Field observations of reactions of incidentally copresent pedestrians to a seemingly autonomous sidewalk delivery vehicle: An exploratory study

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Abstract

This study explored verbal and non-verbal reactions given by pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle. In the last decade, there has been a rise in the development of autonomous vehicles, including autonomous sidewalk delivery vehicles. However, there is little insight in how pedestrians react to such autonomous sidewalk delivery vehicles. Thus, research about reactions to these vehicles is necessary to ensure a smooth integration of these vehicles into society. A field observation was done on a sidewalk where a delivery vehicle was driving on a specific trajectory using a wizard-of-oz design. Reactions of incidentally copresent pedestrians to a seemingly autonomous sidewalk delivery vehicle were explored and used to find various themes. The majority of pedestrians did not approach the vehicle, though there were a few reactions where people approached or fled from the vehicle. The average passing distance found in the present study was around 22 centimetres, which belongs to either the intimate distance or personal distance sphere. Regarding the avoidance path, a large proportion of the pedestrians swerved to only avoid the vehicle, though there were also considerable proportions of pedestrians who took a wide turn or who hardly had to move to evade the vehicle. The other non-verbal themes found in the present study concerned: pedestrians being surprised by the vehicle, taking a picture or making a video of it, and reactions of dogs. There were also four major verbal themes found in the present study: the function of the autonomous sidewalk delivery vehicle, the autonomy of the vehicle, the camera on the vehicle and the safety of the parcels. In addition to these four themes, there were also statements indicating how people thought of the vehicle, of which the majority was positive. The findings from the present study could be used to help with insights about safety as well as the design (external appearance and programming) of autonomous sidewalk delivery vehicles.

Keywords: *autonomous sidewalk delivery vehicle* | *field observation* | *pedestrians* | *wizard-of-oz set-up* | *incidental encounter* | *non-verbal reactions* | *verbal reactions*

Introduction

In the future, there will be an increasing amount of autonomous vehicles. In the last decade there has been a rise in the development of those autonomous vehicles. In 2012, a panel of IEEE members predicted that, by 2040, 75% of the fleet would be autonomous (IEEE, 2012). In addition, Litman (2020) predicted that, in the 2040s to 2050s, autonomous vehicles would be common and affordable and would bring benefits like increased safety and pollution reductions. Because of this rise in interest in and development of autonomous vehicles, the US Department of Transportation's National Highway Traffic Safety Administrations (NHTSA) has even defined five levels of automation for vehicles (Liu et al., 2017). Thus, to ensure a smooth integration of these vehicles into society, research about the public perception and the interaction with these autonomous vehicles is necessary.

There have been various studies that focused on autonomous vehicles, which predominantly looked into how autonomous vehicles should communicate towards other traffic participants, especially pedestrians. Most traffic participants use communicative cues, like eye contact and hand gestures, to interact with others to signal intention (Dey and Terken, 2017; Nathanael et al., 2018). However, with (semi-)autonomous vehicles, these communicative cues will not be available. Therefore, alternative communicative cues are needed to inform other traffic participants of the vehicle's intention. Rouchitsas and Alm (2019) reviewed research done about external interfaces for autonomous vehicle communication to pedestrians. They found that there is no standardized evaluation procedure of interfaces. Therefore, while a great number of studies found that a communication interface benefits pedestrians when interacting with an autonomous vehicle, these interfaces cannot be compared. In addition, some studies had opposing results. For example, Merat et al. (2018) found that lights and sound were preferred to text and speech, whereas a textual design was the most accurate in Chang et al. (2018) in conveying intention to pedestrians. Thus, specifications about what is optimal in an interface are still lacking. However, communication between autonomous vehicles and other traffic participants is only one aspect of the interaction with autonomous vehicles. Though research about other aspects, like the reactions of traffic participants, is important, there are not many studies that look into it.

Besides autonomous cars, there are also autonomous sidewalk vehicles. These autonomous sidewalk vehicles could be used for delivery. There has been an increase in home parcel delivery in The Netherlands for the last few years (*StatLine - Detailhandel; omzetontwikkeling internetverkopen, index 2015=100*, n.d.). This trend is also showing in the United States, where e-commerce sales have increased at an average annual rate of 16% for the last twenty years (United States Census Bureau, 2018). Because of this increase in parcels, various companies have been researching technology for autonomous delivery vehicles, e.g. Starship Technologies, Nuro and Amazon. Another benefit of using autonomous sidewalk delivery vehicles, other than lower costs of delivery, is the considerable reduction of carbon emission compared to delivery vans, though this is only applicable when the delivery area surrounds the depot and a mothership is not required (Figliozzi, 2020). Despite the benefits that using autonomous sidewalk delivery vehicles could bring, more research is necessary before using it in practice around the world.

There are only a few studies that look into autonomous sidewalk delivery vehicles. There is a study that looks into the scheduling between the autonomous sidewalk delivery vehicles and the mothership (Boysen et al., 2018). In another study, Figliozzi (2020) compares carbon emission reductions of various autonomous delivery vehicles, e.g. drones and sidewalk vehicles. Furthermore, in a study of Jennings and Figliozzi (2019), the potential impacts of autonomous sidewalk delivery vehicles on freight efficiency was examined. Lastly, Liu et al. (2020) looked at the optimization of routing for the autonomous sidewalk delivery vehicles. All of these studies focus on the process of delivery and how to optimize it, but do not consider human-vehicle interactions.

However, there are some studies that did look into how people perceive the autonomous sidewalk delivery vehicle. Pani et al. (2020) and Abrams et al. (2021) both looked at the acceptance of autonomous sidewalk delivery vehicles by people using a survey. Pani et al. (2020) estimated the willingness to pay extra (during the COVID-19 pandemic) to receive deliveries using an autonomous sidewalk delivery vehicle based on consumer segments. They found that a majority of the participants (61%) gave positive responses of their willingness to pay extra, though the willingness to pay was also dependent on the amount they had to pay extra. Abrams et al. (2021) proposed a new model to measure acceptance for autonomous sidewalk delivery vehicles and then tested it using an online survey. This acceptance model was specifically made for what they refer to as *InCoPs* (incidentally copresent persons; Rosenthal-von der Pütten et al., 2020). InCoPs are people who encounter a robot because they ‘simply happen to be there’. The encounter with the robot will likely be unintentional and not planned. This reflects the natural situation with an autonomous sidewalk delivery vehicle better than a lab study, as the vehicle will drive to its destination and people will not be aware beforehand that they will encounter it. Abrams, Platte and Rosenthal-von der Pütten (2020) also did a pilot study in which they covertly observed spontaneous human-robot encounters with a fake autonomous sidewalk delivery vehicle. In addition, Vroon, Rusák and Kortuem (2020) investigated the behaviour of people in social conflicts, created by the robot ignoring humans, with a delivery robot. They found that there were fewer conflicts than they expected and that pedestrians seemed willing to move out of the robot's way. The last two studies are the only (pilot) studies in which they investigate the reactions of people to an autonomous sidewalk delivery vehicle in a naturalistic setting.

