

The encounter durations vary between 3 seconds to 15 seconds from which we can’t find a pattern in motivation. On the other hand, the combination seen for the cluster with the longest duration (one positive followed by only positive micro-emotions, turns out to be applicable for all participants in this cluster. We saw different ways of reacting after participants experienced ‘unease’, which is reflected in the following micro-emotions afterwards. This phenomenon triggered our curiosity and we decided to cluster these results again to see if we could find any patterns.

Cluster ‘emotion-cluster’

To look further into the underlying patterns, we grouped participants who firstly experienced a form of ‘unease’ based on the micro-emotion they experienced right after. This resulted in two clusters, with three participants each; ‘Unease + Relief’, and ‘Unease + Curiosity’.

The participants who experienced ‘Unease + Relief’ (see Figure 23), all seemed to interpret the robot as ‘unpredictable’ because of its behaviour, which triggered them to stop walking to investigate what the robot would do next. After a short moment to observe the robot and determine that the robot intended to continue driving, they experienced relief and stepped aside to clear the path of the robot.

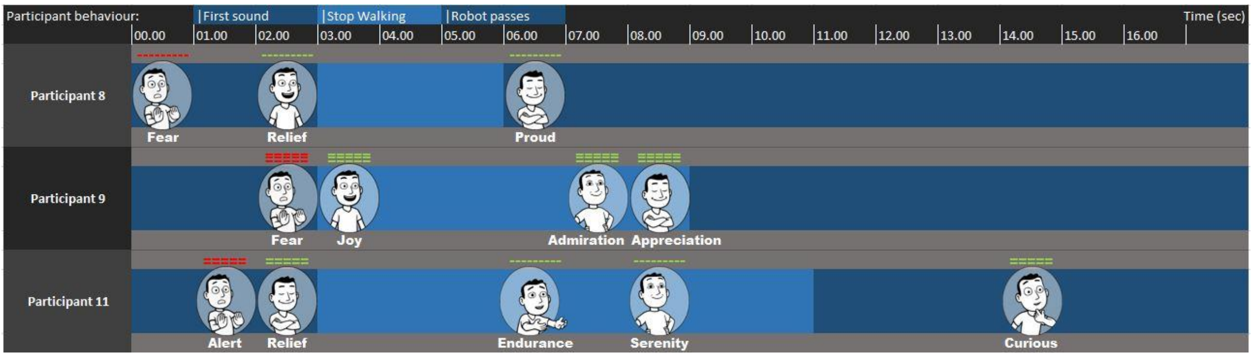


Figure 23: Results of clustering micro-emotions to the emotion-cluster 'Unease + Relief'.

The participants who experienced 'Unease + Curiosity' (see Figure 24) similarly seemed to stop walking as they interpreted the robot as 'unpredictable'. In contrast to the previous cluster, however, after these participants had established an idea about the goal of the robot, they got curious about the behaviour of the robot and how it would react to them, which triggered them to approach the robot to explore this. Because the robot waited to continue, their expectations were not met and they stepped aside to continue their own path.

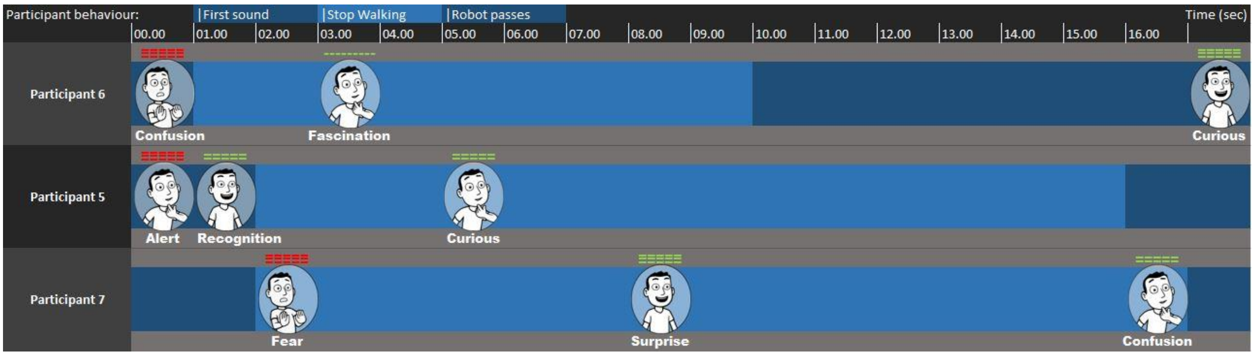


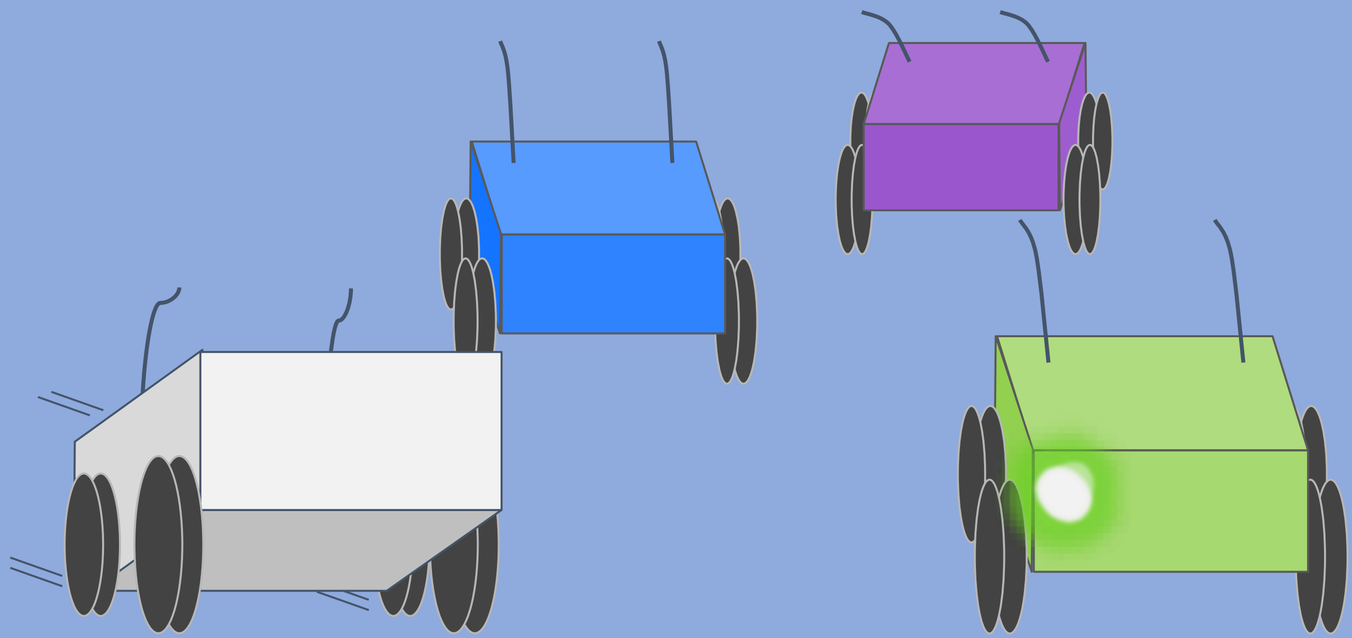
Figure 24: Results of clustering micro-emotions to the emotion-cluster 'Unease + Curious'.

While both emotion-clusters thus initially trigger similar behaviour, they diverge in how the situation resolves. Notably, 'Unease + Curious' on average took longer to resolve, as the robot had to wait for some time as the experienced curiosity had to turn into boredom before these participants would let the robot pass.

In other words, within this sample of limited size, these two emotion-clusters seem to effectively predict how the encounter will resolve. In the next chapter, we redesigned the robot behaviour to anticipate on both of these emotion-clusters.

4. Design brief robot behaviour

In the previous chapter, we found undesired pedestrian behaviour towards delivery robots based on the emotion-clusters ‘Unease + Relief’ or ‘Unease + Curious’. In this chapter, we analysed how robot behaviour could influence these clusters to shape it towards a more neutral behaviour. To do this, we looked into the behaviour in each cluster and created designs briefs. With these, we iterated on suitable solutions, which will be tested on their relevance in the next chapter.



4.1. Design brief

From the case study, we looked at the causes of micro-emotions and observed all encounters and collected all issues that could prevent a neutral encounter. We formulated these issues as requirements that are needed to adapt micro-emotions and increase time-efficiency for the studied encounter. We aimed to increase time-efficiency by motivating pedestrians to continue walking (sooner) and, therefore, providing a clear path for the robot. Because the two emotion-clusters evoke different human experiences to motivate pedestrians to behave, both emotion-clusters have their own requirements and design brief.

Design brief ‘Unease + Relief’

This emotion-cluster is caused by the initial robot behaviour, which will be used by default, should turn most encounters into a neutral encounter automatically but this is not guaranteed. To reduce the number of undesired encounters as much as possible, we decided to redesign the initial behaviour for this specific situation. Naturally, we have to test it to see how different types of participants would experience it. The requirements: - The initial robot behaviour should evoke emotion-clusters that consumes less time than the cluster ‘Unease + Relief’ does - The redesign motivates most pedestrians to continue walking (or starting to continue walking sooner) by reducing/avoiding the experienced micro-emotion ‘unease’ by: - Either making the robot intentions more predictable, as this was mentioned by participants for feeling ‘unease’ - Or by establishing a more intuitive/human-like behaviour that evokes a more human-to-human-like experience by pedestrians.

Design brief ‘Unease + Curiosity’

This emotion-cluster motivated pedestrians to start a time-consuming interaction by the unknown and approachable robot behaviour. Due to a lack of robot feedback to pedestrians input, the human experience changed to boredom before the pedestrian continued walking. The envisioned robot behaviour adapted to micro-emotions requires: - An adaptation form the established micro-emotions caused by the initial robot behaviour applied in the case study which evoked this emotion-cluster - To motivate most pedestrians to continue walking by adapting the experienced curiosity by: - Either stimulating pedestrians feeling of boredom sooner in the interaction to shorten the time before this micro-emotion triggers them to continue walking - Or by being less approachable to lower the pedestrians need for acting on their curiosity to prevent the whole situation - Or by enabling a robot to embrace curiosity to take control of the situation/interaction to deal with the established curiosity from pedestrians.

4.2. Sketches

Based on the design briefs in the previous section, we explored multiple options for suitable robot behaviour that influences pedestrian experiences in the desired direction. Here, we present the used design methods, recreate the robot behaviour from the first test and show our redesigns. Due to the Covid19 situation, we were unable to iterate with actual people as intended. To still get an impression about the redesigns relevance the redesigns are animated (including the original robot behaviour) and evaluated in the next chapter.

For the evaluation test, we needed to prevent any bias by participants and decided to use colours as names for the redesigns (see Chapter 5). To keep this thesis clear we have decided to uses these names in this chapter as well.

Both design briefs attends two phases in the robot behaviour: the initial behaviour, before the detection of an emotion-cluster, and the behavioural reaction, after the detection of an emotion-cluster. Because an robot experience will always be based on a combination of both and a redesign will only address one of the phases, we decided to include the missing phases into the animations.

Designing suitable robot behaviour

Behaviour is best recognized when it can be linked to memories from similar situations. We applied this method while designing robot behaviour that has to evoke a specific micro-emotion. The design briefs describe the goals for each emotion-cluster, which was used to reverse-engineer the intended human interpretation into the robot behaviour. Now we explain the considered approaches.

Offensive and defensive behaviour. Offensive behaviour communicates clearly what a robot intends to do by altering the receiver. Once such an approach is too strong, the receiver will have a negative robot experience, which should be considered in the design. Defensive behaviour can be strongly relatable once the receiver emphasises on to it and is a powerful way in shaping the receiving experience. However, these behaviours are mostly based on a sub-dominant position for the robot, which can easily lead to time-consuming interactions. The influence on the long term has to be considered when using this kind of behaviour for our sketches.

Direct and indirect robot actions. By directing an action directly towards the receivers (e.g. 'reducing distance' or 'challenging playfully'), they would feel a connection to the robot. How beneficial this is depends on the reaction from the receiver that could prefer this connection, which could motivate them to approach in a undesired interaction. By directing an action away from the receivers (e.g. 'acting as victim' or 'looking away'), receivers could be affected with the social implications it relates to (see Chapter 2).

Structuring of the redesign visuals

The visuals in this section are structured, based on the animation details, where it (from top to bottom) starts with an overview of the total behaviour, followed by grouped movements to clarify these better and closed with the robot behaviour during the animations with a timeline. Note that we included some details for the evaluation, which are discussed on Chapter 5.

Sketch for original robot behaviour: Blue

We animated this behaviour (see Figure 25) to enable others to compare to the changes of the redesigns to provide us with insights into the relevance of the design direction.

