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Identifying meaningful user experiences with autonomous products: a case study in fundamental user needs in fully autonomous vehicles.

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Autonomous products (e.g., home cleaning robots, smart fridges, or autonomous vehicles) take over tasks that require time and effort from their users, redefining both the user roles and context around a product. Consequently, meaningful user experiences should be designed to overcome the risk of relegating humans to undesirable tasks and to take the opportunity of employing users' newly available time in contexts such as highly automated vehicles. Meaningful experiences are provided when fundamental user needs (i.e., universal needs that directly contribute to our wellbeing) are fulfilled. Nevertheless, designers face challenges in anticipating and fulfilling user needs related to autonomous products since autonomous technology continues evolving toward products that are not yet in existence. In this paper, we employ a co-creation workshop method to explore how the typology of thirteen fundamental needs can serve as a starting point to design meaningful user experiences associated with autonomous vehicles. Specifically, our goal is to understand how the typology of thirteen fundamental needs (e.g., autonomy, beauty, comfort…) could help in (1) identifying how deep user needs manifest themselves in a given context and (2) conceptualizing meaningful experiences with autonomous devices. In this aim, we elaborate on the challenge of designing meaningful non-driving-related experiences in fully autonomous vehicles, which could emerge in the future if driving tasks become obsolete. The results propose new clusters of activities and a scenario for each fundamental need and ultimately show that engaging with fundamental needs could be a valuable foundation for designing rich human interactions with future technologies.

Keywords: meaningful user experiences; fundamental needs; autonomous vehicles; non-driving related tasks

1 Introduction

In recent years, developments in information and communication technologies have enabled the incorporation of autonomy and autonomous features into a wide range of consumer products (Rijsdijk & Hultink, 2003). Home cleaning robots, automated lawnmowers, smart fridges, smart voice assistants, autonomous vehicles (AVs), or self-driving delivery robots are examples of such intelligent devices. A generally accepted definition of autonomy is, according to Beer et al. (2014, p. 77), “the extent to which a system can carry out its own processes and operations without external control,” which can also be explained as a balance between the “self-sufficiency” (i.e., the ability of self-government) and “self-directedness” (i.e., the required level of human intervention) of a system (Bradshaw et al., 2013). As shown in the examples and definitions given here, autonomy exists as a continuum, meaning that different levels and types of automation can be given to a system (Beer et al., 2014).

The inclusion of autonomy in a product transforms not only the roles of its users but also the context in which the product is used. As described by Beer et al. (2014), robots can perform sensing, planning, or action implementation tasks, either independently or in collaboration with the human user. Thus, autonomous products take over tasks that usually require time and effort from their users, and users are given the opportunity to participate in other activities (de Bellis & Venkataramani Johar, 2020) as well as new roles and demands in the interaction with the system (Beer et al., 2014). Besides, the use of autonomous products can also affect “how, when, and where” a task is performed (Janssen, 2018) or the meaning that a context acquires (Sciannamè & Spallazo, 2021). For instance, an autonomous car could be seen as a personal workplace or a living room (Kim et al., 2015). These transformations affect human experience and behaviour greatly (Beer et al., 2014) and thus create “novel consumer experiences” (de Bellis & Venkataramani Johar, 2020).

Prior work in the literature claimed that those novel interactions should be shaped so that meaningful experiences are created (Ajovalasit, 2022; Pillan, 2016). Meaningful experiences are those that hold significance for users, as defined by Ajovalasit et al. (2022) in their design-oriented interpretation of 'meaning.' We define these experiences as ones that, within the operational and social context of their use, encompass underlying 'reasons why' they hold value for an individual. This is relevant in the context of autonomous products to (1) overcome the risk of relegating humans to undesirable tasks once the systems take over activities that were previously carried out by humans and (2) take the opportunity of employing users’ newly available time in activities that were unconceivable before (de Bellis & Venkataramani Johar, 2020). For instance, in autonomous cars, drivers will be relegated to a passenger role, which could be an opportunity to engage in meaningful non-driving-related tasks (NDRTs).

