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THE APPRAISAL OF ROADWAY ENVIRONMENT AND INFRASTRUCTURE BY DRIVERS WITH AUTISM: A QUALITATIVE STUDY

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ABSTRACT

People with an autism spectrum disorder (ASD) might experience difficulties while driving, e.g., hazard perception issues. These difficulties may be related to cognitive difficulties (internal) such as attention-shifting, sequential performance, and multitasking. Possibly related to these issues, some people with ASD experience stress and anxiety while driving. Among other reasons, stress could relate to the roadway environment and infrastructure design, e.g., sensory overload due to lighting conditions. Yet, no study has examined the relationship between roadway environment and infrastructure and driving experiences of people with ASD. This study aimed to (1) explore how people with ASD experience roadway environment/infrastructure while driving (2) identify coping strategies to deal with interfering elements related to roadway environment/infrastructure. Twelve persons (Mean age: 34.8, 66.7% female) participated using semi-structured interviews to examine roadway environment/infrastructure appraisal. The interviews were analyzed based on a phenomenological hermeneutical approach. Each participant reported both positive (e.g., environment and infrastructure can be supporting, enhance predictability) and negative appraisals (e.g., stress, anxiety) to roadway environment/infrastructure. Various elements (e.g., light, noise, rush) caused additional pressure on (1) the driving performance (e.g., driving too slowly, not noticing important elements), (2) their traffic analyzing skills (e.g., overseeing new situations), (3) and the efficient application of traffic rules. The participants described different coping mechanisms to deal with the influence of interfering elements; for example, alternative transport means or adjusting behavior (e.g., switch off radio, early departure). This study is the first of its kind to demonstrate that besides internal factors (e.g., attention), external factors like roadway environment/infrastructure also influence the driving experience of ASD drivers, potentially leading to driving-related stress and anxiety.

KEYWORDS

Autism spectrum disorder, driving, roadway environment, roadway infrastructure, hermeneutic phenomenology, coping mechanisms

1. INTRODUCTION

Autism spectrum disorder (ASD) is a commonly diagnosed neurobiological developmental disorder (American Psychiatric Association, 2013). Adults with ASD have reported that they experience emotional difficulties at the age of 21 as they transition from school to working life (Smith et al., 2012). Among other causes, the experience of emotional issues could be related to problems with transportation. In a study by Feeley et al. (2015), several people with ASD reported that they felt isolated, depressed, and lack self-confidence due to their transportation problems. Driving is an important step toward autonomy. It facilitates adults in finding a job, maintaining social relationships, and fulfilling an individual's educational needs (Ellaway et al., 2003). The ability to drive contributes to the quality of life, enhances psychological well-being, and creates opportunities in one's daily life (e.g., work, healthcare, etc.) (Chee et al., 2015; Feeley et al., 2015; Dickerson et al., 2007). Therefore, driving directly influences the physical, social, and economic well-being of a person with ASD (Feeley et al., 2015).

1.1 Autism and driving

Cars are still the most common transportation mode in Belgium, especially for people who live and work in rural areas where public transportation is limited (Vias institute, 2020). However, it is not always easy to obtain a driver's license for people with ASD (Feeley et al., 2015). Research showed that people with ASD obtained their driver's license significantly less often and later compared to neurotypical (NT) peers (Curry et al., 2017; Feeley et al., 2015). In general, ASD drivers tend to adapt their responses slower to several stimuli and are less flexible in modifying their reactions. Therefore, they will react less adequately (Fournier et al., 2010), which can negatively influence their learning process as ASD drivers need more time to learn to drive than NT drivers.

Literature on differences in driving behavior between ASD drivers and their neurotypical counterparts has been increasing. They drive one day less per week, rate themselves as poorer drivers (Feeley et al., 2015), and reported more self-reported crashes and violations (Daly et al., 2014; Classen et al., 2013). Some ASD drivers tend to experience stress and anxiety while driving. The latter can also occur when other drivers do follow the traffic rules, as ASD drivers are more rule-bound while driving (Chee et al., 2015; Ross et al., 2018a, 2018b). When examining novice ASD drivers' attitudes, their parents reported less positive and more negative attitudes towards driving from their children compared to parents of NT peers. However, after receiving a training program, there was a significant increase in positive attitudes (Ross et al., 2018a). Novice drivers with ASD also reported the process of learning to drive as very stressful (Almberg et al., 2017; Chee et al., 2015). A mixed-method study by Ross et al. (2018b) examined the learning experiences of young persons with ASD, their parents, and driving instructors. The individuals with ASD reported multitasking, violating traffic rules, and reacting to unpredictable situations as the most common problems. They experienced more stress and indicated that they needed more time compared to NT peers. Concerning basic driving ability, an on-road study by Chee et al. (2017) revealed that they are also worse at maneuvering, especially when turning left or right and crossing a crosswalk. Yet, a driving simulator study by Ross et al. (2019) found no differences between ASD and NT drivers in collisions, stops at traffic lights, and the standard deviation of the lateral

lane position (SDLP). Moreover, ASD drivers experience difficulties with hazard perception (Chee et al., 2019; Sheppard et al., 2017). In some studies, issues with respect to social hazards were found. Compared to NT drivers, they tended to point their attention slower towards social stimuli while driving, and therefore they reacted slower to social hazards. No differences were found in reaction time to non-social hazards (Bischop et al., 2017; Sheppard et al., 2010). Multiple studies reported decreased executive functions (EF) in ASD drivers and link driving errors to executive functioning difficulties (Daly et al., 2014; Brooks et al.,2016; Chee et al., 2019). A more recent study by Ross et al. (2019) indicated lower working memory and attention performance compared to NT drivers. However, they showed that, even though they performed worse on the EF-tasks, once the people with ASD learned how to drive, they could be considered capable drivers. Thus, the relationship between autism and driving does not automatically have to be negative. For example, while some ASD drivers experience driving as a stressful and challenging activity, others also experience a feeling of freedom and independence as they are driving. As another example, the above-mentioned rule-boundness was mentioned as a positive asset by driving instructors (Feeley et al., 2015; Almberg et al., 2017, Cox et al., 2020; Ross et al., 2015, 2018, Cox et al., 2020; Lindsay, 2017). The mix in negative and positive relations between ASD and driving (ability) reflects our target group's essential characteristic. Indeed, it is important to keep in mind that ASD is a spectrum diagnosis, with individual and ASD-related characteristics varying within and between individuals (Ross et al., 2015).

1.2 Autism and roadway environment and infrastructure

Although negative attitudes, anxiety, and stress are recurring disturbing factors in the driving experiences of ASD drivers, little is known about what specifically influences and contributes to these problems. Roadway environment and infrastructure could be possible contributors to these problems. Previously, multiple quantitative studies have investigated how people with autism react and behave to certain roadway elements (Remington et al., 2012; Vanmarcke, 2017; Chee et al., 2019; Reimer et al., 2013; Wade et al., 2016; Elwin et al., 2016;Feeley et al., 2015). However, they did not intend to focus on the appraisal of roadway environment and infrastructure. Instead, they focused on other topics such as gaze patterns, hazard perception, executive functioning, etc. Based on these studies, we can make assumptions about how and why people with ASD react to certain roadway environment and infrastructure elements. However, to this date, no study has researched which specific roadway elements hinder and facilitate ASD drivers, how they experience certain elements, and how they cope with difficult situations.

We propose that, among others, stress and anxiety could be negatively influenced by roadway environment and infrastructure design. The current paper uses the terminology as proposed by Castro (2008) regarding roadway environment and infrastructure. She suggested making a distinction between environment and infrastructure as external factors while driving. The environment consists of all the elements located on and beside the road (e.g., road users, trees, lights, houses, etc.). The infrastructure consists of physical elements that are part of or related to the road (e.g., roundabouts, road markings, etc.). Both the environment and the infrastructure can influence driving behavior. In the next paragraphs,

we will focus on the autism-related characteristics and their relation to the experiences and appraisal of roadway environment and infrastructure.

Firstly, people with autism have a higher perceptual capacity than non-autistic persons. They can process more information from a scene, but they also find it harder to filter the irrelevant items. They are more easily distracted by irrelevant stimuli, such as flashing lights or sounds (Remington et al., 2012). These difficulties exacerbate when complex information is being presented at a fast pace. People with ASD frequently cope with this by processing all the details of the environment separately rather than processing it as a whole, which can cause dangerous driving situations (Vanmarcke, 2017). ASD drivers also tend to fixate and spend more time scanning the central visual field and do not focus on other fields where a potential risk may occur (e.g., parked cars on the left side of the road) (Chee et al., 2019; Reimer et al., 2013). However, it is suggested that, after ASD drivers receive training, they are also able to have proficient scanning patterns (Wade et al., 2016).

People with autism frequently report sensory processing problems, such as hyper- and hypo-reactivity (Chien et al., 2019, American Psychiatric Association, 2013). Hyperreactivity is characterized by experiencing intense reactions to sounds, touch, and visual stimuli (Grandin & Scariano, 2005). This can lead to high-stress levels and can often cause sensory overload reactions (Smith & Sharp, 2013; Top et al., 2019). Such sensory overload reactions happen when a person receives more input from their senses than what their brain can process or when he/she feels emotionally or physically overwhelmed (Stewart et al., 2009). Because of their delicate sensory system, most people with ASD get easily overloaded. However, the triggers are different for every person (Crane et al., 2009; Mikropoulos et al., 2020). However, others suffer from hypo-reactivity problems where they react less intensely to certain stimuli than neurotypical persons (Elwin et al., 2013). Elwin et al. (2016) suggested that due to the hypo-reactivity, people with ASD might miss information in the environment. Both hyper- and hypo-reactivity can influence the experience and appraisal of roadway environment and infrastructure. Drivers might experience particular elements as too intense and therefore causing stress and anxiety. On the other hand, they might not react adequately to certain stimuli because they miss crucial information from the environment and infrastructure.

According to Vermeulen (2009 & 2015), many of the obstacles that people with ASD experience in their daily lives are attributable to difficulties with contextual sensitivity or 'context blindness.' People with ASD experience difficulties in using context when giving meaning. The theory has emphasized the weak central coherence hypothesis (Vermeulen, 2009). Central coherence is the ability to integrate information in context for higher-level meaning (Frith & Happé, 1994; Booth & Happé, 2010). To give meaning to a situation while driving, drivers need to use information from both themselves and the environment (Feeley et al., 2015). However, this might not be easy for ASD drivers, as they might not give enough weight to important elements and give too much weight to unimportant details (Vermeulen, 2015). You are approaching a traffic light, and the light turns to orange. This is a warning that the red light is about to turn on and that you should stop if it is safe to do so. The appropriate reaction to that

orange light depends on the context: the following distance from the car behind you, your distance to the traffic lights, the speed you are going, etc. In other words, you have to use the context to decide what the appropriate action is, continue, or stop. Because people with ASD experience difficulties with using the context when giving meaning, they might be inclined to stop while continuing to drive would have been the better option, for example, if they needed to brake harshly due to the imminent transfer from the orange to the red phase.