In the original test, the robot was perceived as '*Unpredictable*', '*clumsy*' and '*scary*'. In the animation, this is represented by:

- The robot driving in the middle of the road.
- The movements and accelerations are direct, like they are optimized from the robots perspective.
- The communication, about making the turn and starting or stopping, is minimal.
- The robot waits until the pedestrian moves aside before it continues driving.

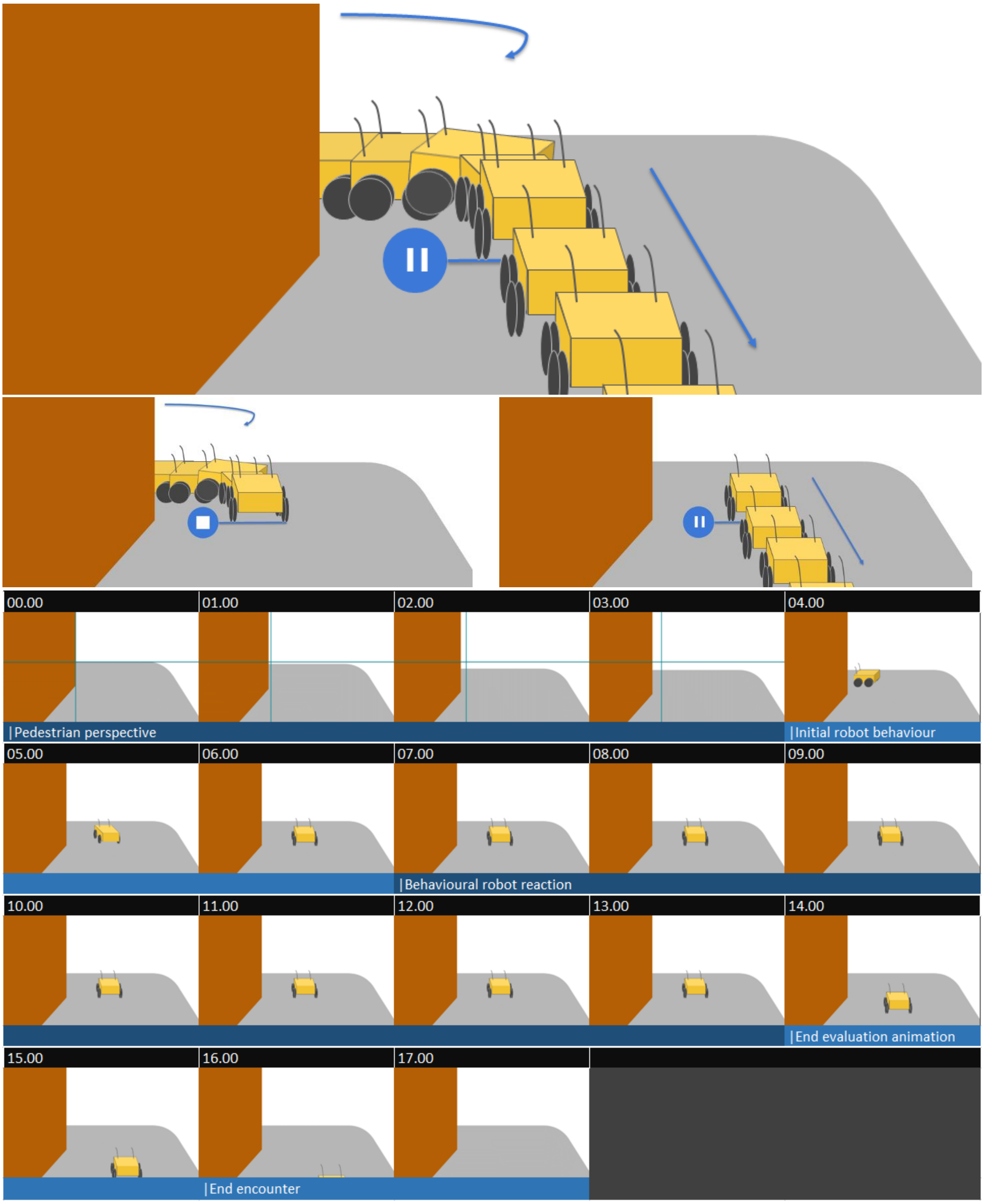


Figure 25: Original robot behaviour and reaction: Blue. This robot drives directly around the corner, detects a pedestrian and stops driving; it waits until the pedestrian moves and it continues driving as soon its path is clear. The total overview on top shows most of the robot frames and uses icons to point to the frames that stop or wait.

Sketch for 'Unease + Relief': Green

In this redesign of the initial robot behaviour (see Figure 27), we intended to prevent the 'unease' experience. Most findings for undesired behaviour in this emotion-cluster (and other 'unease' experiences) were addressed to the robot being '*unpredictable*'. Predictability was accomplished by communicating the robots intentions and increasing the 'safety' experience of the robot.

By communicating the robots intentions a pedestrian could better recognize and anticipate on the robot and could therefore better predict what the robot is going to do. In our situation, the robot has to communicate what direction it will go and that it avoids active interactions in order to continue driving. Vehicles normally communicate their intended direction with a blinking light. Although there are more possible cues to communicate this (like arrows, sounds, etc.), blinking lights are the most recognized option for a traffic-related situation. For this reason, we added blinking lights to the robot that blink before it will make the turn.

Designing blinking lights would mean a change in the robots embodiment (see Figure 26). By changing the embodiment we could evoke different micro-emotions, which would distract participants from the communicating experience and therefore reduce the value of an evaluation. For this reason we decided to only include the light that would be emitted, which is highlighted on the top in Figure 27.

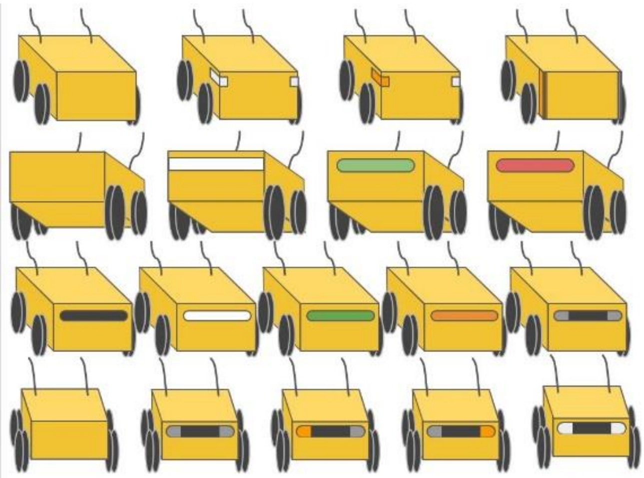


Figure 26: brainstorms for including blinking lights for the robot turned out to influence the robot appearance too much and therefore it would distract from the redesigned behaviour.

The lack of experiencing 'safety' in the original robot behaviour, was mainly caused by the sudden of the robots appearance with a small distance in between. By increasing this distance, the robot can be observed longer, which provides pedestrians more time to react and for this reason evoke a more save experience. The only possible issue could be that, in our encounter situation, the robot would drive on the wrong side of the road (the Netherlands), which could evoke confusion instead of the intended predictability.

During the process of redesigning predictable robot behaviour, we looked into the factors that evoked the 'unease' itself and found some interesting options. But due to the limited options that come with an online evaluation, we decided to exclude this direction from the redesigns. Although we haven't applied it, we still found it interesting enough to share. For example the directness of the robot, in sounds, movements, etc., was often related to 'uncontrolled' or 'mechanical', which were strongly associated, in general, with 'danger'. This could be reduced with an equal acceleration, which would result in a robot that starts and stops slower. These more smoothly movements would provide pedestrians more time to detect what the robot is about to do and will therefore improve the predictability as well. As told before this direction was excluded from this redesign. The decision was made because of our limited animation-skills and the complexity of sound design, which would result in an obvious redesign which was likely to bias participants.

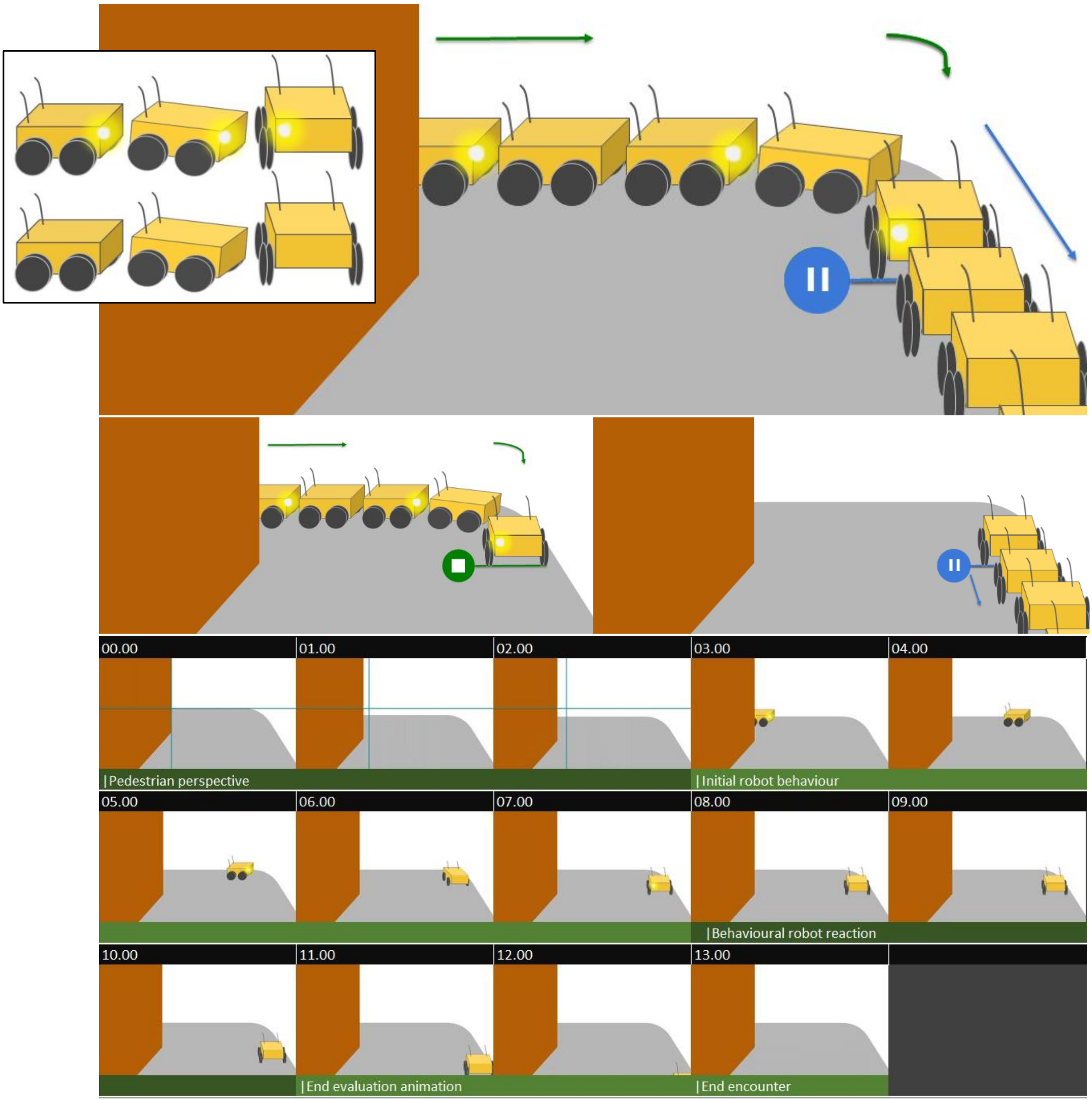


Figure 27: Predictable robot behaviour and the original reaction: Green. Driving on the outside of the corner, with blinking lights, before it detects the pedestrian and stops; it waits until the pedestrian moves and continues driving as soon its path is clear. The total overview on top shows most of the robot frames and uses icons to point to the frames that stop or wait.

Sketch for 'Unease + Curious': Lila

This redesign intends to accelerate the observed process where pedestrians experience boredom and stop interacting with the robot, this would reduce the time consumption caused by this emotion cluster. By speeding this process, we aimed to motivate participants to continue walking sooner. Stimulating boredom was evoked by expectations like '*curious to see what the robot will do next*' that got answered. By providing answers to these curious experiences, we should reduce its intensity, which seemed to happen before it turns into boredom (see Figure 29).

Another observation we made was that participants felt the urge to approach the robot to interact with it. By calling on the pedestrian's empathy for socially recognised behaviour where approaching is undesired, a reduction of the interpreted accessibility could be established. A strong example of such human behaviour is 'shy' (see Figure 28). Here a person doesn't want to interact, because of internal reasons. The clear absent of any blame form the receiver makes it relatively easy to evoke a positive experience for our pedestrians. For this reason we decided to use 'shy' as input for this redesign.

Figure 28: An example of how shy behaviour by humans is expressed.