Contrary to autonomous sidewalk delivery vehicles, there are various studies that look at the reactions of people to other autonomous robots. These reactions vary from curious and interested reactions to no reaction at all (Abrams et al., 2021). In a study of Fischer et al. (2015), they investigated people’s response to a robotic trash can offering its service. They found that people do not want to interact with a robot if they are doing something else. However, if they had trash, people readily interacted with the robot. This shows that willingness to interact with a robot depends on the circumstances. Interviews with people in a shopping mall that had an autonomous information-providing robot showed that the majority found the robot useful and wanted to use it again (Satake et al., 2015), displaying a positive reception of the robot. However, there are also studies that documented ‘abusive’ behaviour towards autonomous social robots by children; behaviours like blocking its way, saying offensive utterances and resorting to violence (Bršćić et al., 2015; Salvini et al., 2010). This abusive behaviour was only present when no adult was close by to supervise. To summarise, most adults show no reaction to or interest in other autonomous robots (i.e. robots other than sidewalk delivery vehicles) and regard the robot as something positive. Children, on the other hand, sometimes show abusive behaviour when no adult is present.

As mentioned before, there are only two (pilot) studies, as of yet, in which they investigated the reactions of people to an autonomous sidewalk delivery vehicle in a naturalistic setting (Abrams et al., 2020; Vroon et al. 2020). However, it is important to have more knowledge of this aspect. Increasing knowledge about natural reactions of people toward an autonomous sidewalk delivery vehicle could help with insights about safety as well as the design (external appearance and programming) of the vehicle. For example, people blocking the vehicle to inspect it is not desirable as it may reduce the efficiency of the delivery of parcels by the vehicle. Therefore, the aim of this study was to explore the verbal and non-verbal reactions that are given by pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle.

To achieve this aim, a field study with natural observation was conducted. Previous studies that looked at the behaviour of people towards an autonomous vehicle (or robot) also used observation (Abrams et al., 2020; Fischer et al., 2015; Rothenbücher et al., 2016; Vroon et al., 2020). An autonomous sidewalk delivery robot drives in urban environments where the people it encounters will not be users, there is no intended interaction. The people it encounters will just 'happen to be there', also referred to as *InCoPs* by Rosenthal-von der Pütten et al. (2020). In this study, the vehicle drove on a sidewalk where human-robot encounters are spontaneous, unlike in a laboratory environment, to mimic reality as there could be a difference in reaction if a person is aware beforehand. The methods used in this study are almost a replication of the pilot by Abrams et al. (2020), wherein they tested the observational equipment and set up for further studies, as the objective of the present study is nearly the same. The present study aims to explore the verbal and non-verbal reactions of pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle. The greatest difference between the methods of Abrams et al. (2020) and the present study is the use of video and audio recordings, which the present study does not use, and the focus of the study. The study of Abrams et al. (2020) was used as a pilot study to test its set-up, while the present study focussed more on the actual reactions given by the incidentally copresent pedestrians. Before the observation started, there were some predetermined aspects of the reactions which would be focussed on.

Approach, flee or ignore

One of the aspects that could be interesting is whether a pedestrian approaches the vehicle, flees from it or ignores it. In this context, ignoring the autonomous sidewalk delivery vehicle does not refer to not showing interest, it means not approaching or fleeing from the vehicle. This aspect is interesting because it could lead to more insights about safety as well as design.

An example of how knowing whether pedestrians approach, flee or ignore the vehicle could lead to more insights about safety concerns the previously mentioned abusive behaviour of children (Brščić et al., 2015; Salvini et al., 2010). With the knowledge that unsupervised children would often resort to abusive behaviour towards autonomous robots, Brščić et al. (2015) developed a statistical model that enabled the robot to predict and escape possible abuse situations. Another example of how it could lead to more insights about safety is the following: if there is more knowledge about pedestrians approaching the vehicle - potentially leading to unsafe situations as the vehicle is still part of traffic – this knowledge could help with the protocol of the vehicle for what it is supposed to do in that situation, e.g. moving away or standing still.

In addition to safety, more knowledge on this aspect (approach, flee or ignore) could also lead to more insights about design. It is possible that the underlying mechanism for the approach or fleeing of the vehicle is the fight-or-flight response. The fight-or-flight response is activated when humans encounter a seemingly dangerous situation (Mahadevan et al., 2018). Hiroi and Ito (2009) looked at the effect of size of the robot on the psychological threat a person felt when a robot moved towards them. They found that the 1.8 metre tall robot caused the highest amount of anxiety compared to robots that were 0.6 and 1.2 metres tall, though the 0.6 metres tall robot still induced anxiety in some people. Therefore, the design of the vehicle could alter whether a pedestrian perceives it as a threat or not. Thus, whether a person approaches or flees the vehicle could be an indication of how threatening they perceive the design of the vehicle to be.

In conclusion, looking at whether a pedestrian approaches the vehicle, flees from it or ignores it could lead to more insights about safety as well as design.

Passing

Another aspect that could be interesting is how a pedestrian passes the vehicle, in particular the passing distance as well as the path a person takes to avoid the vehicle. In previous studies, robots moved towards or past humans who then reported their level of comfort (Bergman, 2020; Neggers, Cuijpers, & Ruijten, 2018; Takayama & Pantofaru, 2009).

Perhaps, one can gain more insights into what a person finds comfortable by looking at their distance and avoidance path instead of making the robot move (past).