Context blindness is also linked to theory of mind and executive functioning. Theory of mind is the ability to comprehend mental states from others to explain and predict their behavior (Baron-Cohen, 1995). Vermeulen (2015) suggested that theory of mind problems in people with autism arise from difficulties in using the context to actively read others' mental states rather than specific deficits in mind reading. Executive functioning (EF) skills are the higher mental processes that enable us to plan, form abstract concepts, stay focused, etc., to self-monitor our behavior (Liss et al., 2001). People with autism experience deficits in specific EF areas: attention shifting, planning, and cognitive flexibility (Hill, 2004). When understanding others' behavior, taking the context into account is crucial (Klin et al., 2003). However, it is equally important in guiding one's behavior. People with ASD might experience impairments in social interaction resulting in difficulties in using the context to interpret others and guide their behavior (Vermeulen, 2015). In conclusion, we suggest that the experienced problems with contextual sensitivity can influence the appraisal of roadway environment and infrastructure in ASD drivers. They create difficulties in correctly understanding, using, and giving meaning to the context and environment.

1.3 Aims of the study

As stated above, it is important to describe experiences and insights from the participants' viewpoint. Therefore, by using a qualitative interviewing method, we aimed to obtain a comprehensible picture of the experiences, insights, reactions, and thinking patterns of ASD drivers, taking their viewpoint into account (Watkins, 2012). Therefore the current study aimed to:

1) Explore how drivers with an autism spectrum disorder experience certain elements of the roadway environment and infrastructure.
2) Identify potential coping strategies used to deal with interfering roadway environment and infrastructure elements.

2. METHOD

No specific research focusing on roadway environment and infrastructure and ASD drivers has been conducted; therefore, the research questions were studied using an exploratory qualitative research method. The research focuses on the appraisal of roadway environment and infrastructure by drivers with ASD. To investigate this appraisal, the current study used a qualitative research design with a phenomenological hermeneutical method. Qualitative research enables the researchers to describe experiences and insights from the participants' viewpoint (Kielhofner, 2006). "The phenomenological hermeneutical method is used for researching lived experiences. It centralizes the participant's

subjective experiences by letting them tell how they experienced specific situations. It can be used for research to explore people's perception of reality" (Lindseth & Norberg, 2004).

2.1 Participants

The current study aimed to include adults with autism who had already obtained their definitive driver's license or those with a learner's permit with at least 20 hours of driving experience. This to avoid effects from the learning to drive process, as this can influence their experiences with roadway environment and infrastructure. Participants were recruited through convenience sampling. As a result of the voluntary participation, all participants were screened through criterion sampling to obtain a purposive sample. The following inclusion criteria were used:

- An official autism spectrum disorder diagnosis (e.g., autistic disorder, Asperger disorder, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified (PDD-NOS) (Maenner et al., 2014)).
- A score of 32 or higher on the Autism-spectrum Quotient (AQ-50): All participants were diagnosed with autism in the past. However, as a double-check, we only included people with a current clinically significant level of autistic traits. A cutoff score of 32 is required (Baron – cohen et al., 2001).
- Dutch speaking,
- Lack of intellectual disability.
- In possession of a learner or permanent driver's license (when in possession of a learner's permit: at least 20 hours experience).
- Drive at least once a week.

Participants were informed about the study by sending an informative poster via e-mail to organizations that work with people with ASD daily (e.g., Autism Centraal, Autisme Limburg vzw, etc.).The poster included a link to a questionnaire where potential candidates could register to participate in the study. The questionnaire included the AQ50 and a few questions about their driver profile (e.g., driver's license, kilometers per week, ASD diagnosis, and 17 years or older.). To obtain a purposive sample that represents the target group as closely as possible, a new mail was sent to obtain extra data (e.g., place of residence, date of birth, and date when they obtained their driver's license). The new data enabled the researchers to select participants intentionally. Candidates that did not reply after one week received a reminder e-mail. No number of desired participants was established, as this depended on when saturation was reached (Morse, 1995).

2.2 Materials

2.2.1 Autism-spectrum Quotient (AQ-50)

The Autism-spectrum Quotient is a self-reported questionnaire to determine to what extent an adult with ASD experiences autistic traits. The instrument consists of 5 domains that are questioned through 50 questions, with a total score ranging between 0 and 50 (i.e., cutoff score: 32). The five domains are social skills, attention switching, attention to detail, communication, and imagination. Each question gets

a score of one point if the respondent records the autistic-related behavior, either mildly or strongly, on a four-point scale (Baron-cohen et al., 2001). The Dutch AQ-50 version's internal consistency was found good (α = 0.71), and test-retest reliability was satisfactory (Hoekstra et al., 2008).

2.2.2 Interview guide

One researcher executed the data collection pre-COVID, which was guided by a semi-structured interview and accompanying photos that supported the in-person interview. The interview guide (see Appendix 1 for a copy of the full interview guide) was developed in collaboration with two other researchers. It included several key concepts regarding roadway design, environment, and infrastructure. The guide is a scheme with open-ended questions, which allows for flexibility of the interviewer. It assisted the researcher in structuring the interview and questioning all the fields of interest. Those fields of interest were the facilitating factors and barriers in roadway environment and infrastructure, the level of disturbing influences of environmental and infrastructural factors on their driving experiences, and the coping strategies which ASD drivers use. However, people with autism can experience difficulties in answering open-ended questions (Frith, 1989). Therefore, accompanying photos were used to support the interview and the participants by providing them with examples. The interview guide was piloted with two persons with ASD (in possession of a driver's license) before the actual experiment started. The accompanying photos, 14 in total, were aimed at representing the Flemish (i.e., the Dutch-speaking part of Belgium) road context as closely as possible. The photos included roundabouts, road narrowings, cyclists on the road, speed bumps, road surfaces in poor condition, a steep bend, intersections (with and without traffic lights), a quiet street in a residential area, traffic in city centers, a traffic jam on the highway and a streetcar on the roadway.

2.3 Procedure

Before selecting the final participants, all potential participants were asked to complete a Dutch online version of AQ-50. After participants completed the questionnaire, they were contacted for participation so they could choose the date and location of the in-person interview. They also had to confirm that they scored 32 or more on the AQ-50 as this was one of the inclusion criteria. All participants choose their own homes as the interview location. Communication was done through e-mail. Before starting the interview, all participants signed an informed consent, which contained: background information, the aims and description of the study, the duration, a declaration of voluntary participation, the risks, a declaration of privacy protection, and contact details. Recordings were made with a mobile phone, and a verbatim transcription was made in Microsoft Word® with Express Scribe Transcription Software Pro®. Based on the researcher's notes, a member check (i.e., asking for verification of the interview findings) was sent to the participants (Thomas & Magilvy, 2011). Each participant needed to confirm these findings.

2.4 Data and quality criteria

2.4.1 Data gathering and analysis

Interviews were conducted and analyzed until the first researcher, an occupational therapist, could not find new information regarding the research topic (saturation) (Morse, 1995). The phase of data collection and data analysis were intertwined. In the beginning, a few interviews were conducted and thereafter analyzed. The same researcher always did the analyses and, after that, they were checked by two senior researchers. Based on the analyses, the interview guide was adapted by the research group. For example, if a question was too difficult to answer (e.g., scale questions), they were adjusted or removed. As the interviews progressed, these analyses became more frequent because saturation was almost reached. All the data were analyzed by NVivo 11 by one researcher, and two members of the research team, a psychologist and a physical therapist, checked the analyses. The interviews were transcribed ad verbatim and analyzed based on the phenomenological hermeneutical method by Lindseth & Norberg (2004). The researcher stayed as close as possible to the original text while analyzing the data without interpreting the made (phenomenological) statements. Thereafter, the (main) themes were interpreted from the participant's perspective and experiences (hermeneutical).

The phenomenological hermeneutical method consists of three steps. In the first step, a naïve reading is executed by the researcher. To this end, the researcher reads the text, and member checks several times to grasp its meaning as a whole. After that, a naïve understanding can be formulated as an initial assumption, which is not yet confirmed by a structural analysis. A thematic structural analysis will be used in the second step to analyze the interview in four steps. (1) The data transcript consists of wholes that convey just one meaning (e.g., a sentence, a paragraph, etc.), i.e., meaning unit. (2) The core of the meaning-unit will be expressed in colloquial language, i.e., condensation. Thereafter, subthemes will be formulated, consisting of iterations in the interview or similar condensation made throughout the interview. The main themes were formed by connecting subthemes. (3) Lastly, a comprehensive understanding is formulated by combining the proposed main themes and reflect them in relation to the research questions (Lindseth & Norberg, 2004).

2.4.2 Quality criteria

To obtain reliable results within qualitative research, Lincol & Guba (1985) propose a model of trustworthiness. The model exists of four elements: credibility, transferability, dependability, and confirmability. Sending a member check to the participants, doing a verbatim transcription, and including citations enhance the research's credibility. Using intentional sampling, setting strict inclusion criteria, and describing sufficient participant characteristics allows researchers to decide whether the results are transferable to other ASD drivers. Dependability is transparently displaying the research process (e.g., NVivo 11, Express Scribe Transcription Software Pro, etc.), correctly reporting the method and data collection, and discussing the results. The last key element in obtaining reliable results is confirmability. In this study, the confirmability was increased by using citations and giving specific examples. Another important aspect of guarding the quality of the study is the concept of reflexivity. The researcher needs to be aware that his or her perceptions and experiences can influence the results. These influences might affect data gathering and analyzing processes. Therefore, the researcher has to take the model of trustworthiness into account during the whole research process (Thomas & Magilvy, 2011).

3. RESULTS

3.1 Sample selection

Figure 1 shows a flowchart of the selection process. Each potential participant received an e-mail in case they were excluded. The 11th interviewed participant did not add any new information that contributed to the research aims. A 12th participant was interviewed as a control but added no further information. Thereafter, we concluded that saturation was reached after 12 interviews. Only drivers with a permanent driver's license were included because no one with a learner driver's license applied to participate in the current study[1]. Adults between 31 and 39 years of age were included in the current study. Table 1 gives an overview of the demographic characteristics of the participants.

During the data collection, the interview guide is modified based on the mentioned themes because of this study's exploratory character. The original guide included two scale questions where participants had to give a score between 0 and 10 regarding the influence of roadway environment and infrastructure on their driving behavior. After conducting approximately two-third of the interviews, it became clear that these questions had no added value. Participants reported that they experienced difficulties with answering these questions as they were not specific enough. Therefore, these were removed. Consequently, these questions' results were not usable and, therefore, not used in the analysis. Similarly, additional questions were added based on participants' feedback (e.g., coping with detours, driving in the dark, noise, etc.).