Shy behaviour, in general, is recognised by a retreating and sub-dominant actions like avoiding eye contact, moving away from confrontations or small, internally directed body language. To simulate the body language, the front of the robots embodiment turns downwards, which makes it seem like the robot 'looks down'. The internally directed expression is strengthened by bending the antennas forward in the same direction as the embodiment. This behaviour is highlighted on top of Figure 29. In order to avoid the confrontation we have chosen the robot to drive back and wait until the pedestrian passes. Once he or she continues walking and a path is provided, the robot could react shy by turning away from the pedestrian and continues driving quickly. Beside the relation this robot reaction has to shy behaviour, this behaviour could recover a bit of the lost time.

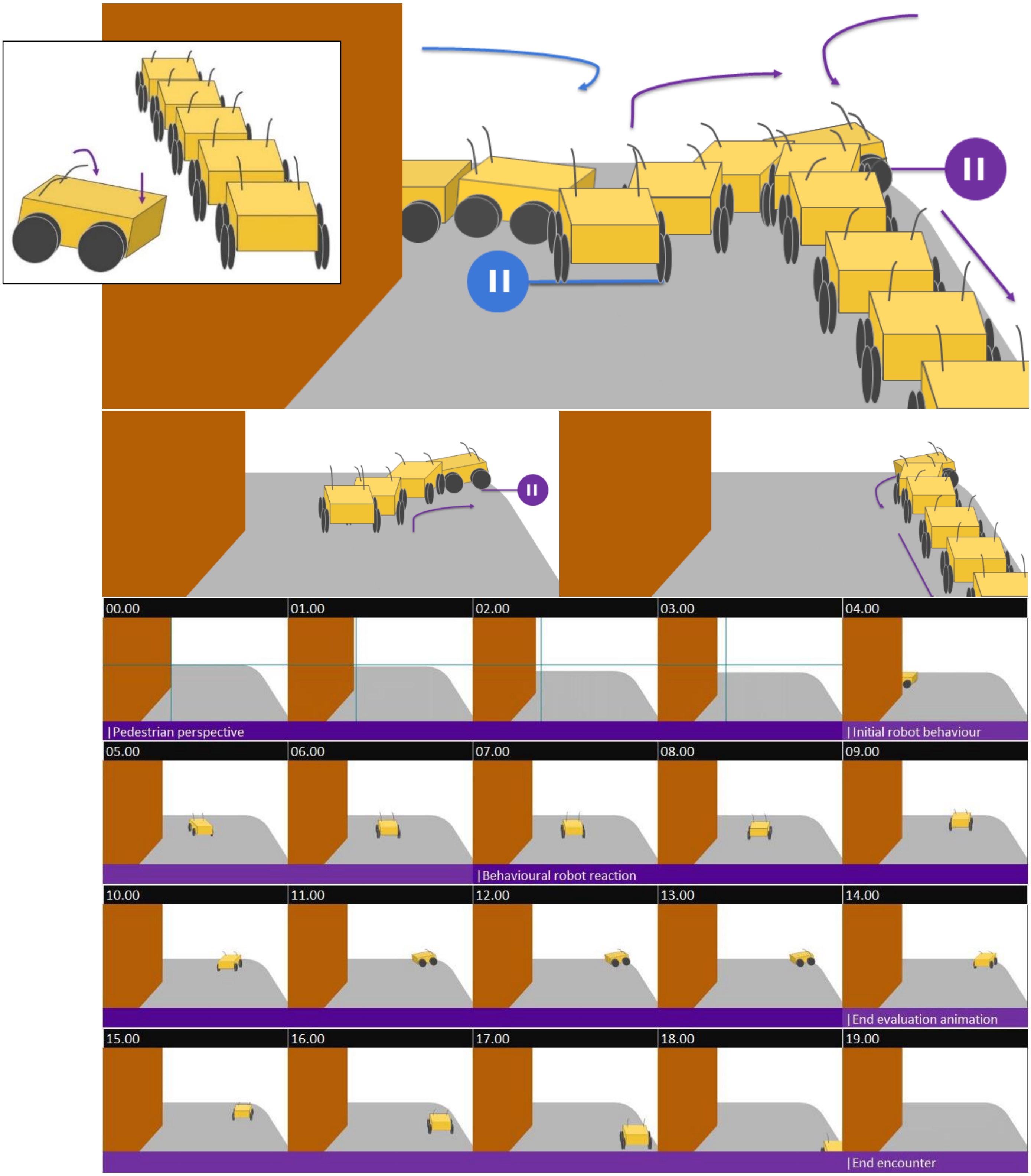


Figure 29: Original robot behaviour followed by the sub-dominant reaction: Lila. This robot drives directly around the corner, detects a pedestrian and stops driving; it bends its antennas forwards while driving backwards into the corner; here the robot waits until the pedestrian passes and continues driving quickly as soon its path it clear. The total overview on top shows most of the robot frames and uses icons to point to the frames that stop or wait.

Sketch for ‘Unease + Curious’: White

To show the broad variety of possible solution area’s we challenged ourselves to embrace the emotion-cluster in order to get in the lead in the encounter to finish it as quick as possible, which would reduce the time consumption. In this redesigned robot behaviour, we aimed for a playful robot that actively approaches pedestrians with this emotion-cluster and invite them to play along. The robot moves playfully until its path is clear. Then the robot would be able to break the connection and drive away quickly from the encounter (see Figure 30).

We defined playful behaviour as energetic and challenging. To show energy in the robots behaviour shakes its embodiment (like an enthusiastic puppy that receives food). This behaviour builds on the curiosity in this emotion-cluster. Based on the measured excitement in the emotion-cluster, we expected pedestrians to anticipate to the robot, which is needed for the robot to take the lead in the interaction.

A problem that we have found is the approachableness from the robot, which was experienced as an invitation to start an interaction. A more offensive approach could help to keep pedestrians on a distance. This could be achieved (without scaring pedestrians) by making loud noises or by quickly approaching on the robots initiative. As long as this action is short and intensive enough it should evoke alertness by pedestrians, but when this action takes too long ‘alertness’ will turn into ‘being scared’, which occurred in the original test where it motivated time-consuming/undesired interactions.

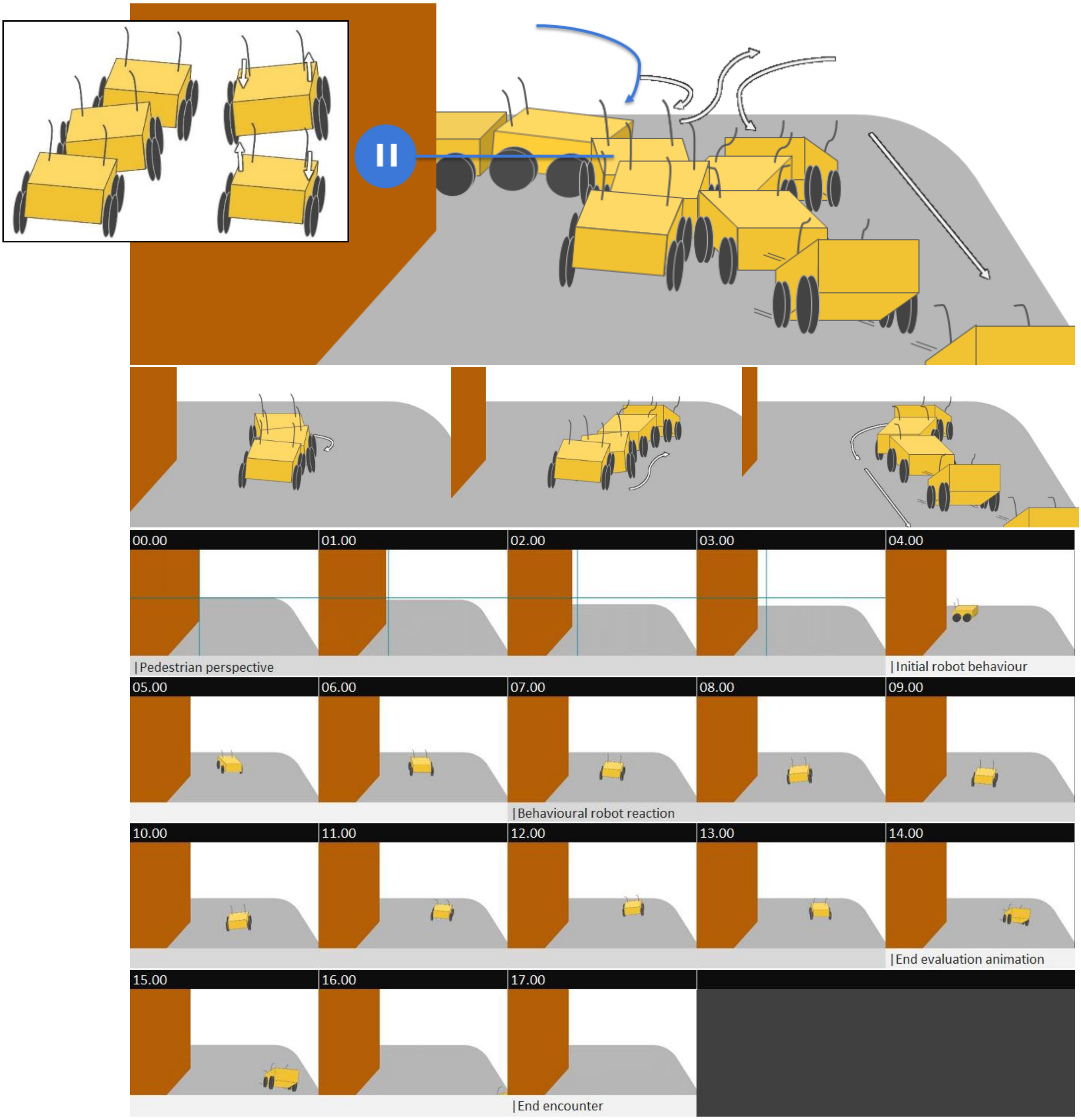


Figure 30: Original robot behaviour followed by the playful reaction: White. This robot drives directly around the corner, detects a pedestrian and stops driving; It starts shaking its embodiment while: it shortly forwards and then backwards drives as long as its path is blocked; then it looks at the pedestrian, breaks this contact and quickly drives of. The total overview on top shows most of the robot frames and uses icons to point to the frames that stop.

5. Evaluation the redesigned robot behaviour

In order for the redesigned behaviours in the previous chapter to be relevant for companies, customers and pedestrians, they have to evoke different and less time-consuming behaviour from pedestrians during an encounter on the sidewalk. Due to the current circumstances (Covid19) we are unable to test with users at the moment. To evaluate our redesigns, we thus conducted an online evaluation test where we animated the robot behaviours were the participants from the previous test reflected on how they experience them. Although this is *no* proof that our designs do what we intended, it still indicates how users (who are familiar with our case study), may experience our designs, which tells us if these first iterations heading into the right direction or not.

In order to get an idea of the relevance of the redesigns, we want to evaluate what participants experienced when they viewed the animations. To get this information, we formulated research questions specifically for this evaluation to reflect how relevant our animations are in comparing to the previous test and to gain insights that indicate the relevance of the redesigns:

Evaluation research questions:

1. “*How do the reactions to "original robot behaviour" in this video study compare to the original study?*”
2. “*How do the reactions of our participants change due to our three redesigns?*”
3. “*How do these reactions depend on people's previous response to the robot's behaviour?*”

In this chapter we explain the setup of the evaluation of the redesign followed by an overview of the results plus the insights we gained from them and finish with review of the values that our redesigns seem to establish.

5.1. Evaluation of the redesigns setup

The evaluation test aims to provide insights from what participants experience, when they see the animated redesigns. In next sections we show the final test structure, our choices throughout the development and our reflection on the change of the physical environment to an online environment for this test.

Evaluation structure

In this section we show the evaluation test setup, what insights we aimed for and how we measured data. This all in an online environment which limited our options in repeating the original test and how we worked with this.

The aimed goal with this evaluation – In this evaluation test we aim to gain insights into how pedestrians experience our redesigns to react to the emotion clusters ‘unease + relief’ and ‘unease + curious’. Due to Covid19, we can’t test our designs with a real robot, therefore, we reflect on how our designs are experienced. This will provide us with an indication of the direction it is heading.

The original test was developed to enable participants to experience and reflect on their micro-emotions in the most natural setting. This can only be done with one robot encounter per participant. Because we want to evaluate three designs where we want to gain insights from all designs from all participants, we have to find a different setup. Once participants are familiar with reflecting on their micro-emotions, we can show multiple options and ask them to analyse these individually and afterwards compare the differences. Because the participants from the original test already have experience with our case study (the original test, encountering a robot in reality and reflecting on their emotions afterwards) they are ideal in performing this evaluation and enable us to use their previous results with the evaluation results.