Nass, Steuer and Tauber (1994) presented the idea that computers are social actors. They found that social responses are easily evoked in interactions with computers. Thus, by extending this idea, people interact with robots in a very similar way as they would with other people. Therefore, the concept of personal space among people may also apply to human-robot interaction. Hall (1969) found that a person's personal space consists of four spheres (see Figure 1), each indicating a different level of comfort: intimate distance (<45 cm), personal distance (45-120 cm), social distance (120-350 cm) and public distance (>350 cm), with the distance being slightly larger in the front than in the back or on the sides (Amaoka et al., 2009). Thus, how much distance a person puts between the vehicle and themselves could indicate how comfortable they are.

In addition to the passing distance, the avoidance path taken by the person could also help with the protocol of how an autonomous vehicle should move around a person. According to Hiroi and Ito (2019), typical pedestrian avoidance paths to bypass another

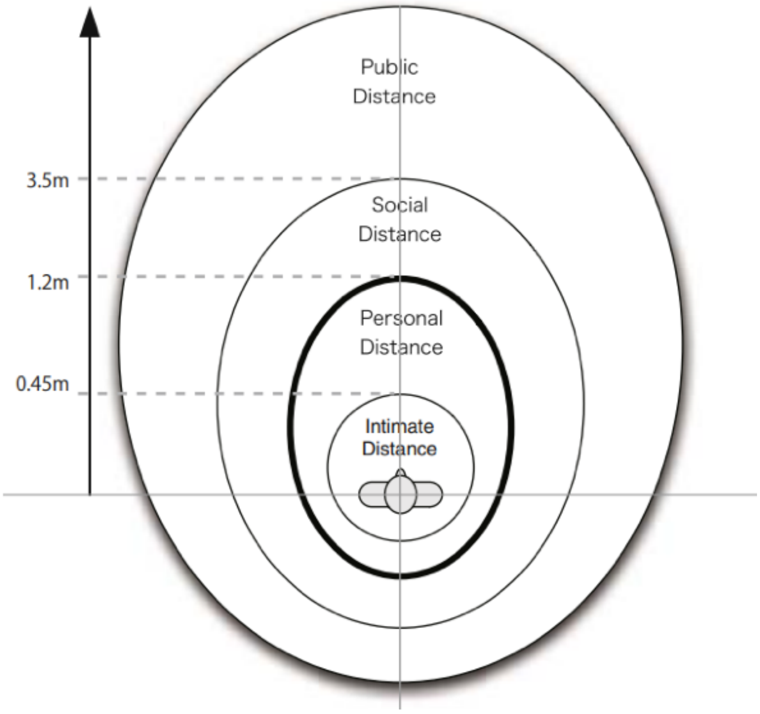


Figure 1. Personal space divided into four spheres: intimate distance, personal distance, social distance and public distance. The spheres show the typical form with the front larger than the other sides (Amaoka et al., 2009).

pedestrian is to swerve just before the person. However, it is possible that this might not apply to autonomous vehicles as there are no communicative cues to indicate the vehicle's intention.

In conclusion, looking at how a pedestrian passes the vehicle could help with developing passing protocols for autonomous vehicles that take a person's level of comfort into consideration.

Aim of the study

There are only a few studies that look into autonomous sidewalk delivery vehicles and only two (pilot) studies, as of yet, in which they investigate the reactions of people to an autonomous sidewalk delivery vehicle in a naturalistic setting (Abrams et al., 2020; Vroon et al. 2020). However, it is important to have more knowledge of this aspect. Increasing knowledge about natural reactions of people toward an autonomous sidewalk delivery vehicle could help with insights about safety as well as the design (external appearance and programming) of the vehicle. For example, people blocking the vehicle to inspect it is not desirable as it may reduce the efficiency of the delivery of parcels by the vehicle. Therefore, the aim of the present study was to explore the verbal and non-verbal reactions that are given by pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle. A field study with natural observation was conducted based on previous studies that also used observation (Abrams et al., 2020; Fischer et al., 2015; Rothenbücher et al., 2016; Vroon et al. 2020). Before the observation started, there were some predetermined aspects of the reactions which would be focussed on as information about it could be interesting. Those aspects were: whether a pedestrian approaches the vehicle, flees from it or ignores it; passing distance; and avoidance path.

Methods

Participants

There were 89 reactions observed in the experiment using convenience sampling. A reaction could be of one person or multiple people belonging together. There were 35 reactions (39%) from single individuals and 54 reactions (61%) from groups of two or more people (with an average group size of 2.19 people). 63.16% of the participants were female and 36.84% were male. All participants were estimated to be sixteen years or older. The participants were also divided into groups based on the estimated age: 16-30 years old (40.14%), 31-50 years old (42.96%), 51-65 years old (11.27%) and older than 65 years (5.63%). The research was performed in accordance with the standards of the local ethics board of Utrecht University.

Materials

The experiment used a vehicle produced by More Work Less Carbon (MWLC), see Figure 2a. The vehicle is about 0.90 metres long, 0.60 metres wide and 0.40 metres high. The vehicle could be manually controlled at a distance using a laptop and game controller. On the vehicle there were two cameras, one on the front and one on the back. The video feeds corresponding to those cameras were shown on the laptop.

In addition, to create the appearance that the vehicle is a delivery vehicle, a transparent box was put on top of the vehicle. This box was filled with three parcels that were recognisable from (Dutch) companies with well-known delivery services, see Figure 2b. The box was 0.60 metres long, 0.40 metres wide and 0.35 metres high (making the vehicle 0.75 metres high in total). During the experiment the box did not have a lid on it, to show the parcels in the box

a. b.