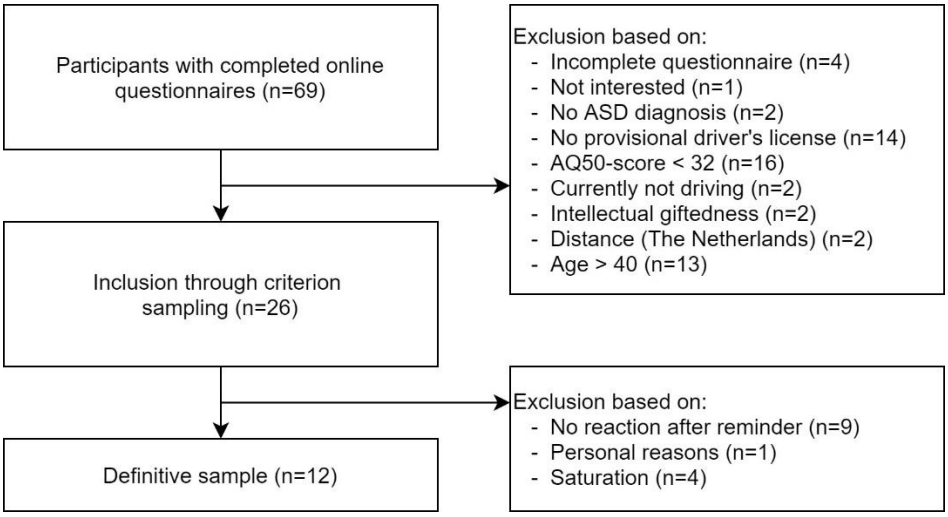

Figure 1: flowchart selection process

	Participants (n=12)
Gender, n (%)	
Female	8 (66.7)
Male	4 (33.3)
Age, $\bar{X} \pm s$	34.8 ± 2.8
Range	31 – 39*
Diagnosis, n (%)	
ASS	5 (41.7)
ASS and comorbidity	7 (58.3)
ADHD	*3 (25)*
OCD	*2 (16.7)*
Anxiety and depression disorder	*2 (16.7)*
Age ASS diagnosis, $\bar{X} \pm s$	29.8 ± 6.3
AQ-50 score, $\bar{X} \pm s$	37.4 ± 4.2
Driver's license	
Car	10 (83.3)
Car and others	2 (16.7)
Age obtaining a driver's license, $\bar{X} \pm s$	19.2 ± 1.3
Kilometers/week, $\bar{X} \pm s$	248.9 ± 228.2
Duration interview, $\bar{X} \pm s$	59.8 ± 10

Table 1: Demographics participants

3.2 Exploratory results

3.2.1 Naïve understanding

A first member check was completed on the spot by summarizing what the participant had said several times during the interview. At the end of each interview, the interviewer made another global summary, which was then confirmed or corrected by the participant. We sent a second member check to the participant after conducting their interview. Nine participants confirmed their findings; three did not yet. The first assumptions were formulated after carefully reading the member checks and interviews. Participants reported stress, anger, and frustration as the primary emotions that they experienced while driving. Factors that influenced these emotions were crossroads, roundabouts, road cracks, road curves, road narrowing, speed bumps, and other road obstacles. Other factors that complicated driving were noise, lights, and driving in the dark. Advertising signs and other eye-catching items distracted them the most. However, roadway environment (e.g., traffic signs) and infrastructure (e.g., road markings) did not always negatively influence the driving experiences of ASD drivers. It could also support ASD drivers under certain conditions: (1) signing consistency, (2) clarity, (3) uniformity, (4) properly indicated, and (5) the situation had to be logical and clear. The ASD drivers reported difficulties with understanding and predicting other road users. Multiple participants reported that everyone experiences both the positive and negative factors in a unique way. In general, the more distracting items presented while driving, the more attention required, the more concentration needed, and the more the driver experienced the drive as exhausting. Their main coping strategies to deal with challenging roadway environment and

[1] Initially, the research team intended to include young-adults (age 17–30), building further on previous studies that mostly included novice and/or young-adult ASD drivers. However, no participants within this age range applied for this study. As a result, the age range was expanded to adults in general. This was justifiable, as our research questions did not include age as a variable of interest. Therefore, in the end, participants were recruited through convenience sampling, leading to the age range between 31 and 39 years in the current study.

infrastructure situations were driving slower and more carefully, using public transport, or driving along as a passenger instead of driving themselves.

3.2.2 Thematic structural analysis

After creating a naïve understanding, the interviews were analyzed according to the thematic structural analysis. Table 2 shows examples of the way of analyzing.

Meaning unit	Condensation	Subtheme	Theme
"…when the sun shines, and you have some streets where the sun shines through the trees or something like that…"	Flashes of light through trees are exhausting	Light distracts	Lighting is an important distracting element while driving
"…you cannot see much already…, you can only see like a few meters in front of you… and that causes stress…"	Indistinctness in the dark causes stress	Driving in the dark is difficult	It is less distracting but more challenging to drive in the dark

Table 2: Examples of thematic structural analysis

Table 3 offers a summary of the main themes and the sub-themes that were identified by analyzing the data. The main themes are placed in the left column. The right column contains sub-themes that were most frequently discussed.

Main theme	Subthemes
1. Positive feelings while driving due to roadway environment and infrastructure elements (n=12)	- Feeling safe while driving due to the roadway infrastructure (RI) - Feeling calm due to the clarity of the RI while driving - Feeling calm while driving due to the roadway environment (RE)
2. Negative feelings while driving due to roadway environment and infrastructure elements (n=12)	- Stress and insecurity while driving caused by the RE - Stress and insecurity while driving caused by the RI - Stress and frustration while driving due to the RE - Frustration while driving due to the RI - Confusion while driving due to RI ambiguities - Confusion while driving due to the RE - Fear and feeling unsafe while driving due to the RI - Fear, stress, and feeling unsafe while driving due to the RE
3. Negative feelings while driving due to other road users (n=11)	- The unpredictability of other road users complicates driving - Feeling uncomfortable caused by other road users - Frustration caused by the behavior of other road users
4. Factors that complicate driving (n=12)	- Street lighting is an important disturbing element while driving - Noise disturbs while driving - Difficulties with driving in the dark

[1] Initially, the research team intended to include young-adults (age 17–30), building further on previous studies that mostly included novice and/or young-adult ASD drivers. However, no participants within this age range applied for this study. As a result, the age range was expanded to adults in general. This was justifiable, as our research questions did not include age as a variable of interest. Therefore, in the end, participants were recruited through convenience sampling, leading to the age range between 31 and 39 years in the current study.

	- Disturbing elements in the RE
5. Inefficient application of traffic rules caused by complex traffic situations (n=10)	- Traffic rules are important, but other road users do not comply with these rules - Creating dangerous situations due to complicated traffic situations - There must be logic in the traffic - Lack of uniformity in traffic rules and reflection in the traffic
6. Rush and chaos pressure the driving performance, information processing, and observation process (n=12)	- Multiple elements distract while driving - Selecting the right elements in a chaotic environment is stressful - Driving behavior and driver are pressured by thoughts and chaos on the road - More attention needed in complex situations - Driving is exhausting due to crowded situations
7. Experience and automatization (n=10)	- Experience is important - Driving is an automated behavior - Experience in driving differs between individuals
8. Adapting behavior to different traffic situations (n=12)	- Adapting the driving style to the environment and situation - Eliminating stimuli - Creating predictability - Using distracting elements as a tool
9. Using alternatives to get around (n=5)	- Using alternative means of transport - Trusting other people as a driver - Taking a passenger along
10. Avoidance behavior in specific traffic situations (n=8)	- (Temporary) avoiding driving - Avoiding situations in certain circumstances

Table 3: Main and subthemes derived from the analysis

When comparing the main themes and themes with the naïve understanding for validation purposes, the structural thematic analysis confirmed the naïve understanding.

Theme 1: Positive feelings while driving due to roadway environment and infrastructure elements

Each participant reported that some roadway environment and infrastructure elements could help them feel safe and calm while driving. The roadway infrastructure can create a safe feeling (e.g., speed bumps, separate bike paths). Both roadway environment (e.g., traffic signs, lighting in busy places, instructions above the highway, etc.) and infrastructure (e.g., clear roadway markings, roundabouts with one lane, etc.) can create calmness as they provided clarity for the drivers. Table 4 offers a complete overview of the roadway environment and infrastructure elements that evoked positive feelings while driving, as reported by the participants in the current study.

R.A.: "Or like the bike paths, it is safer when they are separated, but that is also more clear. However, this is my own opinion. I think that they should do this here as well."

Infrastructure	**Environment**
Road Markings	Well-lit intersections
Traffic signs painted on the road	Not using abbreviations on traffic signs

Yield line/give-way line	Consistently indicating the direction
Road centerlines	Clear separation between what is on the road and what is beside the road
Designated parking spaced	Traffic lights
Intersections with arrows painted on the ground	Only limit to essential traffic signs
Scramble intersections	Mile markers with speed indication
Roundabouts with one lane	Unambiguity of traffic signs
Reflecting roadway markings	Well-maintained roads
Separated bike paths	Lighting in busy places
Quiet asphalt	Instructions above the highway
Separated public transport lanes	
Speedbumps	
Clear roadway markings	

Table 4: Overview of elements that evoke positive feelings while driving

Theme 2: Negative feelings while driving due to roadway environment and infrastructure elements

All participants reported stress and insecurity due to the roadway environment (e.g., traffic jams, passing by other drivers, etc.) and infrastructure (e.g., road narrows, crossroads). Participants sometimes perceived the roadway infrastructure as confusing. Parking their car caused stress for most of them as they had to take many factors into account (e.g., rules, other drivers, not being able to find a parking place, etc.). Especially situations where participants had to depend on others made them feel insecure and anxious. For example, a crossroad without traffic lights where they had to rely on the other road users to notice the traffic signs and road markings so they would be able to stop on time.

R.S.: "Oh yes, that road narrowing makes me frustrated because it means that the road will be too small for two cars, so when the other car comes from the other direction, and I cannot see that because of too high corn plants, then I already know that I will not be able to continue and I will have to go aside, and there are puddles on the sides, and I don't know if that is a brook and that stresses me out." (**Error! Reference source not found.**)

Roadway environment elements that created stress and frustration were related to pedestrians' invisibility in the dark and detours. These elements were perceived as being confusing and lacking conspicuity. Roadway infrastructure created frustration as well. Nine participants perceived speed bumps as difficult because of their shock when entering and exiting; it broke their drive's rhythm. Using different materials, colors, heights, etc., in the roadway design was confusing to them.

J.S.: "I find speedbumps very annoying; I am always worried that I will drive my car to pieces there. And you always have to slow down for them … and then you are out of your rhythm. … and that scares and frustrates me."

Especially ambiguity in the road infrastructure created confusion in ASD drivers. Clear roadway markings could create calmness. However, these markings could be perceived as unclear and confusing

(e.g., difficult to see when it rains, difficult to read, etc.). Ambiguity, when using their GPS because of the large number of stimuli they received while driving, led to additional confusion and stress.

D.L.H.: "When driving on a large roundabout, I just do something, but when there are cars in front or behind me, and I do something wrong, or I don't know where I have to go because it is not clear, then I get really frustrated and I if I could, I would immediately pull over my car and get out!" (**Error! Reference source not found.**)

Lastly, ASD drivers experienced roadway infrastructure as scary and unsafe. Road cracks made them anxious because of the cracks, their sound, and previous negative experiences. Road curves provoked unsafe and anxious feelings as they can induce a sense of losing control. Besides the roadway infrastructure, the roadway environment also made them feel anxious and unsafe. Especially other pedestrians, bikers, and parked cars were mentioned as the ASD drivers were afraid of getting involved in a crash with them. Lastly, unknown and crowded situations made people with ASD feel anxious and unsafe as well.

S.A.: "It is about new situations; for me, that is always a bit stressful, and then I need someone sitting next to me, and I don't get used to it quickly. I notice that I don't get used to it soon."

Theme 3: Negative feelings while driving due to other road users

Each participant, except for one, reported that other road users (i.e., roadway environment) made them feel uncomfortable and frustrated. The unpredictability of other road users can make driving a difficult task. Some ASD drivers experienced difficulties in predicting others' behavior and their intentions. Estimating other roadway users their distance was perceived as challenging as well. Roadway infrastructure can contribute to these feelings of frustration and discomfort (e.g., roundabout, road narrowing, etc.). The higher the number of other road users present in the roadway environment, the more uncomfortable feelings the ASD drivers experienced as they felt like they had less control over the situation. ASD drivers also experienced frustration due to the behavior of the other drivers. They perceived others as aggressive and individualistic. Other drivers did not obey the rules, and therefore, they can be considered dangerous.