By comparing the results from the original test with the evaluation test, we can see if the animation from the original robot behaviour evokes similar emotions as the robot in the original test did. Once these emotions are comparable, we can indicate how well the animations communicate our designs. For this reason the animation for the original robot behaviour (see chapter 4) is included in this evaluation test.

By asking the same participants again, we could build on their experience of reflecting on their micro-emotions during a robot encounter. For this reason, we aimed to keep the test as recognizable as possible for them. For this reason, we constructed this test in a way that the measurements tools and interface are as close as possible to the previous test. This contains tools like the emotion-cards but also how the participant controls the robot behaviour (recordings/animations) in the user-interface. In Chapter 5 we explained this in more depth.

Evaluation test walkthrough

The evaluation is based on multiple rounds were an animation was shown to participants on which they reflected afterwards. Figure 31 shows all rounds included in every session and Table 11 provides an overview of all steps per round. The difference between this test and the original test is the amount of presented encounters. This was possible because we wanted participants to compare multiple redesigns which made an unexpected encounter for each design impossible.

Figure 31: Overview of the online evaluation slide which contain the four robot animations and the reflection cards for the participant to fill in their micro-emotions.

	Participant	Moderator
1. Preparation	(not present)	- Randomizes animation order - Prepares empty emotion-cards - Prepares questions & recording software
2. Set-up	- Asks potential questions	- Explains what is going to happen - Explains using tools (if needed) - Starts the screen recording
3. Study (in 4 rounds)	Animation: - Watches the animation Reflection: - Reflects on the overall experience - Selects events that define the experience	Animation: - Observes participants Reflection: - Asks questions about the experience & micro-emotions - Guide participant through the reflection
4. Wrap-up	- Asks potential questions	- Stops screen recording - Rounding up online evaluation - Thanks participant

Table 11: Evaluation phases from beginning to end, including every action per step for both the participant and the moderator.

Adjusted animations

During the redesigning in Chapter 4 we animated the original robot behaviour from the original test to enable us communicate the original robot behaviour. This animation is included in the evaluation test to serve as a baseline for comparing our findings on this video study to the outcomes of the original test. In order to get an unbiased feedback where participants aren't aware of the role of this animation, we presented this animation exactly like the redesigns.

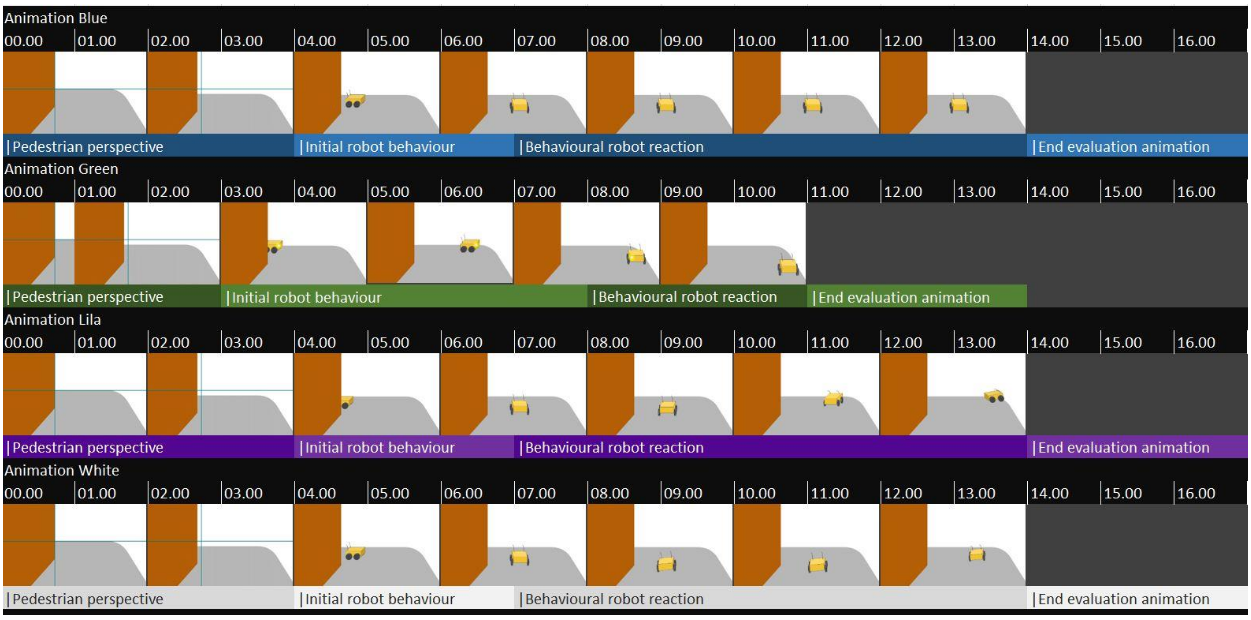


Figure 32: Adjusted animations to stop at the moment that a pedestrian would react. This to prevent participants getting biased by our ideas of how this reaction could happen.

Establishing the pedestrian's perspective – A redesign is considered (potentially) valuable once pedestrian's behaviour during an encounter *doesn't* influence the time-efficiency of the delivery robot, by *not approaching* or *stepping aside sooner* after the robot performed its behavioural reaction towards a certain emotion-cluster. An animation always influences participants by the perspective that indicates how the pedestrian would walk (or not walk). The robot behaviour is best experienced from the perspective of the pedestrian who encounters the robot, like the perspective in the original test. To show this perspective, we added an animation at the beginning of every animation where walking on the sidewalk is simulated (see Figure 33). During the walking-animation the robot isn't visible, to prevent any possible relation between the movements and the robot behaviour. After establishing the perspective in this way, the perspective was fixed for all designs.

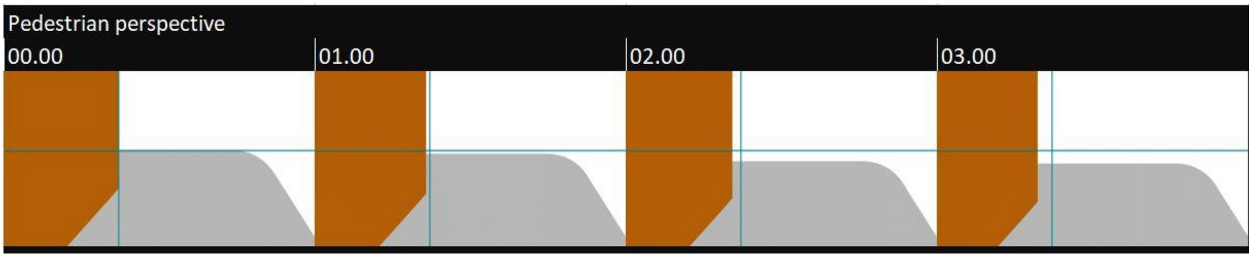


Figure 33: Including a pedestrian-perspective by zooming in on the sidewalk like it would in real life (the lines in the frames have the same position in all frames to show the change in perspective).

Constructing the redesign animations – The redesigns are either based on the initial robot behaviour or the behavioural robot reaction based on the original initial robot behaviour. In order to show the designs in their own context is decided to construct all animations in the same way: #1 establishing the situation (pedestrian perspective), #2 the initial robot behaviour and #3 the behavioural reaction from the robot. Figure 32 shows an overview of the evaluation animations used in the evaluation test, based on this structure to present the context.

Animation designed to prevent the emotion-cluster 'Unease + Relief' should show the new initial behaviour, but we had no idea how they would react. Because all animations need to have the same structure, we need to include a behavioural reaction which indicates how this new initial behaviour would react. For this reason we decided to use the original behavioural robot reaction as behavioural reaction. This way participants could reflect on the redesign in comparison with the original behaviour.

Animations designed to react to the emotion-cluster 'Unease + Curious' have to enable participants to reflect on the behavioural robot reaction. In opposite to an animation that prevents an emotion-cluster do emotion-cluster emerge from the original initial robot behaviour, which has to be presented in order for participants to reflect on.

Including the original initial robot behaviour – To answer our first research question and to help participants to recognise certain elements from their previous test experience we included the original robot behaviour from the previous test. This could allow them to emphasise the situation and therefore improve their current experience, which should provide us better feedback. But, this behaviour all also receive some feedback which will reduce the amount of feedback we get on the redesign. We value qualitative feedback over quantitative feedback and therefore decided to include the behavioural context into the animations.

The redesigns made in Chapter 4 include our envisioned encounter until the end of the encounter, which include both the robot and the pedestrians perspective/movements. In this evaluation we want to gain insights into the unbiased reactions and by showing our vision, we bias the participants in what reaction is expected from them. For this reason is decided to stop the animations at the moments that the pedestrian should continue walking and removing every other pedestrian behaviour that could be connected to an intended reaction.

Measurement methods

Besides the fact we could not test with a real-life robot like in the first test, testing online has different requirements, which challenges us to find alternatives while keeping the setup recognizable for the participants. Below we explain how we adjusted our developed tools to measure micro-emotions, found software to enable participants to control the animations and all the other methods used during the evaluation test.

Measuring micro-emotions with the emotion card – In order to reflect on experiences and micro-emotions, we digitalized the emotion cards (see Figure 34) (see Chapter 2 for the original emotion card design). This design has the same construction as the original version to support participants with a tool that they are familiar to use.

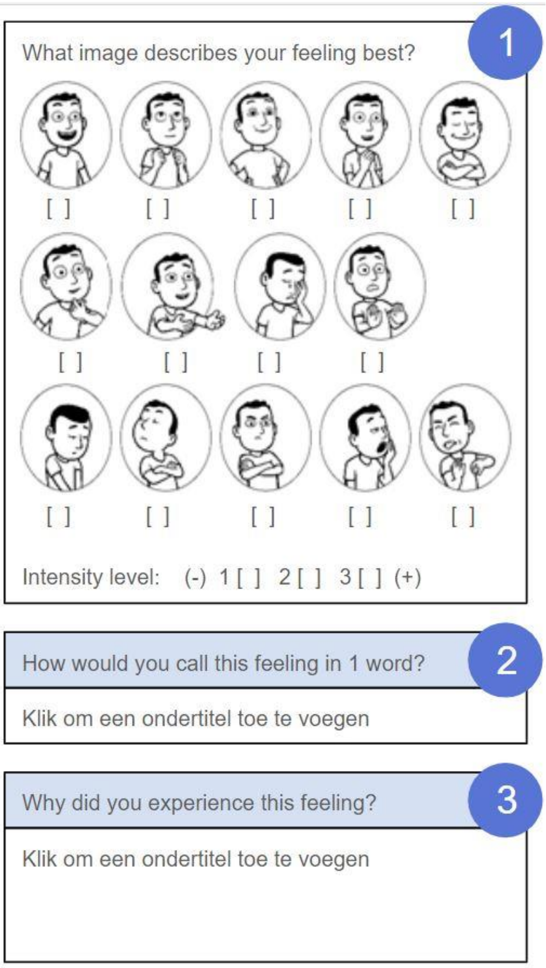


Figure 34: Emotion-cards during the online evaluation where participants reflect on their experienced emotions by 1) select the PrEmo illustration, 2) describe the feeling with 1 word and 3) providing a short description about what triggered this feeling.

Software tools that enable digital communication – Because the evaluation is online, a digital setup is required that 1) enables us to record the sessions, 2) put the participant in control of the interface (watch animations & fill in the emotion cards) and 3) enable us to safely receive and store the test results automatically afterwards.

The digital setup should provide solutions for all these requirements. Most software tools provide only solutions for one or two of these requirements, so we decided to combine multiple tools: 'Google Presentations' (a digital platform for collective presentation editing) to show the animations and the emotion cards and 'Zoom' (video-call service) to communicate with participants and record each session directly on the moderators computer.

The participant opens the Google Presentation on his or her computer and shares this via the screen-sharing-option Zoom. This method enables the participant with all control over the animations and emotion cards (requirement 2) while the moderation is enabled to record, observe and guide the whole process (requirement 1). For the results, Google Presentations is an online tool from the moderator where all data is restored, which make the results automatically available afterwards without any action from the participant (requirement 3).

Preventing a bias – To prevent biasing participants with the names we gave to the redesign, which will indicate what we intent the achieve with every animation, we decided to give the animation names that are unrelated to the context, without limiting the communication during the test. By naming with colours it became easy to communicate about the animations without biasing participants. The colours we used aren't used in the sidewalk context or in the designs and are therefore suitable. This idea is explained to the participants at the beginning of the test. Figure 32 provide an overview of the animations used during the evaluation test and what name they got and how the animations are constructed.

Because of the included context of every redesign in the animation itself, the order we present them can't and shouldn't influence participants. To be sure, we used the balanced Latin square to randomize the order for all participants. Table 12 shows the test rounds for every participant and the corresponding animation. Note: the balanced Latin squire has four options which gets repeated by the fifth participant.