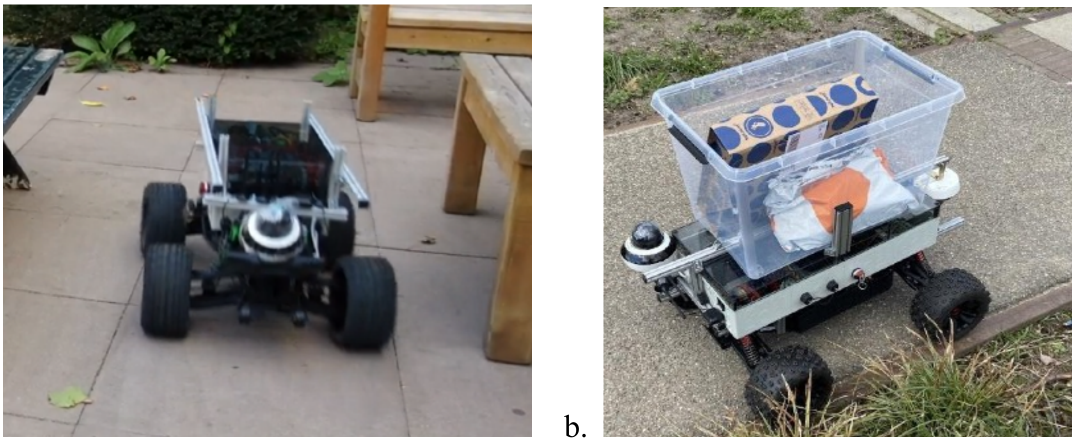


Figure 2. a) The vehicle produced by MWLC. b) The vehicle with the transparent box containing the recognisable parcels from well-known (Dutch) companies.

more clearly.

The observed reactions of the InCoPs were written down in a table, see Appendix A, that was tested and improved upon using a pilot run.

Design

To observe the reactions of InCoPs, a field observation was done. A pilot run was done before conducting the real experiment. The experiment was conducted on three separate days. Each day consisted of three sessions of around thirty minutes with fifteen minute breaks in between. On the first two days the vehicle drove in a counter clockwise direction and on the third day in a clockwise direction.

Procedure

The experiment was conducted on a part of the Oosterspoorbaan in Utrecht, where a seemingly autonomous sidewalk delivery vehicle drove on a specific trajectory, see figure 3. The Oosterspoorbaan consists of two (paralel) separate paths, where pedestrians could choose to walk on the same path as the vehicle or on the other path. A wizard-of-oz set-up was used because of ethical considerations. The 'wizard' manually controlled the vehicle from a distance to make it seem like the vehicle drove autonomously to the incidentally copresent pedestrians. The maximum speed of the vehicle was 5 km/h and the wizard had a protocol of how to drive the vehicle, see Appendix B. The most important rules were that the vehicle should stop when a child was within a radius of one metre or if a person was in front of the vehicle.

Figure 3. The red line indicates the trajectory of the seemingly autonomous sidewalk delivery vehicle on the Oosterspoonbaan, Utrecht. The highest dot indicates the place where the wizard sat. The dot in the middle of the trajectory indicates the place where the experimenter observed the pedestrians.

The experimenter was sitting on a bench in the middle of the trajectory of the vehicle while trying to establish the illusion that the experimenter was not with the vehicle.

When a pedestrian (or a group of pedestrians) encountered the sidewalk delivery vehicle, the experimenter observed and wrote down their reactions (in a table, see Appendix A). Aspects that were written down were: the time of the encounter, gender of pedestrian(s), estimation of the age group, what they were doing (e.g. walking their dog), if the pedestrians approached, ignored or fled from the vehicle, if the pedestrians looked at the vehicle, the avoidance path, (estimated) passing distance and verbal reactions. The passing distance was estimated using tiles (which were present on part of the path), which were measured beforehand. Not all pedestrians that encountered the vehicle were observed. Partially, because it was done by hand, which takes some time to write down fully, causing the observer to miss some reactions.

Data analysis

The grounded theory method (Glaser & Strauss, 1967) was used during the experiment. After each experimental day (as well as the pilot), all written down observations were perused to look for themes. With these initial themes, the observation for the next experimental day had more focus on those aspects in addition to the pre-existing aspects (e.g. avoidance path) to try to reach theoretical saturation. For example, the direction that pedestrians approached the vehicle (from the front or from behind) was included based on the impression that pedestrians behaved differently (e.g. passing distance and path) when approaching the vehicle from the front compared to from behind. Furthermore, for practical reasons involving time, there was a maximum number of reactions used in this study established beforehand. Thus, there was some selection in which reaction should be observed and written down. Some decisions were based on the initial themes found in the previous data.

For the analysis of all the data, the experimenter read through all of the written down observations to look for behavioural patterns and themes (bottom-up), as well as looking at certain aspects based on literature (top-down). For the verbal reactions, themes were identified using a bottom-up approach. These themes consisted mainly of the initial themes already identified during the course of the experiment.

Results

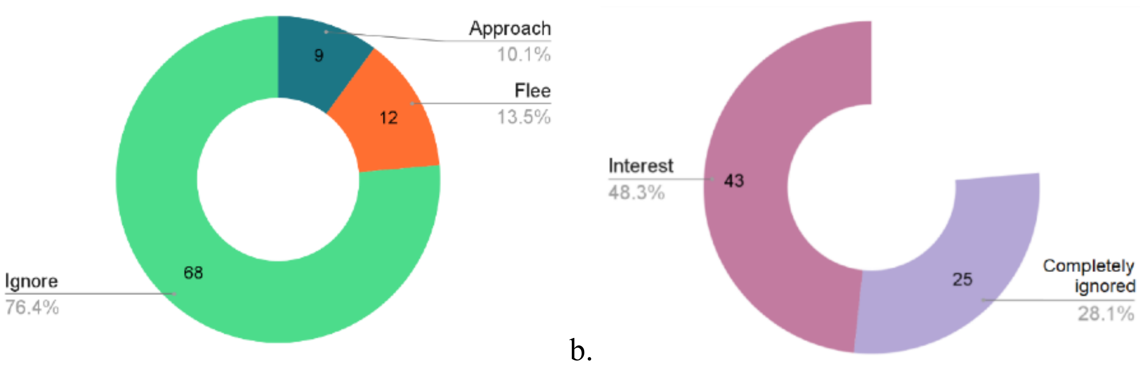
The grounded theory method (Glaser & Strauss, 1967) was used to find various themes. After perusing the data of the first observational day, the initial themes found included: the interest of pedestrians in the vehicle while still ignoring it, pedestrians mentioning stealing parcels, as well as the reactions of dogs. Thus, those aspects received more focus on the two other observational days. After the second observational day, there was an impression that pedestrians behaved differently when approaching the vehicle from the front compared to from behind. Therefore, this was further investigated on the third observational day. The decision to make the vehicle drive in a clockwise direction on the third day was to create more instances of pedestrians approaching the vehicle from the front, as most pedestrians choose the (for them) right path to walk on instead of the left.