S.B.: "Yes, of course, the less traffic there is, the less you have to do, like taking everything into account, of course, the more calm and comfortable I am."

Theme 4: Factors that complicate driving

All participants reported sound and lighting as complicating factors while driving. Sounds can hinder them while driving (e.g., trains, air conditioning, sound of the car, etc.). All participants emphasized their need for silence and quietness while driving. Lighting or illumination could be fatiguing when drivers constantly had to switch between lit and unlit parts. A stroboscope effect (e.g., sun shining through trees) and too much street lighting could be tiring as well. Not only was street lighting indicated as fatiguing,

but also car lights, Christmas lights, the flash of a speed camera, and neon signs. The ASD drivers experienced driving in the dark as difficult because many roadway environments and infrastructure elements were not clearly visible. On the other hand, they were less affected by other elements that can be considered distracting in daylight. Participants also reported difficulties with detecting signs above the road or that were not located in their visual field. They would often miss these signs, which hindered them (e.g., taking the wrong exit, driving too fast, etc.).

P.G.: "No, it just bothers me, and then if there is a sound and I know that it comes from my car, then this has to stop, then I want to find where it comes from, but you don't always have the possibility to look for that, or it is rattling in the trunk. Then I try not to pay attention anymore to it, but I listen to it anyway, and that distracts me, and I don't want that."

D.L.H.: "I always find it more difficult to drive in the dark because I can't see the road markings, or I don't see them. … When it is dark, and it rains, I just drive somewhere, but yeah, I find it so unclear and so chaotic that I don't know what Is expect of my driving anymore. For the rest, when it is dark, you don't see the signs that good anymore, and when there are also neon lights, no, then I am 10 times more distracted."

Theme 5: Inefficient application of traffic rules caused by complex traffic situations

Ten out of twelve participants reported that they got frustrated when road users did not obey the traffic rules. They reported that the discrepancy between traffic rules and other road users' execution is too high. The traffic code is reported as an important guide as it provided clarity and structure. Moreover, ASD drivers experienced difficulties in analyzing new or complex traffic situations. They only focused on specific elements. This could result in unsafe driving behaviors (e.g., driving slower, sudden stops, etc.). The ASD drivers valued traffic rules but found it frustrating that their logic was not always present, and therefore, situations were not always clear to them. Another frustration they experienced was the lack of uniformity in traffic rules, material usage (e.g., concrete speed bumps, plastic speed bumps, rubber speed bumps, etc.), and organization of roadway elements (e.g., speed bumps, parking, road narrows, etc.). Therefore, ASD drivers were not able to drive efficiently.

V.A.: "Yes, but for me, it's reassuring (the traffic code), but for other drivers, it is more flexible; they apply it more flexibly, and that makes it difficult for me."

Theme 6: Rush and chaos put pressure on driving performance, information processing, and observation process

Various elements draw the attention of all the participants while driving. Especially advertising boards were distracting to our sample of ASD drivers. However, whether an element was distracting or not depended on the person and his or her interests. Although traffic signs could clarify the situations, a proper distribution was reported as important as too little or too many traffic signs caused confusion and chaos. ASD drivers also reported that there were too many different traffic signs, they stood too close

together, and there was occasionally too much information on one sign. ASD drivers experienced filtering the right aspects from the environment (e.g., various and many traffic signs, too many other traffic participants to determine which ones are extra important to pay attention to (other cars, cyclists, pedestrians), etc.) as stressful and many relevant elements disappeared in the chaotic environment. Rush hour, environmental bustle, and distraction by their thoughts induced pressure on the driving performance of the ASD drivers and created a more negative feeling after driving. Depending on the situation, people with ASD needed to invest more attention and concentration to cope with all stimuli (e.g., unknown, crowded situations, etc.). In conclusion, driving was perceived as an exhausting activity as it always required much concentration to cope with all stimuli.

V.K.: "Because it is quite fatiguing, so I, it is okay, and I don't really mind to drive a car but is asks, it costs quite some energy."

Theme 7: Experience and automatization are important while driving

The majority of the participants reported that they had difficulties with learning how to drive. These difficulties did not necessarily persist in the current driving experience. Yet, all participants agreed that they had a lot of driving experience; and a few participants even stated that they felt comfortable while driving in traffic. Their accumulated driving experience helped ASD drivers while encountering new situations and enabled personal growth as a driver. All participants agreed that certain subtasks of driving and driving itself became automated due to their driving experience. This allowed them to shift their attention to other stimuli in the roadway environment. On the other hand, participants suggested that automatization of the driving task combined with a roadway environment of low complexity could cause a lack of attention or mind-wandering, which may lead to dangerous situations

V.N.: "That is correct, my dad used to do that, he raced on the fields, and he told me he wanted that too: 'You have to learn fast, it will be easier for your exam, then you can focus on other things instead of if thinking about switching gears."

D.L.H: "Yes, and because I think that I know my car by now and I drive already a long time with that car, and I don't know how it is and yes, I do, I drive a little less careful because I don't have to think about everything, think about these actions you know."

Theme 8: Adapting behavior to different traffic situations

Each participant reported adapting their driving style to the environment and situation (e.g., driving slower in bad weather conditions, during rush hour, etc.). They used eye-catching environmental or infrastructural elements to remember their route. When they found themselves in busy situations, when they needed more concentration or were distracted, they simplified the task by reducing incoming stimuli (e.g., turning off the radio or GPS). To create predictability, they planned their routes or tried to predict known situations. The use of GPS can allow for predictability for ASD drivers. Roadway infrastructure can aid when providing clear directions (e.g., road arrow markings, direction signs, etc.). On the other hand, ASD drivers also reported using commonly distracting elements as a tool (e.g., radio, GPS, etc.)

to distract them from their thoughts. Other, less mentioned, coping strategies were: screaming out of frustration, early departure (to avoid time pressure and to provide additional margin to anticipate unforeseen circumstances), wearing orange glasses in the dark, and using the sunshade to avoid the street lights.

R.A.: "I find the radio annoying; I try to turn it off as much as possible. But yeah, when you have other people in your car, almost everyone wants the radio on, so yeah. … I then try not to turn up the radio too loud because it distracts me."

P.G: "The radio is on, yes. Because otherwise, it is too quiet, and I start thinking in my head."

Theme 9: Using alternatives to get around

Five out of twelve participants reported that they frequently used alternative means of transport. Three participants used public transportation (e.g., train, tram, etc.). In contrast, two other participants experienced public transport as uncomfortable and stressful. Therefore, they chose to ride along as a passenger or take a passenger with them while driving as an extra reassurance.

D.L.H.: "Because yes, then yes, that are a couple of eyes more, those people also aren't allowed to sleep when they are sitting next to me in the car, but it helps for that when there is someone accompanying me. Because yes, otherwise, I wouldn't do that (driving to the sea)."

Theme 10: Avoidance behavior in traffic situations

Participants reported that they avoided driving when they felt physically or mentally tired. When they experienced too high-stress levels or anxiety while driving, they pulled their car over so they could pick themselves up or to rebecoming calm and relaxed. The ASD drivers avoided specific situations regarding both roadway environments (e.g., rush hour, traffic jams, city centers, etc.) and infrastructure (e.g., speed bumps, driving in the dark, etc.).

D.L.H.: "I don't like driving in the city? That is way too busy and too much. Yeah, yeah, I always miss important things, and I always do things wrong when I drive in the city. … Yeah, I don't do that anymore now, driving to, I go to Antwerp, my parents live there, but I never use my car to get there."

3.2.3 Comprehensive understanding

Main themes one to seven underpinned the primary study aim: 'explore how drivers with ASD experience roadway environment and infrastructure.' Main themes eight to ten underpinned the secondary study aim: 'identify the coping strategies used to deal with interfering roadway environment and infrastructure elements.'

After summarizing and reflecting on the main themes and sub-themes in relation to the research question and the context of the study, we arrived at a comprehensive understanding which enables us

to interpret the results as a whole. As a result, specific main themes were grouped into broader categories.

- Themes 1 to 3 were named 'Positive and negative feelings while driving.'
- Themes 4 to 6 were named 'Situations that negatively affect driving experiences.'
- Theme 7 was named 'Experience and automatization.'
- Lastly, themes 8 to 10 were named 'Coping strategies.'

Figure 2 offers a schematic representation of how all the main themes connect. The figure clearly shows that the roadway environment and infrastructure could provide both environmental facilitators and barriers while driving and how ASD drivers coped with these barriers. The inner-circle represents theme 1, the positive feelings that participants experienced while driving. Both the roadway environment and infrastructure could provide a safe feeling, calmness, and clarity. These elements were the facilitators that reduced the stress levels of the autistic drivers. This theme is placed in the middle because the goal is for ASD drivers to have a pleasant driving experience.

Theme 2 to 6 contain elements that directly threaten these positive feelings, and they are listed in the second circle. The second circle elements created environmental barriers while driving and might have negatively influenced the stress levels that ASD drivers experienced during their trip. A first factor were the negative feelings while driving that were provoked by roadway environment and infrastructure. The environment and infrastructure were often perceived as confusing and illogical. This caused stress, uncertainty, frustration, confusion, and an unsafe feeling in ASD drivers. Other road users could also evoke negative feelings as their behavior was perceived as being unpredictable. As a result, participants felt as if they had less control over the situation.

Moreover, people with ASD highly valued traffic rules. Yet, other drivers did not always obey these rules, and as a result, the ASD drivers could not see the logic in the situation and were not able to drive efficiently. Participants also noticed other disturbing factors that complicated the driving task, such as noise, lighting, and driving in the dark. All negative factors combined could create rush and chaos while driving, which complicated driving even more and put extra pressure on the driving performance. This pressure, and the stress and frustration it evoked, could also negatively influence the analysis of complex traffic situations. As a result, a vicious cycle could be created in which all the factors influenced each other continuously.

The third circle includes automatization and experience; both concepts were reported to positively influence the driving experience and behavior of ASD drivers. Therefore, it could reduce their stress and other negative feelings caused by the second circle's elements. The outer circle contains personal facilitators or the coping strategies that ASD drivers used to handle all the factors listed in the second and third circles. These strategies could reduce the participants' stress levels and evoked positive feelings while driving."