Participants:	Round 1	Round 2	Round 3	Round 4
13	Blue	Green	White	Lila
14	Green	Lila	Blue	White
15	White	Blue	Lila	Green
16	Lila	White	Green	Blue
17	Blue	Green	White	Lila

Table 12: The balanced Latin square order of animations for each participant.

Recruiting previous participants – From the original test we know what micro-emotions and emotion clusters were evoked by the robot. Because we focussed in the redesign on influencing these emotion clusters, we now could specifically ask participants based on emotion-clusters. This allowed us to distinguish results based on the relevance of the design for a participant which provided relevant insights into our redesigns.

Conducting a pilot – In order to see of the evaluation setup functioned as intended we conducted a pilot. We asked someone who didn't participate in the original test because we were limited by the amount of people from that test. In order to provide the same starting point as the other participants would have, we explained the participant what happened in the previous test by showing an robot encounter and walked through one cycle of reflection on micro-emotions (the participant reflects on the recording which he didn't experienced himself). This participant was unaware of the redesigns before the test started, but by practising with the setup before, he could perform the pilot without any problems.

The pilot was a complete walkthrough and there were no major changes needed. For this reason the results from the pilot could be included in the data used for analyses. By having a participant who was unaware of the previous test, we can compare the results to see if our evaluation test was unbiased by asking participants who are familiar with our research.

Collecting and structuring data – In this evaluation, we aim to get insights in the same form as we got from the first test: micro-emotions over time and the motivations for their triggers. In order to get this, we document the data in a comparable way. The results structure of this test are similar to the original test by using a timeline to show the micro-emotions over time per participant enriched with relevant quotes from the participants (see Figure 35).

Time (sec)	00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00
Animation 'Blue'	|Pedestrian perspective				|Initial robot behaviour			|Behavioural robot reaction						
Animation 'Green'	|Pedestrian perspective			|Initial robot behaviour					|Behavioural robot reaction					
Animation 'Lila'	|Pedestrian perspective				|Initial robot behaviour			|Behavioural robot reaction						
Animation 'White'	|Pedestrian perspective				|Initial robot behaviour			|Behavioural robot reaction						

Figure 35: The animation phases of all animations collected in a single overview.

5.2. Results evaluation test

After we collected all data from the evaluation test we discussed on the previous sections, we validated every evaluation, combined insights per redesign and created an overview. This section shows how we structured the results and the final results overviews per animation. These overviews are later on used to analyse our designs and for making the final conclusions in the next chapter.

Because the pilot could be performed as a normal test we could compare this data with the other results and saw that our pilot provided similar results as the other results. For this reason we decided to in include these data to the results as well. The only downside is the lack of results from the original test that shows the emotion cluster to the original initial robot behaviour, which is used to determine if a participant would trigger the redesigned robot behaviour.

Structuring results – Because the evaluation test has no recordings of the participant's behaviour, we couldn't structure the data based on the participant behaviour like we did in the original test. This evaluation is intended to review the robot behaviour and therefore, we used the structure of the animations (see Chapter 4) #1 Pedestrian perspective, #2 Robot's initial behaviour and #3 Robot's behavioural reaction. This way we link the micro-emotions to specific triggers of the animated robot behaviour. With this overview we determine if 1) the redesigns evoke what we aim for and 2) if the animation context was clear for the participants.

During some of the evaluation test, the moderator noted that a participant struggled with reflecting on specific animations. This happened for different reasons like they didn't understand the movements of the robot or they needed time/practise to get familiar with the reflection process. In the case were this happened, the researcher checked this with the participant to make sure that this was the reason. After a confirmation, we marked the results for that specific animation as invalidate to exclude it from the results. For this reason have some animations (presented in the next section) more data than others.

From most participants (4 out of 5) we know what micro-emotion they had during the original test. In the case were the emotion-cluster was unknown, we added this to the results in order to combine the emotion-clusters to the redesigns.

Original robot behaviour: Blue

The aim for the robot blue was to simulate its behaviour from the original test were participants described the robot as 'unpredictable' and 'scary' (see Chapter 4). Figure 36 shows the results.

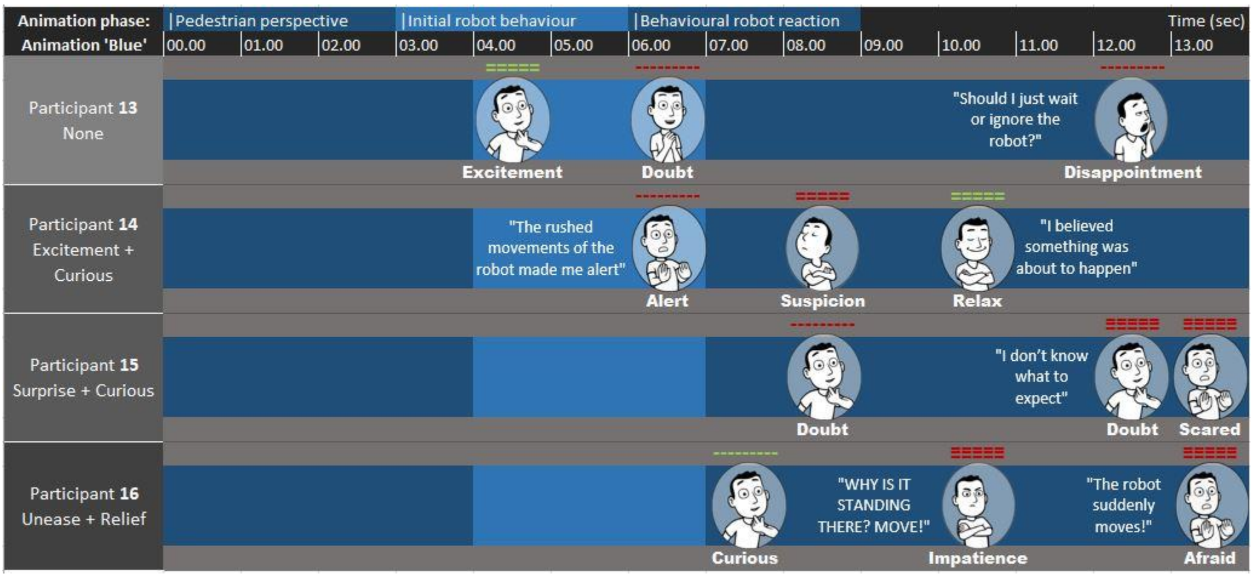


Figure 36: An overview of micro-emotions defined by participants about their experience of the reproduced original robot. The data from participant 17 are removed because the evaluation itself wasn't understood at the point which resulted in irrelevant data. On the left participants are listed and on the right their experienced micro-emotions over time.

This animation was preferred the least to meet on the streets by all participants who described it as '*unpredictable*', '*frustrating'* and '*broken'*. They experienced a lack of communication and got scared by the sudden movements. For these reasons, they would react by stop walking once they see the robot and step aside or back at the moment that the robot continues driving '*suddenly'*.

Because the motivations from all participants are based on the same robot aspects that evoke similar micro-emotions, we can't find a patterns between the different emotion-clusters that are experienced in the previous test. The current participant reaction seems to have no connection to the previously reaction to this robot behaviour.

We got comparable results from the original test. This animation was a bit stronger experienced than the original, but with the same robot aspects. Therefore we concluded that this animation is representable for the robot behaviour performed during the original test and that participants are able to imagine to encounter the animations.

Redesigned initial behaviour for ‘unease + relief’: Green

The aim for this robot was to be predictable during its initial behaviour to prevent ‘Unease + Relief’ as first emotion-cluster (see Chapter 4). Figure 37 shows the results.

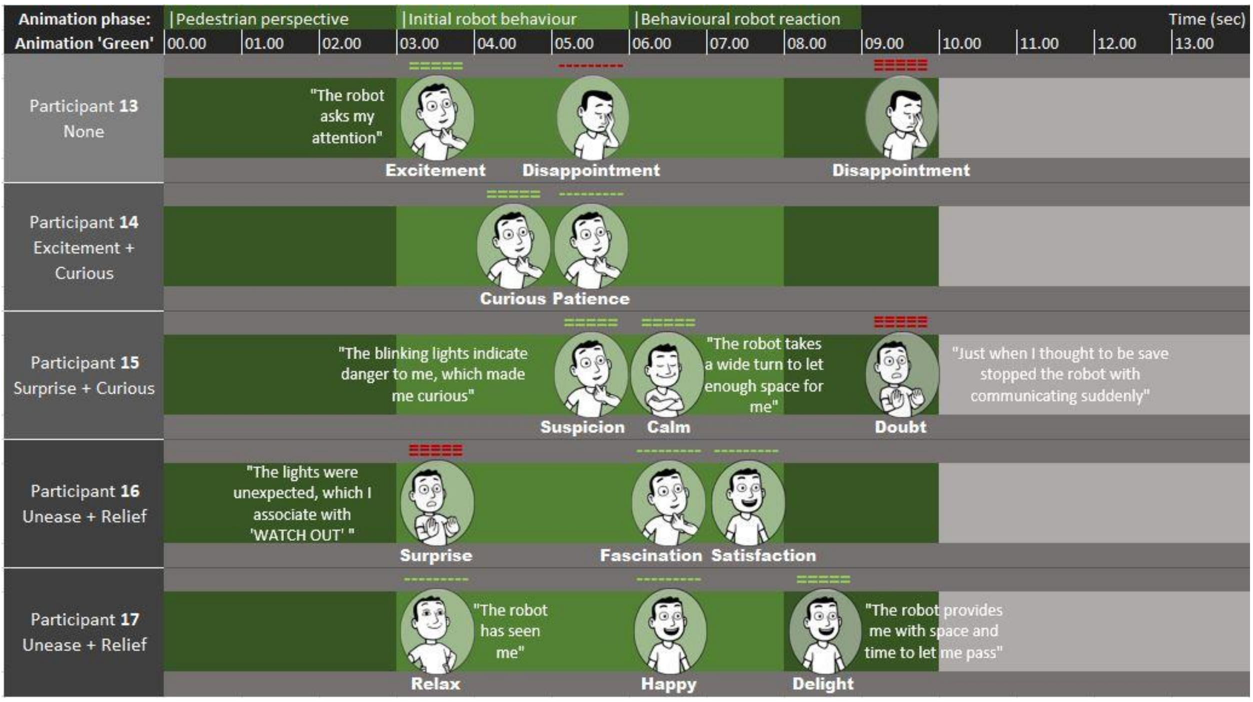


Figure 37: An overview of micro-emotions defined by participants about their experience of the subdominant robot. On the left participants are listed and on the right their experienced micro-emotions over time.

Although this initial behaviour consumes more time in this video before it starts performing its behavioural reaction the robot movements are perceived faster than the original initial behaviour. Participants perceived this initial behaviour as ‘*predictable*’, ‘*observant*’ or ‘*communicative*’.

The lights were in all cases recognized as light, but sometimes as warning/attention-seeking lights and sometimes as a blinking light. This evoked mixed experiences by the participants. The participants who recognized the blinking lights experienced these lights as pleasant because they had the impression that the robot communicated to them about where it would drive, but when participants recognized them as warning lights, which they experienced as ‘*danger*’, which resulted in ‘*Unease*’. However, driving-on-the-outside-curve was recognized by all participants. Although this evoked different emotions, the robot’s intentions were ‘*predictable*’.

All participants would leave this robot alone when they encountered it on the sidewalks, when it would only perform its initial behaviour. This changes after the robot performed the original behavioural reaction. This was caused by the lack of communication that was experienced before. This was experienced as ‘*suddenly*’ and ‘*unpredictable*’ (comparable with the original results).

This redesign contains multiple changes which influence the experience differently. In the next iteration we could design the blinking lights to measure the effect better. Overall, ‘unease’ occurs less than before, which indicates that this redesign is heading the right direction and increasing the time-efficiency.

Redesigned robot reaction for ‘unease + curiosity’: Lila

The aim for this robot was to react towards the emotion-cluster ‘unease + curious’ by behaving sub-dominant to reduce curiosity (see Chapter 4). Figure 38 shows the results.