Meaningful experiences help fulfill users’ fundamental needs (i.e., universal needs that directly contribute to our wellbeing), as claimed by Desmet and Fokkinga (2020) and Geiser and Kim (2021). We argue that human-centered design (HCD) approaches are suitable for creating meaningful experiences around a product (Ajovalasit, 2022); HCD begins with strong user research and employs input from users in every stage of the design process. Methods such as user observation, interviews, focus groups, or usability tests support design decisions. Nevertheless, concerning autonomous products, it is hard for designers to anticipate future user needs as the technology continues evolving, and many of the contexts that it enables do not exist yet. Consequently, user experience is designed as an evolution of the current manual tasks rather than as a new context where user roles and experiences are transformed. For instance, prior work in autonomous vehicles (Kim et al., 2015; Pfleging et al., 2016; Tang et al., 2020) identified non-driving-related tasks that can also take place in manually driven cars, failing to uncover the unique new experiences that could be provided within AVs.

In our view, the fact that deep human needs evolve more steadily than technology makes them a good starting point to bridge this gap (Kim et al., 2018; Friedman, 2017; Kim, 2016). Many scholars have investigated fundamental human needs, starting from Maslow to the current typology of thirteen fundamental needs by Desmet and Fokkinga (2020). Having a pre-defined set of user needs might be of help for designers in analyzing their manifestations in future autonomous contexts.

In this paper, we employ co-creation workshops to explore how fundamental needs can serve as a starting point to design meaningful user experiences with emerging autonomous devices. Specifically, our goal is to understand (1) how fundamental needs manifest themselves in a given context, and (2) how fundamental need typologies help conceptualize meaningful experiences with autonomous devices. In this aim, we elaborate on the challenge of designing meaningful non-driving-related experiences in fully autonomous vehicles (FAVs), which we address by involving potential users in the design of such scenarios. The choice of this context is motivated by the fact that, due to the current maturity of autonomous driving technologies, designers are not capable of asking users about their past experiences or to analyze them in a real context. The results obtained include new non-driving-related activities and scenarios, which conceptualize the car as a space that could provide unique experiences. Based on the insights gained, we reflect on the approach taken and propose implications for both design research and practice.

2 Background

2.1 The typology of thirteen fundamental needs

Meaningful user experiences in human-automation interaction are more likely to be achieved when automated systems adequately support user's goal-oriented tasks and evoke positive subjective feelings about the experiential qualities of the interaction (Desmet & Hekkert, 2007; Fokkinga et al., 2020; Hassenzahl et al., 2010). More importantly, the underlying mechanisms of goal-oriented activities are basic needs fulfillment as intrinsic motives that give rise to experiential states and behaviors (Sheldon & Gunz, 2009). To this end, we conceive that fundamental human needs can serve as guidelines to help us uncover opportunities in designing meaningful user experiences in the context of autonomous devices.

So far, various need typologies have been proposed to conceptualize the abstract phenomenon of basic human needs. One of the most well-known in psychology and motivation research is Maslow's Hierarchy of Needs (Maslow, 1943), which categorizes physiological and psychological needs into five levels. The self-determination theory (Ryan & Deci, 2017), on the other hand, specifically addressed three basic psychological needs (autonomy, competence, and relatedness). Despite the wild recognition and application of these two conceptual models, scholars in the fields of Human Computer Interaction and User Experience (UX) have claimed the necessity of a more nuanced and pertinent vocabulary to inform design-focused research and practice. In this background section, we review prior work that contributed to design-oriented need frameworks. Sheldon et al. (2001) proposed ten candidate needs that can contribute to the acknowledgment of satisfying events. In later research, Hassenzahl et al. (2010) revised the ten psychological needs to seven (including autonomy, competence, relatedness, stimulation, security, popularity, and meaning) to study the salience of needs in human-technology interaction and their correlations to positive affect.

To our knowledge, the most up-to-date and elaborated design-focused framework can be the typology of thirteen fundamental needs (see Table 1). This set of needs was developed by Desmet and Fokkinga (2020) in terms of an extensive review of existing typologies and theories of basic needs, together with the authors' reflections on academic and user-centered design practice in the past decade. Considering the (a) granularity (a concise yet detailed overview to inspire human-centered design initiatives) and (b) applicability (can be applied to different life domains and scenarios), we, therefore, adopted this typology as an overarching theoretical lens and conceptual basis to explore meaningful user scenarios in the interaction with fully autonomous vehicles.