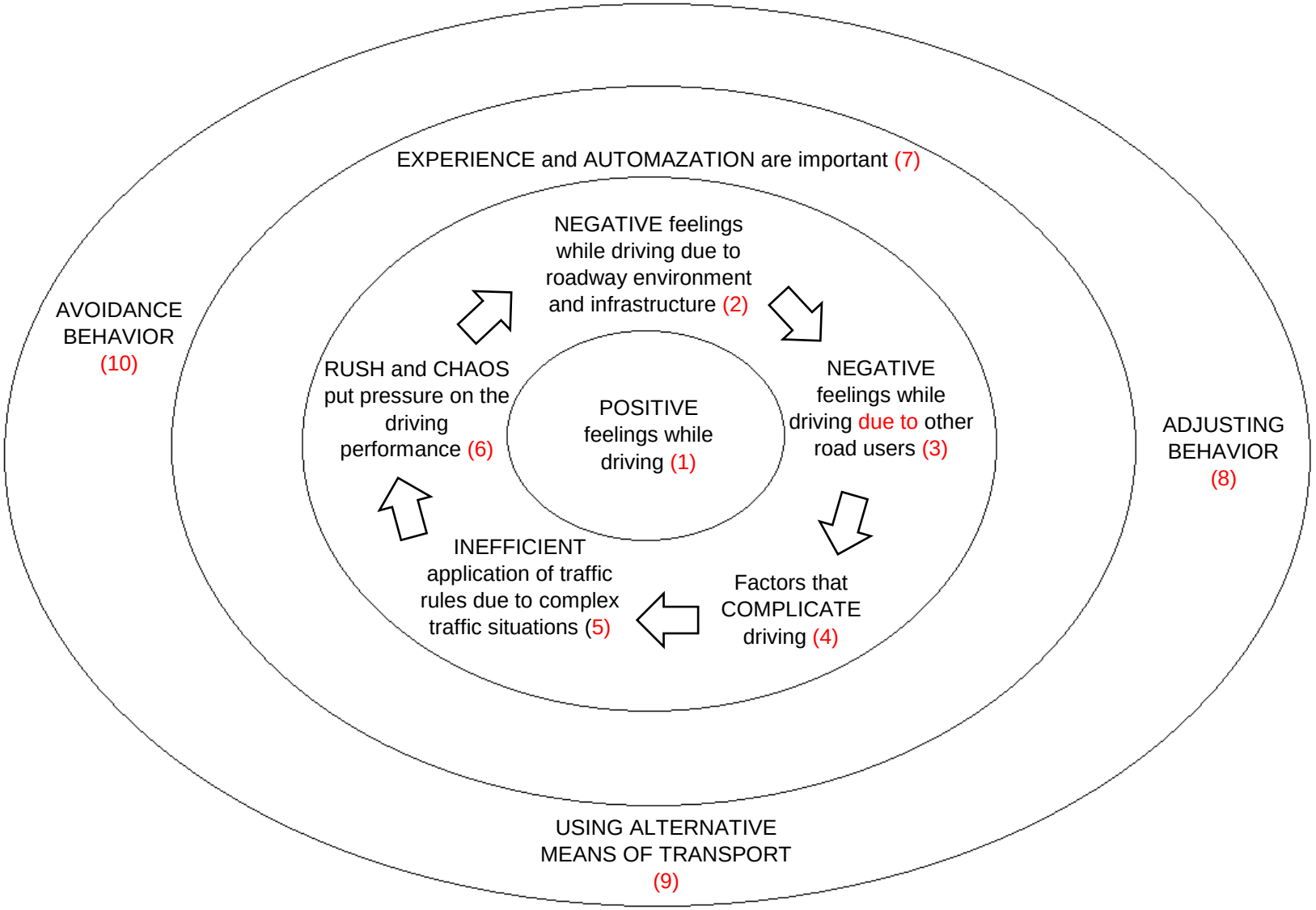

Figure 2: Schematic representation of the main themes

4 DISCUSSION

This study is unique and the first of its kind, aiming specifically to explore the appraisal of roadway environment and infrastructure by autistic drivers and which coping strategies they use to deal with interfering roadway elements. With or without autism, every individual experiences roadway environment and infrastructure from their viewpoint, resulting in different judgments and statements. Nevertheless, all participants did report similarities as well. Individual characteristics can partly explain these differences and similarities. On the other hand, autism is a 'spectrum' disorder, which means that they show a wide variation in the severity and type of symptoms (National Institute of Mental Health, 2020), which could add to the explanation.

The results of the current study were obtained from semi-structured interviews. When the participants were asked for their feedback after the interview, they indicated that the semi-structured interview guide (Appendix 1) and the photos (Appendix 2) were useful prompts as it inspired them. They reported that they often experience difficulties when they have to generate ideas themselves to discuss their experiences. Difficulties with answering interview questions might arise from the theory of mind problems as it is difficult for people with autism to picture abstract things and explain this to another person (Frith, 1989). Additional, there is a clear relationship between ASD and alexithymia. Alexithymia indicates the lack of terms to express emotions and moods (Poquérusse et al., 2018; Ross et al., 2018). We believe that the use of photographs made the questions less abstract and, therefore, more comfortable to deal with and to answer (Rao & Gagie, 2006). Despite previously reported issues with open-ended questions in ASD (Watkins et al., 2017), the participants expressed that the usage of open-ended questions was one of their main motivations to participate in this study. In the current study, they felt as if they could explain and nuance their answer more and still could describe concrete situations. Yet, participants reported difficulties with answering the two included scale-questions because they were not specific enough in their opinion. Therefore, these questions were removed from the interview after conducting approximately two-third of the interviews, and the data not used in the analysis. Even though participants indicated that they were motivated by the open-ended questions, they indicated that the scale questions were too difficult to answer as they were too broad. As a result, participants might have no longer been able to answer them comfortably (Frith, 1989; Watkins et al., 2017). Nevertheless, further studies could use the video-stimulated recall methodology instead of using photos to guide a semi-structured interview. This is a research technique in which the participants are recorded during a specific situation. Thereafter, the recordings are used as a stimulus to help them recall their thoughts, emotions, ideas, etc., about the encountered situations (Consuegra et al., 2016; Rowe, 2014).

The interview guide was specifically designed for the current study based on various books and identified concepts, but these findings were not tested before starting the data gathering. However, fewer questions regarding the used coping strategies were included, which might have influenced the results. Nevertheless, saturation was reached, and results were found of the appraisal of roadway environment and infrastructure in ASD drivers.

A more thorough discussion of each category derived from the comprehensive understanding is provided below.

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Theme 1 – 3: positive and negative feelings while driving

Participants reported both positive and negative feelings while driving due to the roadway environment and infrastructure. It stood out that there is only a fine line between the roadway environment and infrastructure elements perceived as positive and the elements perceived as negative. Positive feelings could easily switch to negatives due to small infrastructural or environmental inconsistencies, others' actions, etc. When roadway environment and infrastructure were clear and guiding, it evoked positive feelings. An important factor herein relates to the concept of self-explaining roads in which the environment and infrastructure provoke the right driving behaviors (Castro, 2008; Walker et al., 2013) and thus creating predictability and clearness for ASD drivers. However, negative feelings appeared to be present to a greater extent. Studies have shown that the objective road situation does not always correspond with the perceived state of that environment on the part of the individual within it, and this could lead to inappropriate driving behavior (Theeuwes, 1994; Kaptein & Theeuwes, 1996; Walker et al., 2013) which could make ASD drivers stressed, frustrated, anxious and confused. Various other studies reported issues concerning the emotional experience of people with ASD while driving. For example, studies reported that ASD drivers felt less self-confident while driving (Lindsay, 2017), felt anxious about driving (Chee et al., 2015), and reported less positive and more negative attitudes towards driving (Ross et al., 2017). In the current study, various negative feelings were related to other roadway users. It is suggested that ASD drivers experience difficulties in understanding others' intentions, unexpected changes while driving (Cox et al., 2012), and interacting with other road users (Almberg, 2017). People with ASD experience context blindness and contextual sensitivity issues. They use the context less when giving meaning to a situation than non-autistic people (Vermeulen, 2015). However, contextual sensitivity is vital in understanding human behavior and actions (Zibetti & Tijus, 2005) and flexibility in problem-solving and reacting to unpredictable events (Kokinov & Grinberg, 2001). This could explain why participants reported difficulties predicting others' behavior and trusting other drivers. Respondents also described problems when unpredicted events occurred like detours. The current results coincide with findings from Ross et al. (2018). In that study, ASD respondents also reported difficulties with unpredictable situations, difficulties in violating traffic rules, etc.

Theme 4-6: situations that negatively affect driving experiences

Respondents all reported both social (e.g., inefficient application of traffic rules, rush, chaos created by other roadway users, etc.) and non-social (e.g., sound, lighting, driving in the dark, road signs, etc.) situations that complicated driving. People with ASD either encounter sensory stimuli more intense or less intense than neurotypical persons (Ben-Sasson et al., 2009). We suggest that these sensory difficulties might have affected how the participants in the current study perceive and cope with certain stimuli like lighting, noise, chaos, and rush. Feeley et al. (2015) suggested that ASD drivers are more easily distracted by disturbing elements besides the road (e.g., billboards, etc.) than other drivers, which was confirmed by our participants. Driving requires high-order executive functions to respond to unexpected and unpredictable situations (Wilson et al., 2018; Classen et al., 2013). People with ASD show various executive function problems like working memory, speed of information processing,

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selected and divided attention, hazard perception, etc. (Patrick et al., 2020), which might have influenced how our participants perceived situations. Even though our participants mentioned that they were easily distracted by disturbing elements while driving during the interviews, they also indicated that they experienced difficulties with noticing traffic signs that were not located within their central visual field. When comparing visual search patterns from ASD drivers with non-autistic peers, research showed that ASD drivers fixated and spent more time in the central visual field and had the tendency to focus less on relevant stimuli (e.g., direction signs, their speedometer) (Chee et al., 2019). This might arise from the weak central coherence they experience. People with ASD tend to focus more on details and not on the greater part because they process information slower and less efficiently, which complicates driving (Vanmarcke, 2017). Participants also reported that they got frustrated when other road users do not obey the traffic rules. In support, a study by Ross et al. (2018) showed that ASD drivers had good knowledge of the traffic rules. However, ASD drivers experienced difficulties when violating traffic rules, even if necessary. It did not only frustrated ASD drivers, but it also provoked anxiety. Furthermore, an on-road study by Chee et al. (2017) showed that despite a general underperformance of ASD drivers, they outperformed neurotypical peers in aspects related to rule-following. Moreover, a study by Daly et al. (2014) also showed that ASD drivers were more rule bounded.

Theme 7: Experience and automatization

The study participants deemed automatization while driving to be very important. If a behavior is not automated, higher demand of conscious attention during driving and maneuvering is required, which could exhaust the mental resources to cope with the critical demand of information processing in driving (Hatakka et al., 1999). Possibly, drivers with ASD need more time for this automatization process. Studies suggested that learning to drive is more difficult for people with ASD compared to NT peers (Cox et al., 2012; Cox et al., 2016; Ross et al., 2019). It is emphasized that novice ASD drivers need more lessons (Almberg et al., 2017; Ross et al., 2018), adapted training modules (Chee et al., 2015; Wilson et al., 2018; Ross et al., 2015), and shorter lessons (Ross et al., 2018) to reach the same driving level as their peers. Various authors suggest that specific training can enhance the driving performance of ASD drivers (Wade et al., 2017; Cox et al., 2017; Brooks et al., 2016) and that, after the learning phase, ASD drivers are as capable drivers as neurotypical drivers (Ross et al., 2019). This might suggest that experience and automatization are important factors in the driving behavior in people with ASD, as it is indicated that training can enhance their overall performance.

Theme 8 – 10: coping strategies

All participants reported the use of coping strategies when dealing with interfering roadway environment and infrastructure elements. Although the DSM-V (American Psychiatric Association, 2013) suggested that people with ASD show restricted and repetitive behavior patterns, participants indicated that they could adapt their behavior to a particular situation. Our findings confirmed this; all twelve ASD drivers reported that they adjusted their behavior to create predictability and eliminate irrelevant stimuli.

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The second identified and least used coping strategy is the use of alternative means of transport. Few other studies reported using alternative means to cope (Feeley et al., 2015; Curry et al., 2014). However, participants in these studies experienced certain difficulties in driving as a passenger or using public transport. They reported that they missed activities due to the unavailability of persons or public transport, getting to the station without help, or having difficulties with planning a public transport trip.

The last identified coping strategy concerned avoidance behavior. This is supported by Daly et al.'s (2014) research; their participants indicated that they avoided rush hour, bad weather, driving in the dark, and gave themselves voluntary restrictions on driving. The same coping strategy is found in multiple studies on older drivers. They self-regulate their driving behavior by avoiding certain situations like parking their car, driving at night or in the rain, etc. (Baldock et al., 2006; Conlon et al., 2017).