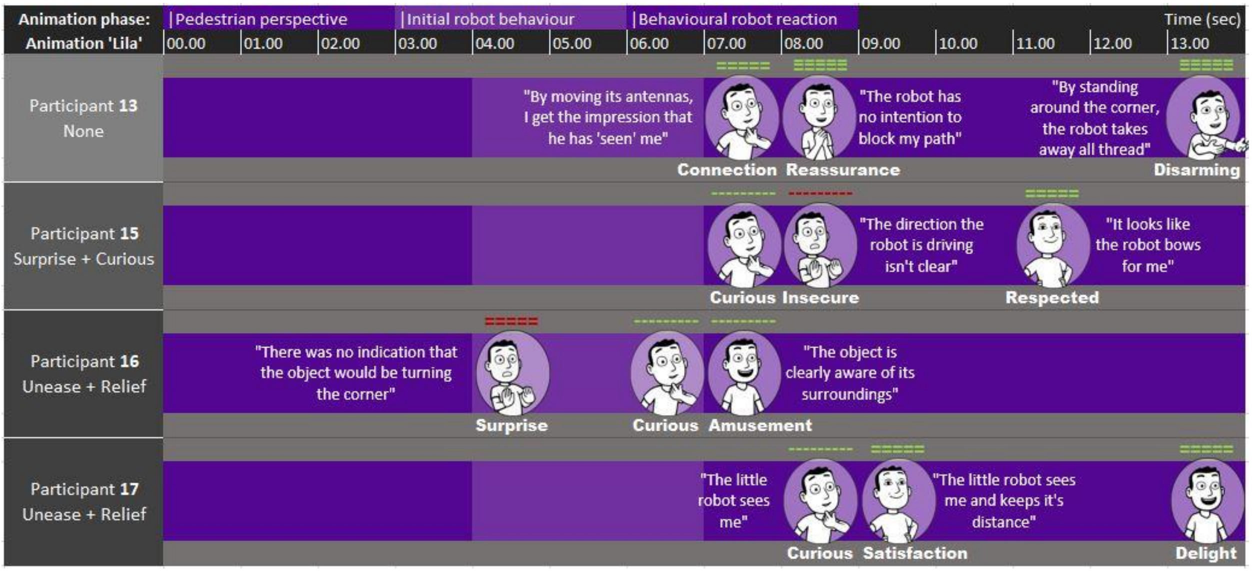


Figure 38: An overview of micro-emotions defined by participants about their experience of the sub-dominant robot behaviour. The reaction from participant 14 is removed because the situation wasn’t clear which resulted in irrelevant data. On the left are the participants listed and on the right their experienced micro-emotions over time.

This animation is reviewed as the most ‘*human-like’* behaviour which the participants would prefer to encounter on the streets because they felt ‘*like a king who passes*’, ‘*recognized’* or ‘*disarmed’*. All participants would continue walking as soon as the robot moved into his position in the corner and leave the robot alone. The movement of the antennas got noted by all participants who felt that something was about to happen. In all cases the experience was positive because of the robots communication. This small movement evoked many positive micro-emotions in a short amount of time. This behaviour is reflected as human-like-behaviour and could be an interesting direction to improve the robot behaviour in another iteration.

The participants who experienced curiosity by the original robot behaviour had no intention to approach the robot because they emphasized with the robot and felt dominant in this situation. We see by all participants that they interpreting the robot as sub-dominant, but where some experienced this as ‘*shy’* others experienced this as ‘*serving’*. The influence for both experiences is a reaction where the robot is left alone. Another iteration is required to explore the differences in interpretations and their evoked reactions.

In some participants found it confusing when the robot drove backwards because they didn’t understand what was happening and called this ‘*strange’* behaviour. This could be caused by the animation quality. When this happened the rest of the animation was still recognized.

Because all participants were prepared to continue walking afterwards, we can confirm that this behaviour can potentially increase the time-efficiency in cases with this emotion-cluster.

The participants with previous emotion-cluster ‘unease + relief’ seemed to prefer this behaviour and would stop walking to watch the robot. This would result in an even more time-consuming encounter and is therefore not suitable as reaction for this emotion-cluster.

Redesigned robot reaction for 'unease + curiosity': White

The aim for this robot was to reduce curiosity from the emotion-cluster 'unease + curious' by behaving playfully to embrace it (see Chapter 4). Figure 39 shows the results.

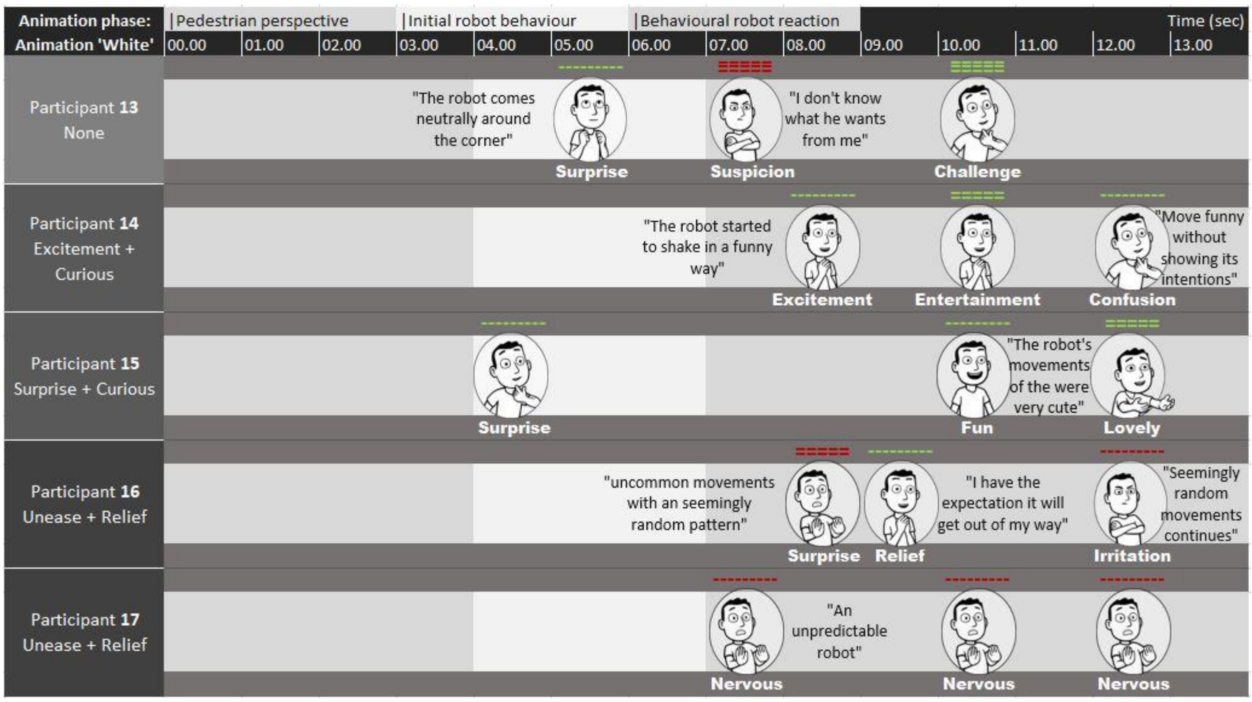


Figure 39: Overview of micro-emotions defined by participants about their experience of the curious-embracing robot. On the left participants are listed with their experienced micro-emotions over time on the right.

This behavioural robot reaction is experienced as either '*uncommon*' and '*nervous*' or '*energetic*' and '*funny*'. This is a broad difference that can be explained by the different emotion-clusters upfront.

Participants with the 'curious' in their emotion-cluster experienced this robot behaviour as pleasant and challenging were they feel entertained but keeping their distance. They enjoyed observing the robot because of the '*funny*' and '*cute*' movements. Besides the '*not threatening*' behaviour, they still watched closely to see what to robot would do next. This way they could step aside to provide space for the robot. This behaviour is less time consuming than measured in the original test and could therefore be a potential solution for the robot in these situations.

Participants with 'relief' in their emotion-cluster experienced this behaviour as nervous and random. They got confused because they felt uncertain by the unpredictability. Because they tried to understand the motivation of the robot without success, they would keep their distance and '*walk around it in a big circle*' to avoid contact. Although this behaviour achieves what is intended (the pedestrian doesn't approach the robot), it shapes for this emotion-cluster behaviour that is likely to be more time consuming for both the robot and the pedestrian and established some negative advertisement by the pedestrian at the same time. Based on these indications we predict that this behaviour isn't suitable as a robot reaction for the emotion-cluster 'unease + relief'.

These results indicate that participants would watch this robot and not approach it. This is what we aimed for and we can therefore confirm the direction of the redesign.

5.3. Findings from analysed results

Based on the result overviews in the previous section, we now are able to answer the research questions established for this evaluation at the begin of this chapter. We will reflect on the broader implications of these findings in the next chapter.

1. "*How do the reactions to "original robot behaviour" in this video study compare to the original study?*"
As discussed before, we included the data from the pilot to the results. By comparing this data with others, we see the same experiences and behavioural reactions occur as the other participants. This disproves that participants interpreted this robot behaviour singularly based on their experiences. This recognition returns in other animations that use the original initial robot behaviour, here most participants (3 out of 5) said they recognise the behaviour from their previous experience. Based on these insights, we conclude that the original robot behaviour shapes pedestrian behaviour in a way that is comparable to the original robot behaviour.

2. "*How do the reactions of our participants change due to our three redesigns?*"
We noted that some of the designed aspects have a more direct influence on participants than others, which in case of an undesired influence seemed to lead to undesired reactions. For example, the blinking lights to improve predictability enabled different interpretations and therefore evoked different experiences. These differences could be caused by the design and require another iteration to enable it to provide insights into the effect on pedestrians. Besides the design mistakes indicate most redesigns to evoke different experiences by participants who said to behave differently to the situations envisioned by the animations.

The redesign to prevent the detected emotion-cluster 'unease + relief' shows mostly reactions and experiences that were intended, but still some undesired reactions as well. Because the initial behaviour is the default state of the robot, it has to suit for most pedestrians. This makes the initial behaviour the most complex behaviour to redesign. By redesigning for the measured emotion-cluster, we influence the experience from all pedestrians. Luckily, we see that our initial behaviour is experienced as '*predictable'*, which is the first step towards a suitable initial behaviour that evokes the least undesired situations.

3. "*How is this reaction dependent on people's initial response to the robot's behaviour?*"
As we showed and compared the previous emotion-clusters in the result overviews, we noticed that some redesigns, that focussed to shape a different emotion-cluster as , could be negatively experienced by pedestrians where another emotion-cluster emerged before. This shows clearly that the robot's behaviour has to adapt to the situation in order to shape human behaviour and that this could be done by adapting micro-emotions.

For the behavioural reaction to shape the emotion-cluster 'unease + curious' we see the reactions where we aimed for: there isn't any intention to approach the robot anymore that would reduce it's time-efficiency. Although this is only an indication, it confirms that these redesigns are heading in the right direction.

6. Conclusions and discussion

In this thesis, we proposed a novel concept for shaping human experiences during interaction with an autonomous robot, specifically a delivery robot: detecting and anticipating micro-emotions and providing a purposeful response. We explored this concept in a case study where pedestrians encountered a delivery robot and designed (and evaluated) robot behaviour and robot reactions accordingly. We measured micro-emotions and recorded human behaviour, in order to gain insights into the micro-emotions that shaped human behaviour and human experience. We found that a regular behaviour of a mobile robot evoked undesired (time-consuming) behaviour from participants that consisted of either micro-emotion cluster of 'Unease + Relief' or 'Unease + Curiosity'. We found in an online evaluation test that it is plausible for a robot to adapt to micro-emotions to shape human behaviour. This can be done by detecting emotion-clusters and what behaviour reaction it requires in order to evoke neutral pedestrian behaviour. With this neutral behaviour, a delivery robot establishes a neutral encounter.

Conclusions

From the research we presented in this thesis we now can answer the main research question: "*Could we shape pedestrian behaviour based on detected micro-emotions during an encounter with a delivery robot?*".

Yes, micro-emotions occur during an interaction and can be measured. By processing micro-emotions in emotion-clusters, we are able to determine an pedestrian experience, on which robot behaviour is able to adapt to shape the pedestrian behaviour.

Yes, different robot behaviour evokes different micro-emotions and can seemingly be designed for the specific emotion-clusters found in our case study.

For the next step towards exploring our concept, we need to observe if our findings are applicable in a real sidewalk situation and we have to explore the options for detecting micro-emotions from the robot's perspective.

Limitations

Limitations from Covid19 – At the begin of this project, we planned to have 2 identical tests where micro-emotions measured in the first test were used to redesign robot behaviour and measure the changes in micro-emotions in the second test. Then the Covid19-crisis emerged after we conducted the first test and we could not test in 'real life' anymore. The alternative setup we came up with was to still redesign the behaviour based on the results already collected and evaluate these in an online test to get an indication of how the participants from the first test experienced this redesigns.

The consequences of this adjustment were that 1) the iteration during the design phase had to be done without any user testing, which required life testing and 2) we could not repeat the same test and would therefore provide a different experience which we should be critical towards because it represents only an indication of the direction of the redesign relevance.

Online evaluation test – Although the Covid19 consequences, we are glad with the online evaluation results. Of course, it would be better to repeat the first test with a changed robot design to confirm the real effectiveness of our design, but as far as confirmations go within our limitations, we succeeded in sharing our ideas and insights of the potential solutions.

Reliability of our developed methods – We developed our own methods, strongly based on existing tools for measuring micro-emotions. Although all original tools where developed to determine detailed product experiences by designers, they are not designed for our context. Therefore, we iterated many times and upgraded them equally. By using these tools in our tests we obtained valuable findings which got conformed by a second use where all data lined up. Although this would mean that our tools function for this specific situation, we cannot guaranty the same effectiveness in a different setup.