Need Categories	Definitions
Autonomy	Being the cause of your actions and feeling that you can do things your own way, rather than feeling as though external conditions and other people determine your actions.
Beauty	Feeling that the world is a place of elegance, coherence, and harmony, rather than feeling that the world is disharmonious, unappealing, or ugly.
Comfort	Having an easy, simple, relaxing life, rather than experiencing strain, difficulty, or overstimulation.
Community	Being part of and accepted by a social group or entity that is important to you, rather than feeling you do not belong anywhere and have no social structure to rely on.
Competence	Having control over your environment and being able to exercise your skills to master challenges, rather than feeling that you are incompetent or ineffective.
Fitness	Having and using a body that is strong, healthy, and full of energy, rather than having a body that feels ill, weak, or listless.
Impact	Seeing that your actions or ideas have an impact on the world and contribute to something, rather than seeing that you have no influence and do not contribute to anything.
Morality	Feeling that the world is a moral place and being able to act in line with your personal values, rather than feeling that the world is immoral and your actions conflict with your values.
Purpose	Having a clear sense of what makes your life meaningful and valuable, instead of lacking direction, significance or meaning in your life.
Recognition	Getting appreciation for what you do and respect for who you are, instead of being disrespected, underappreciated, or ignored.
Relatedness	Having warm, mutual, trusting relationships with people who you care about, rather than feeling isolated or unable to make personal connections.
Security	Feeling that your conditions and environment keep you safe from harm and threats, rather than feeling that the world is dangerous, risky or a place of uncertainty.
Stimulation	Being mentally and physically stimulated by novel, varied, and relevant impulses and stimuli, rather than feeling bored, indifferent, or apathetic.

Table 1. A design-focused typology of thirteen fundamental needs as our study's theoretical lens and conceptual basis (Desmet & Fokkinga, 2020).

2.2 User experience in autonomous vehicles

Automated vehicles are those in which the real-time operational and tactical tasks required to operate a vehicle on-road partially occur without direct driver input (NHTSA, n.d.). Driver-car interactions are, therefore, directly related to the level of autonomy in which a vehicle operates (Meschtscherjakov et al., 2015; Rödel et al., 2014; Tang et al., 2020). Different classifications can be found in the literature to describe autonomy levels, "SAE levels of driving automation" (SAE, 2021), the most extended taxonomy (Coppola & Silvestri, 2019); it describes six discrete and mutually exclusive levels of automation, based on the role division of both the human driver and the system (see Table 2).

	LEVEL OF AUTOMATION	
	Level 0 – No driving automation	The driver performs all driving tasks.
Driver support	**Level 1 – Driver assistance**	Vehicle is guided by driver, but some driving-assist features may be included in the vehicle.
	Level 2 – Partial driving automation	Vehicle has combined automated functions, like acceleration and steering, but the driver must maintain control of all driving tasks and monitor the environment at all times.
Automated driving	**Level 3 – Conditional driving automation**	Vehicle can run autonomously, but the driver must be ready to take control of the vehicle at all times with notice.
	Level 4 – High driving automation	Vehicle is capable of performing all driving functions under certain conditions, but the driver has the option to take control of vehicle.
	Level 5 – Full driving automation	Vehicle is capable of performing all driving functions under all conditions, but the driver may have the option to control the vehicle.

Table 2. SAE Levels of Driving Automation as explained by Coppola and Silvestri (2019).

It is envisioned that primary driving tasks will become obsolete as automation levels increase (Krome et al., 2015; Pfleging & Schmidt, 2015). As claimed by Tang et al. (2020), *"automation will release drivers from the task of driving and allow them to undertake new activities that would not be possible in vehicles controlled manually"* (p. 1), meaning that drivers will be relegated to a passenger role and will be allowed to spend their time in new, non-driving-related tasks.

The emergence of NDRTs is expected to transform the passenger experience within automated vehicles and thus has attracted the interest of both industry and academia. Prior work in the literature aimed at identifying, describing, and categorizing the future activities that users would want to do in autonomous vehicles. For instance, Kim et al. (2015) and Tang et al. (2020) analyzed detailed NDRTs for level 3 of automation; the former had the goal of exploring the novel functionalities of a full-windshield display concept, while the latter was concerned with the required information and functions to support in-vehicle activities. Pfleging et al. (2016) also identified non-driving-related activities in AVs but with a focus on fully autonomous vehicles (level 5 of automation). Table 3 creates an initial overview of the NDRTs from the literature and the fundamental need that they would fulfil (in the typology of thirteen fundamental needs).