Policy and practical implications

Even though there are guidelines on developing highways, intersections, pedestrian facilities (walkways, sidewalks, and crosswalks), etc., there is still a lack of uniformity in the design of roadway environment and infrastructure. All participants reported this lack of uniformity as a factor that negatively influenced their feelings while driving. This demonstrates the need for a more autism-friendly driving environment. Participants in the current study made suggestions on making the environment and infrastructure more suitable for ASD drivers. All these suggestions are listed in table 4. Some examples are uniformity in traffic signs and traffic lights, better indicating a diversion, and using materials that do not make loud noises all the time. The policymakers could take these recommendations and ASD-specific characteristics into account and transform them into new guidelines and principles for roadway environment and infrastructure design, which will better serve the autism spectrum population. However, even though ASD is a common developmental disorder, it is recommended to conduct the current study in other groups such as neurotypical persons, people with ADHD, people with a mild intellectual disability, etc. By doing so, a design for all can be created from which many population groups can benefit.

During the interview, few participants mentioned that by listening to other people with ASD or by going to patient organizations, they learned new coping strategies (e.g., turning off the radio) or gained a better understanding of their behavior. Based on the current article's findings, awareness-raising in people with ASD regarding the issues they experience while driving and learning how to drive can ... It is recommended that in the future, peer support groups for ASD drivers are established, in which they can share their experiences and possible coping strategies about driving with their peers. As a result, they may experience more positive feelings while driving, and this might enable them to reflect more critically on the roadway infrastructure and environment while driving.

5 LIMITATIONS

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No triangulation was used to test the validity (i.e., through the convergence of information from different sources) of the data, researcher, theory, and methodology (Kuper et al., 2008; Carter et al., 2014). Only one researcher collected and analyzed the data. Two senior researchers have checked the analyses of the main researcher but have not independently done the analyses. To avoid the possibility of the influence of the own experiences and way of thinking of the researcher on the iterative process, we recommend that in the future, at least two researchers will analyze the data independently and thereafter compare their findings. However, the researcher in this study tried to minimize biases during the research process. For example, the interviewer was aware that some participants' communication skills might have influenced the researcher's degree of input during the interviews. As a result, the interviewer might have needed more personal interpretation when she analyzed the interviews of someone with more limited comminution skills, which can potentially lead to a bias. Therefore, the interviewer was constantly checking her findings with other members of the research team. Furthermore, all other quality criteria (e.g., credibility, transferability, dependability, and confirmability) were considered to avoid potential biases. The current study took place in a Belgian context, more specifically in Flanders. To determine the degree to which the results of the current study can be generalized or transferred to other contexts or settings (i.e., other countries and regions), follow-up studies need to be conducted in other regions. Interview guides should be adapted, so they represent the driving context of the targeted population. After obtaining the results, comparisons between various countries and regions can be made. Participants were recruited through criterion sampling to obtain a purposive sample. Therefore, this study results can be transferred to the ASD population in Flanders.

The current study included adults between 31 and 39 years of age, based on convenience sampling. This rather narrow age range does not meet the standard categories in terms of age, often distinguishing young adults, adults, and the elderly. However, this narrow age range is also beneficial as an age range cannot be too broad to reach saturation and be as representative as possible. Although age was not related to the current research aims, in future research, it can be relevant to understand and compare the appraisal of roadway environment and infrastructure in other age groups (e.g., young adults, elderly people, etc.) to investigate commonalities and differences in their appraisals. Based on the current findings, we also specifically recommend a follow-up study with novice ASD drivers. The current study participants reported that they still experienced difficulties while driving due to the roadway environment and infrastructure, even after having at least eight years of driving experience. However, automatization and their driving experiences helped them in coping with experienced problems. Since novice ASD drivers do not have the same level of experience and automatization as more experienced ASD drivers included in this study, it is important to assess how the interference of roadway environment and infrastructure might affect their driving experience and learning process, and how they can cope with any experienced difficulties.

Seven out of twelve participants also had another diagnosis besides autism; this might have influenced the results. However, research suggested that the comorbidity between attention deficit hyperactivity disorder (ADHD) and ASD has a real, relevant, and frequent occurrence (Gargaro et al., 2010). A systematic literature review suggested that approximately 17.4% of the ASD population has obsessive-

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compulsive disorder (OCD), and 16.6% have a social anxiety disorder (Bögels & Perrin, 2011). Therefore, we could conclude that our included population resembled the general ASD population. The gender balance in the current study might not reflect the general ASD population as the ratio is 4:1 (male-female). Baio et al. (2018) suggest that the general ratio is 2:1 (male-female). However, females with autism show increased social behavior, less repetitive behaviors than males, and are better at camouflaging their symptoms (Halladay et al., 2015). Therefore, we do not precisely know the current gender ratios. Nevertheless, saturation was reached, and in eight out of ten main themes, ten or more respondents confirmed the findings. Therefore, we conclude that the current gender rate might only have had a small influence on the results.

As mentioned before, the interview guide comprehensively assessed the primary research aim: 'the appraisal of ASD drivers on roadway environment and infrastructure.' The current study's secondary aim: 'identifying potential coping strategies used to deal with interfering roadway environment and infrastructure elements' was a little less deeply questioned. The majority of the questions in the guide were related to the first research aim. As a result, the second research aim shifted a little more into the background. However, a consensus was reached in the participants regarding the coping mechanisms. We, therefore, conclude that we were able to achieve both research aims.

Further research could focus specifically on the coping strategies used by ASD drivers to deal with interfering roadway environment and infrastructure elements. Although we conducted two pilot interviews to determine the quality of our interview guide for people with ASD, it would have been even better to develop the guide based on a focus group of ASD drivers. In a focus group, participants share their experiences and build on others' comments to add richness to a specific concept (Rennekamp, & Nall, n.d.). Therefore, future research could include such a focus group.

6 CONCLUSION

The current study gives a first indication of the appraisal of roadway environment and infrastructure by drivers with autism. All participants experienced both positive and negative feelings generated and influenced by roadway environment and infrastructure while driving. When driving in a calm and structured environment, ASD drivers similarly felt calm and safe. However, other road users, rush, and chaos could create pressure on the driving task. Lighting, sound, and driving in the dark were reported factors that might complicate driving. Most ASD drivers experienced stress, insecurity, frustration, fear, confusion, and unsafe feelings while driving. They attached great importance to clarity, logic, predictability, efficiency, consistency, and uniformity in traffic and traffic regulations. The drivers all indicated that they are very rulebound and that they get stressed as a result of others not following those rules. Most participants emphasized the importance of automatization and experience as it supported them in stressful situations. The ASD drivers described different coping mechanisms for interfering roadway elements: using alternatives to get around and avoiding certain situations.

To the best of our knowledge, no previous studies regarding the appraisal of roadway environment and infrastructure were conducted. Due to this study's novelty, more research on the topic is needed to

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confirm the current study's findings further. More target groups such as novice, young or older ASD drivers, other regions, and equal gender balance should be included as well to be able to generalize the results. Hopefully, the findings of the current study, together with future studies, can lead to a better understanding of the driving behavior and experience of individuals with ASD. Policymakers could take these recommendations and ASD-specific characteristics into account and transform them into new guidelines and roadway environment and infrastructure design principles.

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INFORMED CONSENT - All participants received and signed an informed consent before participating in this study.

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REFERENCES

Almberg, M., Selander, H., Falkmer, M., Vaz, S., Ciccarelli, M., & Falmer, T. (2017). Experiences of facilitators or barriers in driving education from learner and novice drivers with ADHD or ASD and their driving instructors. *Developmental neurorehabilitation, 20*(2), 59-67.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (5th ed.)*. Arlington, VA: Author.

AOTA. (2010). Driving and Community Mobility Service Provision Across the Lifespan and Modes of Transportation. *The American Journal of Occupational Therapy, 64*(6), 112-124

Ashwood, K. L., Gillan, N., Horder, J., Hayward, H., Woodhouse, E., McEven, F. S., Findon, J., … & Murphy, D.G. (2016). Predicting the diagnosis of autism in adults uring the Autism-Spectrum Quotient (AQ) questionnaire. *Psychol Med, 46*(12), 2595-2604.

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., ... & Durkin, M. S. (2018). Prevalence of autism spectrum disorder among children aged 8 years—Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *MMWR Surveillance Summaries, 67*(6), 1.

Baldock, M.R.J., Mathias, J.L., McLean, A.J., & Berndt, A. (2006). Self-regulation of driving and its relationship to driving ability among older adults. *Accident Analysis and Prevention, 38*, 1038-1045.

Baron-Cohen, S., 1995. *Mindblindness: An Essay on Autism and Theory of Mind*. The MIT Press: Cambridge, Massachusetts.

Baron-cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome / High-Functioning Autism, Males and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5-17.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of autism and developmental disorders, 39*(1), 1-11.

Bischop, H., Biasini, F., & Stavrinos, D. (2017). Social and Non-social Hazard Response in Drivers with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 47*(4), 905-917.

Bögels, S., & Perrin, S. (2011) Anxiety Disorders in Children and Adolescents with Autistic Spectrum Disorders: A Meta-Analysis. *Clinical Child and Family Psychology Review, 14*, 302-317.

Booth, R., & Happé, F. (2010). "Hunting with a knife and … fork': Examining central coherence in autism, attention deficit/hyperactivity disorder, and typical development with a linguistic task. *Journal of Experimental Child Psychology, 107*, 377-393.

Brooks, J., Kellet, J., Seeanner, J., Jenkins, C., Buchanan, C., Kinsman, A., … Pierce, S. (2016). Training the Motor Aspects of Pre-driving Skills of Young Adults With and Without Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 46*(7), 2408-2426.

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville A.J. (2014). The use of triangulation in qualitative research. *Oncol Nurs Forum, 41*(5), 545-547.

.

Castro, C. (2008). *Human factors of visual and cognitive performance in driving*. Boca Raton: CRC Press, Taylor & Francis Group.

Chee, D. Y. T., Lee, H. C. Y., Falkmer, M., Barnett, T., Falkmer, O., Siljehav, J., et al. (2015). Viewpoints on driving of individuals with and without autism spectrum disorder. *Developmental Neurorehabilitation, 18*(1), 26-36.

Chee, D., Lee, H., Patomella, A., & Falmer, T. (2017). Driving Behaviour Profile of Drivers with Autism Spectrum Disorder (ASD). *Journal of Autism and Developmental Disorders, 47*(9), 2658-2670.

Chien, Y., Hsieh, M., & Shur-Fen Gau, S. (2019). P50-N100-P200 sensory gating deficits in adolescents and young adults with autism spectrum disorders. *Progress in Neuropsychopharmacology & Biological Psychiatry, 95*, 1-8.

Classen, S., Monahan, M. & Hernandez, S. (2013). Indicators of Simulated Driving Skills in Adolescents with Autism Spectrum Disorder. *The Open Journal of Occupational Therapy, 1*(4), 1-13.

Conlon, E., Rahaley, N., & Davis, J. (2017). The influence of age-related health difficulties and attitudes toward driving on driving self-regulation in the baby boomer and older adult generations. *Accident Analysis and Prevention, 102*, 12-22.

Consuegra, A., Engels, N., & Willegems, V. (2016). Using video-stimulated recall to investigate teacher awareness of explicit and implicit gendered thoughts on classroom interactions. *Teachers and teaching: theory and practice, (), 1-7.*

Cowan, G., Earl, R., Falkmer, T., Girdler, S., Morris, S. L., & Falkmer, M. (2018). Fixation patterns of individuals with and without Autism Spectrum disorder: Do they differ in shared zones and in zebra crossings?. *Journal of Transport & Health, 8*, 112–122.