Benefits of using a sidewalk simulation – Our case study suggests that emotion-clusters can effectively predict how the encounter will resolve. This holds the potential to design the behaviour of artefacts that can adapt to responses of people and shape human experience. However, like we discussed in Chapter 3, it is important to understand that our study was experimental and did not take into account contextual influences of real-life situations that may also trigger micro-emotions and shape human experience. While analysing and responding to micro-emotions, possible contextual influences should also be considered in order to design suitable robot behaviour.

Limitations of our redesigns – Every emotion-cluster has its own motivations for triggering specific pedestrian behaviour. These motivations can overlap between different emotion-clusters, which could mean that a certain robot behaviour could work for one situation, but not in another with similar motivations. For example, when a robot 'looks at a pedestrian', the approachability-of-the-robot aspect is effected and can be used for different situations: an uncertain pedestrian experiences recognition and gets motivated to leave the robot, a curious pedestrian experiences this robot behaviour as an invitation to approach and starts interacting. In this example, although the input is the same, the effects are complete opposites. We think that this is caused by the different micro-emotions which are evoked in the first place. Therefore, the redesigns of behavioural robot reactions we present here have to be considered in the correct context. In order to apply them in a seemingly similar situation can have very different results.

Responding to an already shaped experience – In our analysis, we only interpreted the first emotion-cluster to identify suitable responses for the robot in order to change the behaviour of people. However, I expect that this response will evoke the next emotion-cluster, which also requires a suitable response from the robot. The interaction between the robot and people results in a sequence of emotion-clusters. If the subsequent emotion-cluster is influenced by the previous one(s), it is useful to explore its dependency. This phenomenon has to be explored in a follow-up case study to strengthen the robots predictions of the influence of its behaviour.

In the context of this case study, two micro-emotions provided enough information to relate the human experiences and are therefore clustered. However, the amount of micro-emotions is only one criterion for establishing an emotion-cluster and it could be based on more and/or different interaction aspects like by a certain amount of time or by detection of human behaviour change. Different approaches will have different qualities, which can provide benefits for multiple applications and should be researched per situation.

Future work

Ethical review of concept potentials – Enabling autonomous robot's to shape pedestrian behaviour should be considered to be ethical: are these robots serving us or are they controlling us. In the context of delivery robots, I foresee that most delivering companies are concerned about the impressions they put on the sidewalk from an economical perspective. But of course, this concept could be used for an illegal or harmful purpose as well. Although I'm aware of this, I think that the purpose itself can be achieved with current technologies as well, which makes that we should not doubt the concept but the possible intentions people could have with autonomous robots. Because our concept don't stretch the boundaries of this ethical question and it increases the benefits for all stakeholders, I'm confident to present it. My aim is to achieve adaptive robot behaviour that reacts in an ethical way.

Collaborations between multiple professions – Achieving adaptive behaviour for autonomous robots requires multiple professions, like programmers, researchers and behaviour designers, to elaborate throughout development and the maintaining afterwards. With our concept, we foresee a possibility for new collaboration where these disciplines meet each other in a different way.

Wrap-up

It seems that robots can adapt to human behaviour. Which opens up a new and interesting area. Wouldn't it be great to live with robots that not only serve us but simultaneously adapt to our emotional being?

I imagine robots, which have fun encountering people, stand-up for themselves when needed and apologise when they make a mistake.

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8. Appendix

8.1. Insights from pedestrian & robot observations

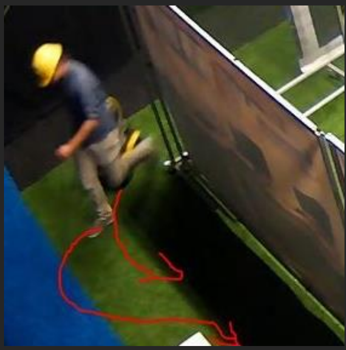
Overtaking the 'slow' robot

This person over takes the robot when he thinks to be faster than the robot, but the robot started to move suddenly and this person had to speed up.

Frustratingly slow robot

This person could not move around the robot when it drove slower. In reaction, the person got frustrated.

Scary & stubbern robot

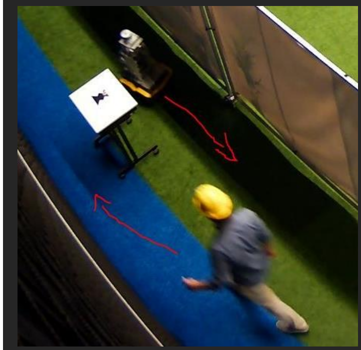


The person was slower than thought, but the robot kept moving. For this reason, the person scared and made a jump forward

Sub-dominant pedestrian

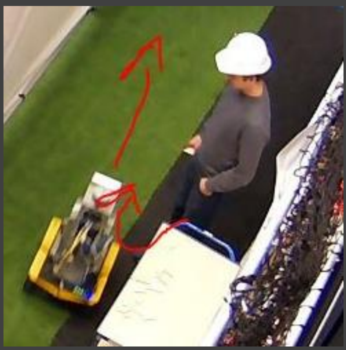
The person adjusted his movements once he figured that the robot had a different goal: Sub-dominance toward the robot.

Clear communication



By seeing the robot approach made this person decide to move to the left side of the table (which he didn't do before). Both the robot and the pedestrian could continue moving.

Frustrating surprise



The person waited for the robot, who stopped suddenly. This evoked frustration by the person who's path got blocked by the robot.

Surprise around the corner

The robot and the person encountered each other unexpectedly around the corner. The person changed his movements in order to avoid a collation.

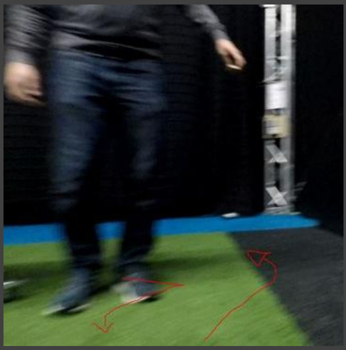
Keeping a distance

Because of the lack of space during an over taking does this person prefer to hold on to the table in order to avoid any contact with the robot.

Getting attention

Only by driving around does a robot get attention. People turn their heads to have a look when they could only hear the robot.

Prepared to follow



An sudden and detriment turn of the robot motivated this person to change his route and follow the robots intentions.

No social issue to stare

Where 'starting to others' is in general (in the Netherlands) unaccepted social behaviour, which seems not to happen towards a robot.

Evoked interest

Autonomous robots evoke interest and some form of challenge by some pedestrians who get stimmulated to test the robot on it reactions.

Scary robot movements

By sudden changes in the robot's driving pattern does it scare the people who walked behind him.

Dominant human behaviour

The more this person got familiar to the robot, the more dominant he behaved. At this moment, the robot had to wait in order to continue.

Getting falimiar

Once this person got familiar with the robot, he started to ignore it more.

Intentions in body language

By moving his shoulders in the direction he was heading, this person communicated on what side he intended to pass the robot.

8.2. Prototyping: initial test

Consent form

The Technical University of Delft supports the practice of protecting research participants' rights. Accordingly, this project was reviewed and approved by the Human Research and Ethics Committee. The information in this consent form is provided so that you can decide whether you wish to participate in our study. It is important that you understand that your participation is considered voluntary. This means that even if you agree to participate you are free to withdraw from the experiment at any time, without penalty. If you wish to withdraw your consent after the experiment is completed, we ask that you try to do so within 24 hours, by contacting the researchers.

The aim of this study is to collect data on people interacting with the environment of a sidewalk. The sidewalk environment is simulated for test purposes. While we do not expect collisions between participants and the environment, please do not participate in this study if you expect to be at higher risk of slipping over or otherwise falling due to the environment.

During the experiment, we will make video recordings (top-down), and we will ask you to fill in short questionnaires. Questionnaire data can be made available to other researchers in an anonymized dataset, to model the displayed behaviours and to inform the design of the environment. The collected videos, on which you might be identifiable, will only be used by members of the IDE faculty, to enrich their insight. These videos and the consent forms will be carefully and securely stored for at most five years (until January 2025).

During the study, you will be asked to walk through the simulation and interact with the environment. Afterwards, you will be asked to review your emotions based on the recordings of your experience (shown by the researcher). This process will be repeated two times. The total duration of this experiment is approximately 20 minutes.

If you have any questions not addressed by this consent form, please do not hesitate to ask.

Declaration of consent (please tick the appropriate boxes)

	YES	NO
1. I agree to participate in this study	◯	◯
2. I have read the study information above and understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	◯	◯
3. I understand and accept that sharing a space with a robot as in this study may, on rare occasions, result in physical discomfort (e.g. near collisions).	◯	◯
4. I understand that my identifiable data is recorded for research purposes as described above, and can be stored until January 2025.	◯	◯
5. I agree for my non-identifiable data to be made available in an anonymized dataset.	◯	◯
6. [OPTIONAL] I agree for the researchers to use video data of me collected during the experiment in academic articles and presentations.	◯	◯

____________________ ______________________ __________________

Name and signature participant Date

____________________ ______________________ __________________

Name and signature researcher Date

Arduino code used in 'Pedestrian of the future'

```
#include <Adafruit_NeoPixel.h>
int PIN=8; int LEDnum=40;
Adafruit_NeoPixel strip = Adafruit_NeoPixel(LEDnum, PIN,
NEO_GRB + NEO_KHZ800);
int colorSet[3]={1,2,3};// Collection of colors
int v=255; //light intensity
int allColors[4][3]={
 {0,0,0},    //Color 0 :: Off
 {200,255,0},//Color 1 :: Yellow
 {0,255,255},//Color 2 :: Cyan
 {200,0,255} //Color 3 :: Magenta
};
String colorNames[4][1]={
 {"Off"}, // Off
 {"110"}, // Yellow
 {"011"}, // Cyan
 {"101"}  // Magenta
}
//Delay waiting time for fading in of the color
int waitingTime=5; int fadeRounds=70;
//Serial parameters
String inputString = ""; bool input=false;
int nrTests=0; int activeRound=0;
bool start=true; bool testContinue=false; bool testActive=false;
bool reset=false;
// Initial setup
void setup() {
 Serial.begin(9600);
 inputString.reserve(200);
 Serial.println("---------------------------------------");
 Serial.println("Initiating...");
 // Initiate LED strip
 strip.begin();
 strip.show();
 // Initiate the Colors's
 Serial.println(" Ready for testing.");
 Serial.println(" Type '?' for help");
 Serial.println("---------------------------------------");
 colorWipeFade(colorSet[0], waitingTime);
}
// Main program
void loop(){
 if(input){
  validateInput();
  inputString = "";
  input = false;
 }else{
  testContinue=false;
 }
 if(reset){
  testActive=false;
  testContinue=false;
  reset=false;
 }
 if(start){
  nrTests++; Serial.print("Test nr.: "); Serial.println(nrTests);
  testActive=true;
  setColor();
  start=false;
 }
 if(testContinue && activeRound<3){
  performRound(activeRound);
 }
 if(!testActive){
  Serial.println("End of the test");
  colorWipeFade(0,waitingTime);
  Serial.println("---------------------------------------");
  activeRound=0;
  start=true;
 }
 delay(20);
}
//Check for input text
void serialEvent() {
 while (Serial.available()) {
  char inChar = (char)Serial.read();
  if (inChar == '\n') {
   input = true;
  }else{
   inputString += inChar;
  }
 }
}
void validateInput(){
 if(inputString.equalsIgnoreCase("?")){ // input tools
  Serial.println("---------------------------------------");
  Serial.println("Legal input: ");
  Serial.println("\t? \tHelp");
  Serial.println("\tn \tNext round");
  Serial.println("\tb \tTurn off light");
  Serial.println("\tr \tReset test");
  Serial.println("\t1 \tGo to round 1");
  Serial.println("\t2 \tGo to round 2");
  Serial.println("\t3 \tGo to round 3");
  Serial.println("\trandom  Generate multiple color sets");
  Serial.println("---------------------------------------");
 }else if(inputString.equalsIgnoreCase("r")){ // reset
  Serial.println(" Reset.");
  reset=true;
 }else if(inputString.equalsIgnoreCase("n")){ // next round
  testContinue=true;
  if(activeRound==3){reset=true;}
 }else if(inputString.equalsIgnoreCase("b")){ // black LEDs
  colorWipeFade(0,5);
 }else if(inputString.equalsIgnoreCase("1")){ // perform round 1
  performRound(0);
 }else if(inputString.equalsIgnoreCase("2")){ // perform round 2
  performRound(1);
 }else if(inputString.equalsIgnoreCase("3")){ // perform round 3
  performRound(2);
 }else if(inputString.equalsIgnoreCase("random")){
  randomFunction();
 }else{
  Serial.println("Type '?' for help");
  reset=false;
  testContinue=false;
 }
}
//Set a specific round ::
void performRound(int roundNr){
 activeRound=roundNr;
 Serial.print("Round :: "); Serial.println(activeRound+1);
 colorWipeFade(colorSet[roundNr], waitingTime);
 activeRound++;
}
//Set Color order
void setColor(){
 for(int j=0;j<28;j++){
```

```
    for(int i=0;i<3;i++){
      int n=random(0,3);
      int temp = colorSet[n];
      colorSet[n]=colorSet[i];
      colorSet[i]=temp;
    }
  }
  Serial.print(" Colors ::\t");
  for(int w=0;w<3;w++){
    Serial.print("   "); Serial.print(w+1); Serial.print(": ");
    Serial.print(colorNames[colorSet[w]][0]);
  }
  Serial.println("");
}
//Update LED (max 255)
uint32_t c=strip.Color(0,0,0);
void colorWipeFade(int cNr, uint8_t wait) {
  int cRx=allColors[cNr][0]/fadeRounds; int cR=0;
  int cGx=allColors[cNr][1]/fadeRounds; int cG=0;
  int cBx=allColors[cNr][2]/fadeRounds; int cB=0;
  c=strip.Color(cR,cG,cB);
  int maxLight =
allColors[cNr][0]+allColors[cNr][1]+allColors[cNr][2];
  int currentLight = -1;
  for(int i=0; currentLight<maxLight; i++) {
    cR=cR+cRx;
    cG=cG+cGx;
    cB=cB+cBx;
    c=strip.Color(cR,cG,cB);
    for(uint16_t u=0; u<strip.numPixels(); u++){
      strip.setPixelColor(u, c);
      strip.show();
    }
    delay(wait);
    // Determin is the values next round are valid
    if(cR>=255 || cG>=255 || cB>=255){
      currentLight = 2000;
    } else {
      currentLight = (cR+cG+cB)+(cRx+cGx+cBx);
    }
    delay(wait/fadeRounds);
  }
  Serial.print(" ");
  Serial.println(colorNames[cNr][0]);
}
// Overview of randomly selected colors
int randomRounds=15;
int randomColors[15][3];
void randomFunction() {
  Serial.println("---------------------------------------");
  for(int j=0; j<randomRounds; j++) {
    Serial.println("");
    Serial.print(">> ");Serial.print(j+1);Serial.print(" ::");
    setColor();
    for(int i=0; i<3; i++) {
      randomColors[j][i]=colorSet[i];
    }
  }
  Serial.println("---------------------------------------");
}
```