There were 89 reactions observed in total.

Approach, flee or ignore

In nine reactions (10.11%), the pedestrians approached the vehicle and in twelve reactions (13.48%), they fled from the vehicle. In the rest of the reactions (68 reactions, 76.40%) the pedestrians ignored the vehicle, see Figure 4a. Of the people who ignored the vehicle, 75% were on the other path and 25% were on the same path.

There were few reactions in which people approached the vehicle. However, an additional 48.31% showed interest in the vehicle (see Figure 4b), for example in the viewing behaviour or by starting a conversation about the vehicle. There was also a large group of



a. b.

Figure 4. a) Donut chart of fractions of reactions in which pedestrians approach, flee or ignore the vehicle. b) Donut chart of fractions of reactions that belonged to ignore in figura a, in which pedestrians showed interest or completely ignored the vehicle.

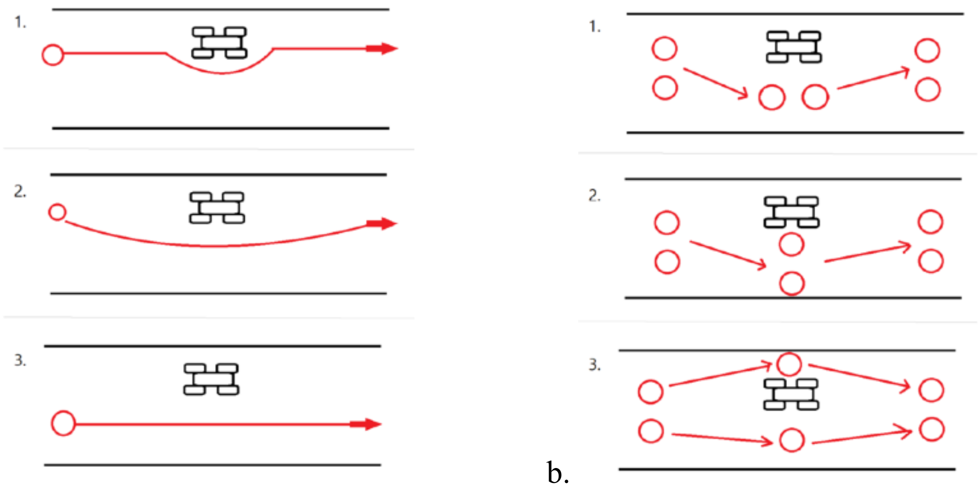
reactions, 28.09%, in which people completely ignored the vehicle except for perhaps glancing at it. Of the people who walked up to it, nobody touched the vehicle. It was mainly to see the vehicle up close. There were two reactions wherein the pedestrians walked up to the vehicle to take pictures.

Of the reactions in which people fled from the vehicle, half came from the front of the vehicle and the other half came from behind the vehicle. In a few instances the probable reasons for 'fleeing' were a dog (2 reactions) and a wide pram that did not fit next to the vehicle on the path. There were no specific reactions that occurred more often when someone approached the vehicle from the front or from behind.

Passing distance & avoidance path

The average passing distance of pedestrians that ignored the vehicle was m = 19 cm with SD = 10 cm. However, this includes groups of pedestrians who walked next to each other. The average passing distance of pedestrians that ignored the vehicle who were alone was m = 22 cm with SD = 10 cm. Passing distance refers to the visually estimated lateral distance between the shoulder of the pedestrian and the side of the autonomous sidewalk delivery vehicle. There was also a slight difference in passing distance between pedestrians (when including groups) who approached the vehicle from the front, m= 20 cm with SD= 9 cm, compared to pedestrians who approached the vehicle from behind, m= 17 cm with SD= 10 cm.

A large proportion of the pedestrians, 44.12%, swerved to avoid the vehicle and then



a. b.

Figure 5. a) avoidance path when passing the vehicle: 1. swerved to avoid the vehicle 2. wide turn 3. hardly any evasion. b) avoidance paths of people walking next to another when passing the vehicle: 1. moved to walk behind each other 2. kept walking next to each other 3. split up on either side of the vehicle.

walked straight back to their starting position, see Figure 5a. There were also a number of reactions in which a wide turn was taken (26.47%), or in which there was hardly any evasion of the vehicle (29.41%).

There were also a number of reactions in which people walked side by side. Some people moved to walk behind each other when passing the vehicle (45.45%), some kept walking next to each other when passing the vehicle (27.27%), and some people split up with one person on each side of the vehicle when passing (27.27%), see Figure 5b. When people split up, in 83.33% of the reactions the vehicle was stationary. Notably, there was also one reaction in which people walked hand in hand but still split up to go around the vehicle on either side without letting go of each other's hands.

Other behavioural themes (miscellaneous)

In 11.24% of the interactions, people showed that they were surprised by the vehicle. In addition, in 6.74% of the reactions, people took a picture or made a video clip of the vehicle. Furthermore, there were ten reactions in which dogs were present. In 40% of those reactions, the dog wanted to approach the vehicle, mainly to snuffle. However, there was also one dog that walked to the grass on the side of the road on its own (it was not wearing a collar) when the vehicle came nearer. Furthermore, in 40% of those reactions, the owners of the dogs tried their best to prevent interaction between the dog and the vehicle by: choosing another path, distracting the dog with a toy, stopping the dog with the leash or giving commands to the dog. There is some overlap in these two categories; in half of these cases (two reactions), the dog approached or wanted to approach the vehicle which the owner tried to prevent.

Verbal themes

There were four major themes in people's verbal responses. There were 54 reactions with multiple people, who could talk among themselves. Firstly, in 33.33% of these reactions, the function of the vehicle was mentioned, which was the delivery of parcels. Secondly, the autonomy of the vehicle was mentioned in 22.22% of the reactions. People wondered if the vehicle was driven by someone else and if so, who. Thirdly, in 11.11% of the reactions, people mentioned the cameras on the vehicle. Some felt that someone was watching them with the cameras. Lastly, in 9.26% of the reactions, people talked about the safety of the parcels and whether they would be stolen. Some indicated that they thought this would not be the case as it was too public and anyone could see.