Cox, D., Brown, T., Ross, V., Moncrief, M., Schmitt, R., Gaffney, G. & Reeve, R. (2017). Can Youth with Autism Spectrum Disorder Use Virtual Reality Driving Simulation Training to Evaluate and Improve Driving Performance? An Exploratory Study. *Journal of Autism and Developmental Disorders, 47*(8), 2544-2555.

Cox, S., Cox, D., Kofler, M., Moncrief, M., Johnson, R., Lambert, A., Cain, S. & Reeve, R. (2016). Driving Simulator Performance in Novice Drivers with Autism Spectrum Disorder: The Role of Executive Functions and Basic Motor Skills. *Journal of Autism and Developmental Disorders, 46*(4), 1379-1391.

Cox, D., Owens, J., Barnes, L., Moncrief, M., Boukhechba, M., Buckman, S., … Wotring, B. (2020). A Pilot Study Comparing Newly Licensed Drivers With and Without Autism and Experienced Drivers in Simulated and On-Road Driving. *Journal of Autism and Developmental Disorders*, 1-11.

Cox, N., Reeve, R., Cox, S., & Cox, D. (2012). Brief Report: Driving and Young Adults with ASD: Parents' Experiences. *Journal of Autism and Developmental Disorders, 42*(10), 2257-2262.

Coyne, I. (1997). Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries?. *Journal of Advanced Nursing, 26*(3), 623–630.

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. Autism, 13, 215-228.

.

Curry, A., Yerys, B., Huang, P., & Metzger, K. (2017). Longitudinal study of driver licensing rates among adolescents and young adults with autism spectrum disorder. *Autism, 22*(4), 479-488.

Daly, B., Nicholls, E., Patrick, K., Brinckman, D., & Schultheis, M. (2014). Driving Behaviors in Adults with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 44*(12), 3119-3128.

Dickerson, AE., Molnar, LJ., Eby, DW., Adler, G., Bédard, M., Berg-Weger, M., … Truijulli, L. (2007) Transportation and aging: a research agenda for advancing safe mobility. *Gerontologist 47*(5): 578–590.

Ellaway, A., Macintyre, S., Hiscock, R., & Kearns, A. In the driving seat: psychosocial benefits from private motor vehicle transport compared to public transport. *Transportation Research Part F, 6*(3), 217-231.

Elwin, M., Ek, L., Kjellin, L., & Schröder, A. (2013). Too much or too little: Hyper- and hypo-reactivity in high-functioning autism spectrum conditions. *Journal of Intellectual and Developmental Disability, 38*(3), 232–241.

Elwin, M., Schröder, A., Ek, L., Wallsten, T., & Kjellin, L. (2017). Sensory Clusters of Adults With and Without Autism Spectrum Conditions. *Journal of Autism and Developmental Disorders, 45*, 579-589.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics, 5*(1), 1-4.

Feeley, C. (2010). Evaluating the transportation needs and accessibility issues for adults on the autism spectrum in New Jersey. In *89th annual meeting of the transportation research board, Washington, DC, 25*.

Feeley, C., Deka, D., Lubin, A., & McGackin, M. (2015). *Detour to the right place: A study with recommendations for addressing the transportation needs and barriers of adults on the autism spectrum in New Jersey.* Retrieved on 21 February 2017, from: http://cait.rutgers. edu/system/files/u18/y_Technical_Report_

Frith, U., & Happé, F. (1994). Autism: beyond "theory of mind. *Cognition, 50*(1–3), 115–132.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodka, N. & Cauraugh, J. H. (2010). Motor coordination in Autism Spectrum Disorders: A synthesis and Meta-Analysis. *Journal of Autism and Developmental Disorders, 40*, 1227-1240.

Fuld, S. (2018) Autism Autism Spectrum Disorder: The Impact of Stressful and Traumatic Life Events and Implications for Clinical Practice. Clinical Social Work Journal, 46, 210–219.

Fuller, R., & Santos, J.A. (2002). *Human Factors for Highway Engineers*. Emerald Group Publishing Limited: Bingley, West Yorkshire.

Gargaro, B., Rinehart, N., Bradshaw, J., Tonge, B. & Sheppard, D. (2010). Autism and ADHD: How far have we come in the comorbidity debate. *Neuroscience and Biobehavioral Reviews, 35*, 1081-1088.

Grandin, T., & Scariano, M. (2005). *Emergence: Labeled Autistic*. New York: Grand Central Publishing.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field methods, 18*(1), 59-82.

.

Halladay, A., Bishop, S., Constantino, J., Daniels, A., Koenig, K., Palmer, K., … & Szatmari, P. (2015). Sex and gender differences in autism spectrum disorder: summarizing evidence gaps and identifying emerging areas of priority. *Molecular Autism, 6*(36), 1-5.

Hatakka, M., Keskinen, E., Gregersen, N. P., Glad, A., & Hernetkoski, K. (2002). From control of the vehicle to personal self-control; broadening the perspectives to driver education. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(3), 201–215.

Hatakka, M., Keskinen, E., Gregersen, N. P., & Glad, A. (1999). *Theories and aims of educational and training measures. In S. Siegrist (Ed.),* Driver training, testing and licensing towards theory based management of young drivers' injury in road traffic, 40. Berne: Schweizerische Beratungsstelle.

Hill. E.L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review, 24*, 189-233.

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the autism-spectrum quotient (AQ): A study in Dutch population and patient groups. *Journal of Autism and Developmental Disorders, 38*(8), 1555–1566.

Kaptein, N.A., and Theeuwes, J. (1996). *Effecten van vormgeving op categorie-indeling en verwachtingen ten aanzien van 80 km/h wegen buiten de bebouwde kom* [Effects of road design on categorization of 80 km/h roads] (Report TM-96-C010). Soesterberg, The Netherlands: TNO Human Factors Research Institute.

Keskinen, E. (1996). Why do young drivers have more accidents? Junge Fahrer Und Fahrerinnen. Referate der Esten Interdiziplinaren Fachkonferenz 12–14 Dezember 1994 in Koln. Berichte der Bundesanstalt fur Strassenwesen. Mensch und Sicherheit, Heft M 52.

Kielhofner, G. (2006). *Research in Occupational Therapy: Methods of Inquiry for Enhancing Practice*. Philadelphia: Davis Company.

Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: Lessons from autism. *Philosophical Transaction of the Royal Society B: Biological Sciences, 358*(1430), 345-360.

Kokinov, B., & Grinberg, M. (2001). Simulating context effects in problem solving with AMBR. In V. Akman, P. Bouquet, R. Thomason, & R. Young (Eds.), Modeling and using context. Vol. 2116 of lecture notes in artificial intelligence. *Proceedings of CONTEXT 2001—Third international and interdisciplinary conference on modeling and using context,* Dundee, Scotland. Heidelberg, Germany: Springer Verlag.

Kuper, A., Lingard, L., & Levinson, W. (2008). Critically appraising qualitative research. *Bmj, 337*, 687–689.

Lindsay, S. (2017). Systematic review of factors affecting driving and motor vehicle transportation among people with autism spectrum disorder. *Disability and rehabilitation, 39*(9), 837-846.

Lindseth, A., & Norberg, A. (2004). A phenomenological hermeneutical method for reasearching lived experiences. *Scandinavian Journal of Caring Science, 18*(2), 145–153.

.

Maenner, M. J., Rice, C. E., Arneson, C. L., Cunniff, C., Schieve, L. A., Carpenter, L. A. et al. (2014). Potential Impact of DSM-5 Criteria on Autism Spectrum Disorder Prevalence Estimates. *JAMA Psychiatry, 71*(3), 292.

Mahjouri, S., & Lord, C.E. (2012). What the DSM-5 portends for research, diagnosis, and treatment of autism spectrum disorders. *Current psychiatry reports, 14*(6), 739-747.

Mikropoulos, T., Delimitros, M., Giantatzis, P., Iatraki, G., Stergiouli, A., Tsiari, A., & Kalyvioti, K. (2020). Acceptance and User Experience of an Augmented Reality System for the Simulation of Sensory Overload in Children with Autism. 6th International Conference of the Immersive Learning Research Network (iLRN 2020): Online, 86-92.

Morse, J. (1995). The significance of saturation. *Sage publications Inc, 5*(2), 147-149.

Myers, R., Bonsu, J., Carey, M., Yerys, B., Mollen, C., & Curry, A. (2019). Teaching Autistic Adolescents and Young Adults to Drive: Perspectives of Specialized Driving Instructors. *Autism in Adulthood, 1*(3), 1-8.

National Institute of Mental Health. (2020). *Autism Spectrum Disorder*. Retrieved on 29 January 2020, from: https://www.nimh.nih.gov/health/topics/autism-spectrum-disorders-asd/index.shtml

Palmer, C. J., Paton, B., Kirkovski, M., Enticoot, P.G., & Hohowy, J. (2015). Context sensitivity in action decreases along the autism spectrum: a predictive processing perspective. *Proc Biol Sci, 282*(1802), 1-9.

Patton, M. Q. (2002). *Qualitative research and evaluation methods (3rd ed.).* Thousand Oaks, CA: Sage

Poquérusse, J., Pastore, L., Dellantonia, S., & Esposito, G. (2018). Alexithymia and Autism Spectrum Disorder: A Complex Relationship. *Frontiers in Psychology, 9*(1196), 1-10.

Rao, S., & Gagie, B. (2006). Learning through Seeing and Doing: Visual Supports for Children with Autism. *Teaching Exceptional Children, 38*(6), 26-33.

Reimer, B., Fried, R., Mehler, B., Joshi, G., Bolfek, A., Godfrey, K., … Biederman, J. (2013). Brief Report: Examining Driving Behavior in Young Adults with High Functioning Autism Spectrum Disorders: A Pilot Study Using a Driving Simulation Paradigm. *Journal of Autism and Developmental Disorders, 43*(9), 2211-2217.

Remmington, A.M., Swettenham, J., & Lavie, N. (2012). Lightening the Load: Perceptual Load Impairs Visual Detection in Typical Adults but Not in Autism. *Journal of Abnormal Psychology, 121*(2), 544-551.

Rennekamp, R., & Nall, M. (n.d.). *Using Focus Groups in Program Development and Evaluation*. Retrieved on 31 January 2020, from: https://psd.ca.uky.edu/files/focus.pdf

Ross, V., Jongen, E., Brijs, K., Vanroelen, G., Beelen, C., Maltagliati, I., … Vanvuchelen, M. (2019). The relation between driving errors and executive functioning in intellectually able young novice drivers with autism. *Transportation Research Part F, 63*, 38-54.

Ross, V., Cox, D., Reeve, R., Brown, T., Moncrief, M., Schmitt, R. & Gaffney, G. (2018a). Measuring the attitudes of novice drivers with autism spectrum disorder as an indication of apprehensive driving: Going beyond basic abilities. *Autism, 22*(1), 62-69.

.

Ross, V., Jongen, E., Van Vlierden, K., Brijs, K., Brijs, T., Hens, R., … Vanvuchelen, M. (2018b). Process of learning to drive by young persons with autism: experiences of the young persons themselves, parents, and driving instructors. *Transactions on Transport Sciences, 9*(2) – 42-56.