Cheat-sheet: test 1

[1 Introduction]
Welkom to '**Pedestrians of the future**'!
Thanks for your help.

The goal of today is to get an idea of what feelings define your experience on the sidewalk.
Every experience is based on a collection of short moments where you see or touch something.
I have some tools to help you and **I will guide you through this** and you can't do anything wrong.
It's important to know there is no time rush, **take all the time** you need.
When you are done, you walk out on the other side and we will talk about your experiences.
You will be **recorded inside the simulation**.
Afterwards, we will look at these recordings together to be sure that we talk about the same moments. From the recordings, you will **3 meaningful moments** that influenced your experience most.

For every moment you select, I will ask you to **fill in this card** [show event-card].
1) You **select an image** that describes your feeling best and at what intensity level this is applicable;
2) You **describe the emotion** it represents for you;
3) You **explain what made you experience** this emotion;

Do you have any questions at this point?

[2 Reflection]
How was it? What did you experience?
[*show video*]
What moments do **you think defined your experience**? Can you show me in the video?
[pause video on that moment]
What happened here?
Why is it important?
Can you **fill in a card** for this moment?

[*repeat previous steps*]
Once there are **no more important moments**:
I will ask you to go through the sidewalk **simulation again** after I reset the setup. Remember to take your time.

Event-card:
[M] Info: practical data about a participant and selected moment;
[M] Situation: What happened at the selected moment;
[P] Image: what image describes the participant's feeling best;
[P] Emotion-word: Describe the emotion in one word + define intensity-level;
[P] Motivation: what triggered this emotion the experience;

[3 Final reflections]
During the third round, the participant will **meet the service robot** in the sidewalk simulation.
After their walkthrough: "how did you experience this round?"
They will react to their meeting with the robot.
After expressing their first impression, I explain the real goal of the user-test:

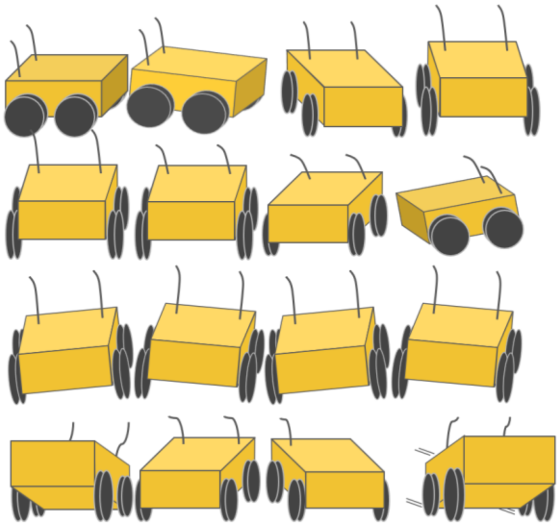
"The robot is part of the test. I research how people react to service robots on the street. By not sharing this upfront is your reaction unbiased and most realistic compared to a real-life situation. Hopefully, you are alright with this. From now on, there will be no more surprises."

Then I ask the participant to share their experienced micro-emotions, exactly like he or she did in the previous two rounds, but this time focused on their experience with the service robot.

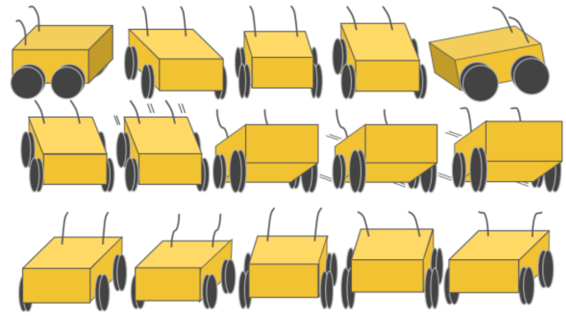
[4 Closing test]
[*Hand over consent form*]
Offer to go through it together and make sure that the participant knows:
He or she **can withdraw** his or her participation at any time without a reason if desired.
In this case, all collected data from them will be destroyed.
He or she can **sign a consent** form when they allow me to use the data for my research.
Ask if the participant could **not tell anybody** that haven't done this test about what happened because that set the expectations.
This test will be repeated in a few months and then I need participants again.
Thanks for your participation!!

8.3. Prototyping: evaluation

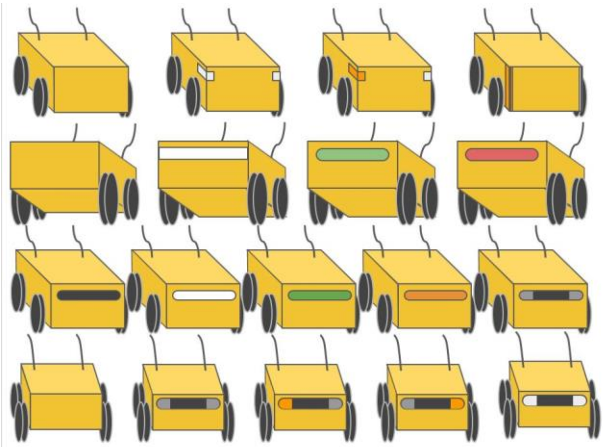
Animations process



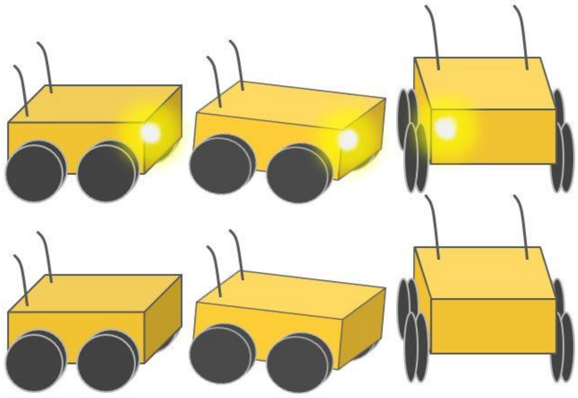
Exploring robot animations: rotations, position embodiment, etc..



Exploring robot emotions and position: turning around, velocity, antennas, etc..



Brainstorm Lightning design



Used lightning for the evaluation animation (same images are copied and enriched with a fading circle to simulate light).

Cheat-sheet: test 2

[PP __]

[Introduction] We evaluate 4 robot animations like you did in the previous test. I shared a like to a google form that contain all animations. Watch a movie completely and reflect afterwards on your findings and select the 3 moments that defined this experience for you. I will guide you through this evaluation.

[Colour: ______]
[How was this experience?]

[What moments are most important for you?]

1.
2.
3.

[How would you react to this situation?]

[Colour: ______]
[How was this experience?]

[What moments are most important for you?]

1.
2.
3.

[How would you react to this situation?]

[Colour: ______]
[How was this experience?]

[What moments are most important for you?]

1.
2.
3.

[How would you react to this situation?]

[Colour: ______]
[How was this experience?]

[What moments are most important for you?]

1.
2.
3.

[How would you react to this situation?]

[Afterwards]
[Can you imagine to encounter these robots in real life?]

[Do you have any commands or questions?]

[Closing the evaluation]
"Last important note: if you, at any time in the future, decide to retreat your participation, you can contact me without a reason and I will delete all recordings. Is this clear?"

8.4. Processing micro-emotions: envisioned model

To give an idea about how this project could be used as product, a model is envisioned in Table 13 where we thought of possible emotion-clusters, related pedestrian behaviour and (simplified) robot behaviour which would achieve neutral pedestrian behaviour.

Table 13 shows all known information from which we isolated a few encounters to show the overlap in detected emotions between emotion-clusters (see Table 14, 15 & 16). By including the order and combinations of micro-emotions, this envisioned model is able to adapt to human behaviour.

The columns in this table represent different stages of the model:

- **Detected (Micro-)Emotions** [DE]: all observed and processed micro-emotions.
- **Experiences** [Ex]: Related emotion-clusters recognised from previous encounters.
- **Pedestrian Behaviour** [PB]: Experienced reactions measured in previous encounters.
- **(Delivery) Robot Behaviour** [RB]: Designed behavioural actions to evoke neutral behaviour.

Detected Emotions (DE)	Experience (Ex)	Pedestrian Behaviour (PB)	Robot Behaviour (RB)
Determination Frustration	"The Neutral": > OE: Amusement, Determination; > PB: Keep walking	Keep walking: > Desired: yes; > RB: Neutral;	Neutral: > Move: predictable; > Speed: normal; > Lights: off;
Amusement Annoyance	"The Teasing": > OE: Amusement, Annoyance; > PB: Block road;	Block road: > Desired: no; > RB: Warn;	Warn: > Move: towards pedestrian; > Speed: slow; > Lights: red;
Confusion Wonder	"The Challenge": > OE: Determination, Frustration; > PB: Walk along;	Walk along: > Desired: no; > RB: Warn;	Increase > Move: forwards; > Speed: normal; > Lights: orange, blinking; > Camera: facing pedestrian;
	"The Mysterious": > OE: Confusion, Wonder; > PB: Pet robot;	Pet robot: > Desired: no; > RB: Increase;	

Table 13: This envisioned data model enables robots to select and develop behaviour based on experienced situations with micro-emotions.

Detected Emotions (DE)	Experience (Ex)	Pedestrian Behaviour (PB)	Robot Behaviour (RB)
1. Determination 2. Amusement	“The Neutral”: > OE: Amusement, Determination; > PB: Keep walking	Keep walking: > Desired: yes; > RB: Neutral;	Neutral: > Move: predictable; > Speed: normal; > Lights: off;

Table 14: A situation with the ‘neutral’ emotion-cluster.

Detected Emotions (DE)	Experience (Ex)	Pedestrian Behaviour (PB)	Robot Behaviour (RB)
1. Amusement 2. Annoyance	“The Teasing”: > OE: Amusement, Annoyance; > PB: Block road;	Block road: > Desired: no; > RB: Warn;	Warn: > Move: towards pedestrian; > Speed: slow; > Lights: red;

Table 15: A situation with the ‘Teasing’ emotion-cluster.

Detected Emotions (DE)	Experience (Ex)	Pedestrian Behaviour (PB)	Robot Behaviour (RB)
1. Determination 2. Frustration	“The Challenge”: > OE: Determination, Frustration; > PB: Walk along;	Walk along: > Desired: no; > RB: Warn;	Increase > Move: forwards; > Speed: normal; > Lights: orange, blinking; > Camera: facing pedestrian;

Table 16: A situation with the ‘Challenge’ emotion-cluster.