In addition to these four themes, there were also statements indicating how people thought of the vehicle. 81.25% (thirteen reactions) of these statements were positive, examples of such statements can be directly translated to things such as "This is amusing", "Fascinating!" and "This is handy, we should have this too". Examples of (translated) negative statements were "You'll have to wait a long time for your parcels to arrive if you do it like this" and "Soviet Union". The meaning behind “Soviet Union” is a bit vague. However, it likely has something to do with espionage or something in that trend.

Case studies

There were two reactions in which people addressed the vehicle, which can be translated to "hi" and "keep on driving". There was even a reaction in which a person attributed emotion to the vehicle. She called the vehicle "shy" when it was stationary. There was also someone who said he was going to "challenge" the vehicle. These are instances that show that some people treated the vehicle somewhat like a person.

Furthermore, there were three reactions in which a person walked around the vehicle on the side where there was less space on the path. This happened when the vehicle was located where the experimenter sat on a bench. The people choose to walk on the other side of the vehicle rather than the side of the benches, possibly because invasion of the personal space of the vehicle was preferred over invasion of the personal space of the human experimenter.

Discussion

The present study explored the verbal and non-verbal reactions that are given by pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle. A field study, of spontaneous human-robot encounters, with natural observation was conducted as previous studies also used observation to investigate people's behaviour (Abrams et al., 2020; Fischer et al., 2015; Rothenbücher et al., 2016; Vroon et al. 2020). The aim was to add new information to the literature, as there are only two (pilot) studies as of yet, in which they investigated the reactions of people to an autonomous sidewalk delivery vehicle (Abrams et al., 2020; Vroon et al. 2020). In addition, the present study aimed to add new information which could help with insights about safety as well as the design of the vehicle. To explore the verbal and non-verbal reactions that are given by pedestrians that incidentally encounter a seemingly autonomous sidewalk delivery vehicle, the grounded theory method (Glaser & Strauss, 1967) was used to identify various themes.

The first theme concerns whether a pedestrian approached the vehicle, fled from it or ignored it. As mentioned in the introduction, in this context, ignoring the autonomous sidewalk delivery vehicle does not refer to not showing interest, but instead refers to a person not approaching or fleeing from the vehicle. It was found that the majority of pedestrians ignored the vehicle, though there were a few reactions in which people approached or fled from the vehicle. However, a substantial number of pedestrians showed interest in the vehicle even though they did not approach it. This has interesting implications for safety protocols of an autonomous sidewalk vehicle. It shows that the majority of pedestrians ignore the sidewalk vehicle, even though they are interested in it, and thus do not hinder it delivering parcels.

The methods of the present study are almost a replication of the pilot by Abrams et al. (2020), who also investigated spontaneous, natural encounters between pedestrians and autonomous sidewalk delivery vehicles in an urban environment. Because it was a pilot study, they only expounded on two reactions they observed. The first reaction Abrams et al. (2020) expounded on involved a family with two children who both approached the vehicle to inspect and touch it. However, the parents tried to stop the children. As previously mentioned in the introduction, Brščić et al. (2015) and Salvini et al. (2010) documented abusive behaviour towards autonomous social robots by unsupervised children. Perhaps, if the parents were not present, the children from Abrams et al. (2020) would have shown abusive behaviour as well. It is possible that children approach an autonomous vehicle or robot more often or easily than adults do, no matter their intention. However, because the present study did not include any pedestrians (estimated) under the age of sixteen, this can neither be confirmed nor denied by the reactions observed. In the second reaction that was expounded on by Abrams et al. (2020), an older couple ignored the vehicle and did not show interest either. This reaction fits with the approach, flee or ignore theme from the present study. In addition to the pilot study of Abrams et al. (2020), Starship Technologies also describe reactions of pedestrians who encountered their autonomous sidewalk delivery vehicle. They claim that 70% did not pay the vehicle any attention (Zhang, 2017), which supports the results found in this study. However, this was stated in a blog post and not a published article. Therefore, it is unsure how they measured the responses of the pedestrians and the validity of these claims is unknown.

A limitation concerns the experimental design used in the present study. Because the reactions of pedestrians are explored using observation, the underlying thought process and motivation are unknown. There were a number of reactions observed where the pedestrian fled from the vehicle. However, because of the experimental design, it is unknown what the cause for the fleeing was. Perhaps some pedestrians found the vehicle threatening, inducing their fight-or-flight response (Mahadevan et al., 2018). The vehicle was 0.75 metres tall, which might have induced anxiety in some pedestrians, similar to how the 0.6 metres robot also induced anxiety in some people in the study of Hiroi and Ito (2009). In a few instances, the cause of fleeing could be assumed based on the circumstances, for example a wide pram that did not fit next to the vehicle on the path. Though the causes for fleeing in the remaining reactions continue to be unknown. For future research, one might interview the pedestrians when they flee to find out what the underlying motivation was.

The second theme found in the present study concerns the distance and avoidance path pedestrians took to pass the vehicle. The average passing distance of pedestrians that ignored the vehicle was about 20 centimetres. As mentioned in the introduction, Hall (1969) divided a person's personal space into four spheres: intimate distance (<45 cm), personal distance (45-120 cm), social distance (120-350 cm) and public distance (>350 cm). However, the distance is slightly larger on the front compared to the sides, with the numbers mentioned before indicating the distance to the front (see Figure 1). The passing distance from the present study used the distance between the sides of the person and the vehicle. Therefore, based on the shape of the spheres, the passing distance found in the present study belongs to either the intimate distance or personal distance sphere. Regarding the avoidance path, a large proportion of the pedestrians swerved to only avoid the vehicle, though there were also considerable proportions of pedestrians who took a wide turn or who hardly had to move to evade the vehicle. Furthermore, the reactions of people who were walking side by side before passing the vehicle could also be divided into three groups: some moved to walk behind each other (1); some kept walking next to each other (2); and some split up with one person on each side of the vehicle (3). Notably, there was also one reaction in which people walked hand in hand and split up to go around the vehicle on either side without letting go of each other's hands.