Ross, V., Jongen, E. M. M., Vanvuchelen, M., Brijs, T., Brijs, K., & Wets, G. (2015). Exploring the driving behavior of youth with an autism spectrum disorder: A driver instructor questionnaire. In*: 8th international driving symposium on human factors in driving assessment, training and vehicle design*, 98–104.

Rowe, V.C. (2014). Using video-stimulated recall as a basis for interviews: some experiences from the field. *Music Education Research, 11(4),* 425-437.

Schaaf, R., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., … Kelly, D. (2013). An Intervention for Sensory Difficulties in Children with Autism: A Randomized Trial. *J Autism Dev Disord, 44*, 1493-1506.

Sheppard, E., Ropar, D., Underwood, G., & van Loon, E. (2010). Brief Report: Driving Hazard Perception in Autism. *Journal of Autism and Developmental Disorders, 40*(4), 504-508.

Sheppard, E., van Loon, E., Underwood, G., & Ropar, D. (2017). Attentional Differences in a Driving Hazard Perception Task in Adults with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 47*(2), 405-414.

Smith, L.E., Greenberg, J.S, & Mailick, M. (2012). Adults with Autism: Outcomes, Family Effects, and the Multi-Family Group Psychoeducation Model. *Curr Psychiatry Rep, 14(6)*, 732-738.

Smith, R. S., & Sharp, J. (2013). Fascination and isolation: A grounded theory exploration of unusual sensory experiences in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders, 43*(3), 891–910.

Silvi, C., Scott-Parker, B., & Jones, C. (2018). A Literature Review of the Likely Effects of Autism Spectrum Disorder on Adolescent Driving Abilities. *Adolescent Research Review, 3*(4), 449-465.

Stebbins, R. A. (2001). *Exploratory Research in the Social Sciences.* Thousand Oaks, California: Sage Publications.

Stewart, M., Russo, N., Banks, J., Miller, L., & Burack, J. (2009). Sensory Characteristics in ASD. MJM, 12(2), 108-111.

Suri, H. (2011). Available from Deakin Research Online: Purposeful Sampling in Qualitative Research Synthesis. *Qualitative Research Journal, 11*(2), 63–75.

Theeuwes, J. (1994). *Self-explaining roads: An exploratory study* (Report TNO-TM 1994, B-18). Soesterberg, The Netherlands: TNO Human Factors Research Institute

Thomas, E., & Magilvy, J. K. (2011). Qualitative Rigor or Research Validity in Qualitative Research. *Journal for Specialists in Pediatric Nursing, 16*(2), 151–155.

Ting Chee, D., YeungLeea, H., Patomella, A., & Falmker, T. (2019). The visual search patterns of drivers with Autism Spectrum Disorders in complex driving scenarios. *Journal of Transport & Health, 14*, 1-9.

Tomer, A. (2017). America's commuting choices: 5 major takeaways from 2016 census data. *Brookings.* Retrieved on 23 January 2020, from: https://www.brookings.edu/blog/the-

.

avenue/2017/10/03/americans-commuting-choices-5-major-takeaways-from-2016-census-data/

Top, D. N., Luke, S.G., Stephenson, K.G., & South, M. (2019). Psychophysiological Arousal and Auditory Sensitivity in a Cross-Clinical Sample of Autistic and Non-autistic Anxious Adults. *Frontiers in Psychiatry, 9*(783), 1-12.

Van de Velde, D., Bracke, P., Van Hove, G., Josephsson, S., & Vanderstraeten, G. (2012). How do men with paraplegia choose activities in the light of striving for optimal participation? A qualitative study, based on a phenomenological–hermeneutical method. *Disability & Society, 28*(5), 645-659.

Vanmarck, S. (2017). *Perturbed cortical hierarchies in Autism Spectrum Disorder: The case of high-level vision* (Doctoral dissertation, KULeuven, Leuven, Belgium). Retrieved on 18 October 2019 from https://limo.libis.be/primo-explore/fulldisplay?docid=LIRIAS1769060&context=L&vid=Lirias&search_scope=Lirias&tab=default_tab&lang=en_US&fromSitemap=1.

Vias institute. (2020). *Mobiliteitsbarometer: Januari 2020.* Retrieved om 18 February 2020 from: https://view.officeapps.live.com/op/embed.aspx?src=https://mobility-dashboard-pptx.s3-eu-west-1.amazonaws.com/Mobility+Barometer_both_JAN20.pptx

Vermeulen, P. (2015). Context Blindness in Autism Spectrum Disorder: Not using the forest to see the trees as trees. *Focus on Autism and Other Developmental Disabilities, 30*(3), 182–192.

Vermeulen, P. (2009). *Autism as context blindness.* AAPC Publishing: Kansas.

Wade, J., Zhang, L., Bian, D., Fan, J., Swanson, A., Weitlauf, A., … Sarkar, N. (2016). A Gaze-Contingent Adaptive Virtual Reality Driving Environment for Intervention in Individuals with Autism Spectrum Disorders. *ACM Transactions on Interactive Intelligent Systems, 6*(1), 3:1-3:23.

Walker, G., Stanton, N., & Chowdhury, I. (2013). *Self-Explaining Roads and situation awareness. Safety Science, 53,* 18-28.

Watanabe, T., & Rees, G. (2016). Anatomical imbalance between cortical networks in autism. *Scientific reports, (6),* 1-10.

Watkins, L., Kuhn, M., Ledbetter-Cho, K., Gevarter, C., & O'Reilly, M. (2017). Evidence-based Social Communication Interventions for Children with Autism Spectrum Disorder. *Indian J Pediatr, 84*(1), 68-75.

Wetton, M., Hill, A., & Horswill, M. S. (2011). The development and validation of a hazard perception test for use in driver licensing. *Accidental Analysis and Prevention, 43*(5), 1759–1770.

Whiting, L. S. (2008). Semi-structured interviews: guidance for novice researchers. *Nursing Standard, 22*(23), 35-40.

Wilson, N., Lee, H., Vaz, S., Vindin, P., & Cordier, R. (2018). Scoping Review of the Driving Behaviour of and Driver Training Programs for People on the Autism Spectrum. *Behavioural Neurology,* 1-17.

Wood, J. & Gadow, K. (2010). Exploring the Nature and Function of Anxiety in Youth with Autism Spectrum Disorders. *Clinical Psychology Science and Practice, 17*, 281 – 292.

.

World Medical Association. (2001). World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bulletin of the World Health Organization, 79*(4), 373.

Yan, D., Chee, T., Chung, H., Lee, Y., & Patomella, A. (2017). Investigating the driving performance of drivers with and without autism spectrum disorders under complex driving conditions. *Disability and Rehabilitation*, 0(0), 1–8.

Zalla, T., Sav, A. M., Stopin, A., Ahade, S. & Leboyer, M. (2009). Faux Pas Detection and Intentional Action in Asperger Syndrome. A replication on a French Sample. *Journal of Autism and Developmental Disorders, 39*, 373-382.

Zibetti, E., & Tijus, C. (2005). Understanding actions: Contextual dimensions and heuristics. In A. K. Dey, B. N. Kokinov, D. Leake, & R. M. Turner (Eds.), Modeling and using context. Vol. 3554 lecture notes in computer science. *Proceedings of CONTEXT 2005—5th international and interdisciplinary conference (July 5–8, 2005, Paris, France)*. Heidelberg, Germany: Springer Verlag.

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APPENDIX 1*:* INTERVIEW GUIDE (TRANSLATED FROM DUTCH)

Introduction and opening question

Introduction:

Introducing the researcher, explaining the study's aims and interview, explaining the protection of the participant's privacy, dignity, and rights, and asking them to sign an informed consent.

Opening question:

Can you introduce yourself? What are your hobbies, what do you do for work/education, what are your interests?

Introductory questions:

The interview will include questions regarding your experiences with certain elements of roadway environment and infrastructure while driving. Can you describe, in general, when you drive your car and for what occasions?

Roadway infrastructure are physical elements like the road itself, road markings, and elements to control traffic like a speedbump. Roadway environment contains everything that is located around the road. This can be the environment related to traffic like traffic signs and lighting. It also contains non-traffic related environments like buildings, trees, billboards along the street.

You now see a few photos of situations that you might encounter while driving. When you drive to work, and you come across these situations, how do you experience these?

Are there certain aspects that catch your eye, that stand out regarding roadway environment and infrastructure?

Are there certain aspects that cause difficulties while driving?

Are there certain aspects that help you while driving?

- What is the reason for experiencing these aspects like this?
- How do you cope with these aspects while driving?

Supporting questions regarding roadway infrastructure:

Can you think back to a moment when you drove to your grandmother? Imagine you driving on a road that is in bad condition. There are road cracks and holes; how do you experience this while driving?

Imagine that while driving to your work and a broad road turns into a more narrow road. How do you experience this road narrowing?

- Examples: narrow road, broad road, narrow road with parked cars, a broad road with parked cars, narrow/broad road with/without central and border markings.

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Can you think back to a moment when you were driving? How do you experience a speed bump or another obstacle on the road like a road flower box, a road narrowing, etc.?

Can you give me an example of a road where road marks are present and where not? How do you experience both roads while driving?

- Examples: road markings, pre-sorting, follow directions indicated by arrows or written on the road, triangular priority markings, walkway, cycling path, stops, bus, taxi, …

Can you think back to the last time you have driven? Were there curves/turns present on your route? When you are driving, and there are curves/turns, how do you experience this?

- Examples: Short turns quickly behind each other, one large turn, a turn with/without central and border markings, sharp turn, slight turn.

- What hinders you while driving?
- What is the reason that you experience it that way?
- How do you cope with these things while driving?

<u>Supporting questions regarding roadway environment:</u>

When you are driving, and there are large billboards placed next to the road, how do you experience this?

Do you experience this the same regarding trees and buildings next to the road?

- Examples: advertising with or without lighting, small or large trees, houses next to the road, restaurants, people next to the road.

Almost every road is lighted; this can be public lighting or traffic signs. When you drive past one of these, how do you experience this?

- Examples: temporary traffic light, orange flickering traffic lights, traffic lights above the road, traffic light next to the road, public lighting: standing poles next to the road lighting on houses.

What is your experience with traffic signs?

- Examples: warning signs (red triangles), priority signs, mandatory signs (blue), prohibitory signs (red rounds), standstill and parking, designation signs (city center, zone signs, driving direction).

Which aspects hinder or aid you at a crossroad?

- Examples: crossroad with priority to the right, crossroad with a priority road, crossroad with traffic lights, crossroad with 2, 3, 4, 5 roads, crossroad with a traffic island.

Every day, you hear on the radio that it is a busy morning and evening rush. At what times is the traffic less dense? How do you experience the traffic around you?

- Examples: trucks, other cars, cyclists.

- What hinders and helps you while driving?
- What is the reason that you experience it that way?
- How do you cope with these things while driving?

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Closure:

When I give you a scale from -10 to 10 where -10 stands for ‘complete negative influence,’ 0 for ‘no influence’ and 10 for ‘totally comfortable,’ how do you experience the influence from roadway infrastructure on your behavior?

- How do you experience the influence of roadway environment on your driving behavior?
- How do you experience the influence of the surrounding traffic on your driving behavior?

When I give you a scale from 0 to 10 where 0 stands for ‘totally uncomfortable’ and 10 for (totally comfortable), how comfortable do you feel in traffic?

Concluding question:

We talked about a lot of different subjects regarding the main theme. Are there still elements that you want to report regarding your experiences with roadway environment and infrastructure while driving?

Summarize the interview, thank the participant, and ask for feedback about the interview.

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