The passing distance found in the present study corresponds with previous findings by Pacchierotti, Christensen and Jensfelt (2006). They found that people judged a lateral distance of 40 centimetres as most comfortable in a narrow corridor. Lateral distance was defined as the distance from the centre of the person to the side of the robot. However, in the present study the passing distance is defined as the distance between the sides of the person and the vehicle. The average human shoulder width is around 40 centimetres (*DINED*, n.d.). Thus, to get the distance used in the present study so that the findings can be compared, 20 centimetres (half a shoulder width) have to be subtracted from the findings of Pacchierotti et al. (2006). The adjusted passing distance found in Pacchierotti et al. (2006) was therefore 20 centimetres, which corresponds with the findings of the present study. However, Neggers et al. (2018) reported a slightly wider preferred passing distance of about 36 centimetres, though this difference could have been caused by various other factors.

The passing distance found in the present study belongs to either the intimate distance or personal distance sphere even though those spheres indicate a very intimate relationship or being friends, respectively (Hall, 1969). If the pedestrians regarded the autonomous sidewalk delivery vehicle as another person, or a social actor (Nass et al., 1994), then the passing distance should have fallen into the 'social distance' sphere, as the relationship type belonging in that sphere is "strangers". However, there were two reactions in which people addressed the vehicle and even attributed emotion to the vehicle. These instances show that some people did treat the vehicle somewhat like a person. On the other hand, there were also three reactions in which a person walked around the vehicle on the side where there was less space rather than the side of the benches where the experimenter sat. Therefore, it is a possibility that it is more uncomfortable for someone to have an unknown person in their personal space compared to a(n unknown) vehicle. Thus, it is uncertain whether people regard the vehicle as a social actor or not, in particular concerning personal space, and if the spheres might be smaller for vehicles invading personal space compared to people.

Similar to Hiroi and Ito (2019), who stated that typical pedestrian avoidance paths to bypass another pedestrian are to swerve just before the person, a large proportion of pedestrians in the present study swerved just before the vehicle. This is also supported by the older couple from Abrams et al. (2020) who passed the robot with only a slight turn. However, there are also a considerable amount of reactions in which a pedestrian took a wide turn to avoid the vehicle. Thus, there is still a possibility that pedestrians are hesitant about the vehicle's intention. Furthermore, Hiroi et al. (2019) state that a robot should begin the avoidance path while it is still far from a person to communicate that it is trying to keep a public distance. There is a chance that people are more comfortable when they are the ones in control, i.e. when they move instead of the robot. However, this is unlikely as Takayama & Pantofu (2009) found that there was no difference in maintained distance when people approached the robot compared to when the robot approached them.

An alternative explanation for the small passing distance found in the present study concerns the location where the observation took place. There were two paths that were each 1.58 metres wide. The maximum distance one could have from the autonomous sidewalk delivery vehicle while still remaining on the path was 0.40 metres. This falls just in the social distance sphere. Therefore, it is possible that the passing distance is smaller than one would usually apply when passing the autonomous sidewalk delivery vehicle to keep walking comfortably on the path. This is supported by the fact that Pacchierotti et al. (2006) also measured passing distance in a narrow corridor. This could also be a reason for why some pedestrians changed paths (flee) when passing the vehicle. Perhaps, they did not want the vehicle in their personal space and decided to change paths. Thus, more research needs to be done in a location where pedestrians have more space to pass the autonomous sidewalk delivery vehicle.

The other behavioural themes found in the present study concerned: pedestrians being surprised by the vehicle, pedestrians taking a picture or making a video of the vehicle, and reactions of dogs. A substantial fraction of reactions with dogs showed that the dog wanted to approach the autonomous sidewalk delivery vehicle even though some of the owners of those dogs tried to prevent the dog from approaching. Though, there was also one dog who fled from the vehicle on its own (there was no collar). It is interesting to see that dogs have a variety of reactions to an autonomous vehicle ranging from approaching it to fleeing from it. This could help with the design of protocols of autonomous sidewalk vehicles for when encountering a dog. Another aspect that could be interesting is that dog owners also often try to avoid interaction between their dog and the autonomous sidewalk vehicle. This could imply that they do not trust the autonomous sidewalk delivery vehicle around their dog or the other way around. Future research that investigates the reactions of dogs to autonomous sidewalk vehicles as well as the thoughts of their owners needs to be done to gain more insight into encounters between people walking their dogs and autonomous sidewalk vehicles.

The last themes concern the verbal reactions of pedestrians. There were four major verbal themes found in the present study: the function of the autonomous sidewalk delivery vehicle (1), the autonomy of the vehicle (2), the camera on the vehicle (3) and the safety of the parcels (4). In addition to these four themes, there were also statements indicating how people thought of the vehicle. The majority of those statements were positive. The negative statements concerned the efficiency of the vehicle and how the vehicle could be used to spy on people. Notably, the comment about using the vehicle for espionage could tie in with the theme where pedestrians mention the camera on the vehicle. It is likely that people are still somewhat wary of autonomous sidewalk vehicles and what happens to the video material from its camera considering this reaction. The reactions in which the safety of the parcels is mentioned often refer to other people stealing the parcels, likely because the box on the delivery vehicle did not have a lid. However, this also implies that the thought of stealing the parcels had occurred to them as well, even though they did not act upon it. The predominantly positive reactions of pedestrians found in the present study are conform to what Starship Technologies claimed, that the pedestrians who paid attention to the autonomous vehicle were “overwhelmingly positive” (Zhang, 2017), and to the findings of Satake et al. (2015), where people displayed a positive reception of the robot in a shopping mall.

A limitation of the study was that the wizard-of-oz set-up sometimes did not work. The 'wizard' manually controlled the vehicle from a distance to make it seem like the vehicle drove autonomously to the pedestrians. However, in 8.99% of the reactions, the pedestrians searched for the person controlling the seemingly autonomous sidewalk delivery vehicle. This shows that the expectations of those pedestrians was that the vehicle was probably controlled by someone close by and did not drive autonomously. Thus, they might have thought that technology is not that far yet. Regardless, they did not believe that the sidewalk delivery vehicle drove autonomously and thought that someone was watching them from somewhere. Therefore, they could have shown a different reaction, as people who think that they are being watched show different behaviours (Bateson, Nettle, & Roberts, 2006). Ultimately, 75% of the pedestrians that searched for the wizard also found the wizard.

There is a second limitation that concerns the experimental design of the present study. The reactions of the pedestrians were observed in person and were written down using pen and paper. It is possible that the experimenter missed some parts of the reactions because they were writing at that moment or because it was too quick to see normally. The previously mentioned studies in which behaviour was observed as well, except for Vroon et al. (2020), used cameras to record the behaviour (Abrams et al., 2020; Fischer et al., 2015; Rothenbücher et al., 2016). Thus, preventing data to be lost as the whole reaction was filmed and could be examined fully. The present study chose not to use cameras because of ethical considerations. There was no clear exit in the location, thus asking for consent to use the video material was practically impossible. Future research should have a location in which there is a clear exit where consent can be asked after the encounter (to ensure a natural reaction).

In summary, reactions of incidentally copresent pedestrians to a seemingly autonomous sidewalk delivery vehicle were explored and used to find various themes. The majority of pedestrians did not approach the vehicle, though there were a few reactions in which people approached or fled from the vehicle. The average passing distance found in the present study was around 22 centimetres, which belongs to either the intimate distance or personal distance sphere. Regarding the avoidance path, a large proportion of the pedestrians swerved to only avoid the vehicle, though there were also considerable proportions of pedestrians who took a wide turn or who hardly had to move to evade the vehicle. The other behavioural themes found in the present study concerned pedestrians being surprised by the vehicle, taking a picture or making a video of the vehicle, and reactions of dogs. There were also four major verbal themes found in the present study: the function of the autonomous sidewalk delivery vehicle, the autonomy of the vehicle, the camera on the vehicle and the safety of the parcels. In addition to these four themes, there were also statements indicating how people thought of the vehicle, of which the majority was positive. The present study was an exploratory study. The findings from the present study revealed new avenues, concerning pedestrians' natural reactions towards autonomous vehicles, that should be further investigated for future road safety as well as the design (external appearance and programming) of autonomous sidewalk delivery vehicles.

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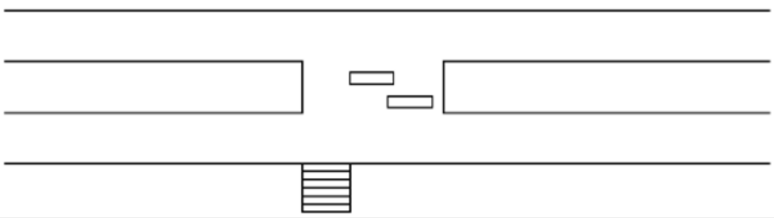
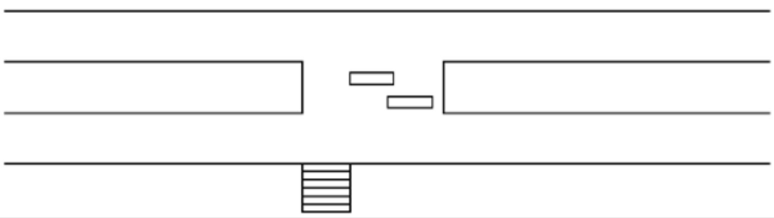
Appendix A: Observation table

<table>
<tr><th>Time</th><th>Gender</th><th>What</th><th>Look + t (s)</th><th>A / I / F</th><th>Distance (cm)</th><th>Age</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td><td>Yes/no:
t/subj:
Sort:</td><td></td><td>Stripes:
Cm:</td><td>16 – 30:
31 – 50:
51 – 65:
65+:</td><td rowspan="2"></td></tr>
<tr><td colspan="7">Avoidance path:
</td></tr>
<tr><td></td><td></td><td></td><td>Yes/no:
t/subj:
Sort:</td><td></td><td>Stripes:
Cm:</td><td>16 – 30:
31 – 50:
51 – 65:
65+:</td><td rowspan="2"></td></tr>
<tr><td colspan="7">Avoidance path:
</td></tr>
</table>

Appendix B: Wizard protocol of how to drive the vehicle

Protocol (in descending order of priority)

1. Is there a child within a radius of one metre of the vehicle? Stand still until the child is out of the radius.
2. Stop when there is something one metre in front of the vehicle. In front of the vehicle refers to the area between the Z degree angles (which is the area visible from the front camera), see Figure 6. Continue the route after three seconds from when the road is clear again.
3. Drive 5 km/h according to the planned route (as close as possible to the intended line).
4. If someone touches the vehicle (independent of the position of the person), the vehicle will continue to drive.

Note. The wizard may have to adjust some things based on experience.

Possible situation 1: aggression

- Someone hits (with an object) or kicks the vehicle? The vehicle will continue to move unless this person is in front of the vehicle (step 2)

Possible situation 2: child

- Is there a child within the specified radius (step 1)? Stop. Does it run away? After 3 seconds, continue driving (step 2) at 5 km/h (step 3).

Possible situation 3: touching

- A passer-by touches the vehicle. If the passer-by is not in front of the vehicle, the vehicle continues to drive.

Possible situation 4: overtaking from the rear

- In the case that someone overtakes the vehicle from the rear, the vehicle simply continues to drive. However, if the overtaking person is too close to the vehicle after overtaking (at a distance less than one metres), follow step 2.

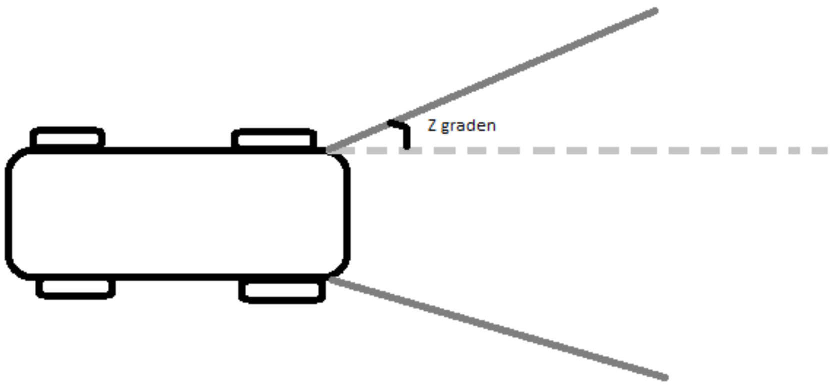


Figure 6. Shows the area in front of the vehicle where the vehicle should stop if a person is in it.