Fundamental need	Non-driving-related task (reference)
Autonomy	*Preparing food or drink (Tang et al., 2020); prepare meals (Pfleging et al., 2016).*
Beauty	-
Comfort	*Relaxing, changing clothes, looking around (Kim et al., 2015); changing clothes, looking outside (the vehicle) (Tang et al., 2020); watching out of the window (Pfleging et al., 2016).*
Community	*Social networking, caregiving (Kim et al., 2015); communicating with other vehicles (Tang et al., 2020); social media (Pfleging et al., 2016).*
Competence	*Manage schedule, office work (Kim et al., 2015); working/studying; trading stocks (Tang et al., 2020); office tasks, learning languages, knitting, playing instruments (Pfleging et al., 2016).*
Fitness	*Fitness, meal, snack, sleep, make up, washing, clean up (Kim et al., 2015); eating/drinking, sleeping/resting, personal hygiene, applying makeup, doing simple sports (Tang et al, 2020); eating & drinking, sleeping, cosmetics, fitness (Pfleging et al., 2016).*
Impact	-
Morality	-
Purpose	-
Recognition	-
Relatedness	*Video telephone, phone call, talking (Kim et al., 2015); making audio/video calls, talking to each other (Tang et al., 2020); talking to passengers, texting, calling, interacting with passengers (Pfleging et al., 2016).*
Security	-
Stimulation	*Multimedia, reading, web surfing, game, taking a picture, shopping, drinking, singing (Kim et al., 2015); listening to music, watching films and videos, playing on the mobile phone, playing board games, taking selfies, listening to/reading news, reading a book, online shopping (Tang et al., 2020); listening to music/radio, internet, reading, watching movies, playing (video) games, smoking, taking pictures (Pfleging et al., 2016).*

Table 3. User activities identified in previous studies, classified according to the typology of thirteen fundamental needs (Desmet & Fokkinga, 2020).

By analyzing Table 3, we highlight the following twofold ideas. First, most of the tasks that are identified in previous studies are activities that could also take place in manually operated cars (e.g., reading, web surfing, sleeping, making calls, changing clothes…). Autonomy will not only allow drivers to engage in those already existing activities but will also transform the context of what a car is (i.e., a mobile private space that could take any meaning). Therefore, we argue that there is still room to uncover new experiences and opportunities that could be provided within such a context. Second, the NDRTs listed do not satisfy all needs of the typology of thirteen fundamental needs; while some of the fundamental needs have associated activities that could contribute to their fulfilment (being 'fitness' and 'stimulation' the ones with the most examples), some other categories (i.e., beauty, impact, morality, purpose, recognition, and security) are still under-explored. In this study, we hypothesize that those fundamental needs could serve as guidelines to help designers uncover and conceptualize meaningful user experiences.

To address this gap, we propose to use the typology of thirteen fundamental needs as a starting point of the design process to explore how it could support the creation of meaningful user experiences for FAVs. As claimed by (Riener et al., 2022), "fascinating positive experiences will be the core of future premium mobility" (p. 209), and thus exploring the potential for a "great user experience" (p. 215) as well as the underlying human needs is necessary.

3 Method

To address the aim of this study, we designed a qualitative co-creation workshop (Sanders & Stappers, 2020) that we conducted with mixed groups of end users and novice designers. The workshop had two specific goals, regarding how the typology of thirteen fundamental needs could be used as (1) a trigger to identify tangible need manifestations in the context given (i.e., FAVs) and (2) a starting point to create meaningful experiences with autonomous devices. Workshops are a useful method to "reveal deeper levels of understanding" since "both tacit and latent knowledge" (p. 75) can be accessed when participants are engaged in 'making' activities (Sanders & Stappers, 2020). Previous work also used co-creation workshops in the context of autonomous vehicles and experience design (Kim et al., 2015; Lee et al., 2022) or mobility-related studies (Ebbesson, 2022; Gomez Beldarrain et al., 2022). Our study was approved by the Human Research Ethics Committee (HREC) of the university (reference number: 101355).

3.1 Participants

We used snowball sampling techniques (Patton, 2015) to recruit potential participants, which we reached using personal and professional contacts. The only selection criteria used was their willingness to participate and no incentive was provided for the participation. Two main types of participants can be distinguished: (1) most of them were master students with technical study backgrounds, and (2) a group of novice designers was also included (i.e., design master students). We decided to evenly distribute those novice designers among the workshops (see Table 4), under the assumption that they would favor a suitable creative atmosphere.

3.2 Co-creation workshop

In the co-creation sessions, we included sensitizing, idea generation, and co-design activities, after which we asked participant groups to present their outcomes. Every workshop took place in a university room and had a duration of 90 minutes. A single researcher facilitated the workshop, explained the exercises and theoretical explanations needed, and provided participants with design materials.

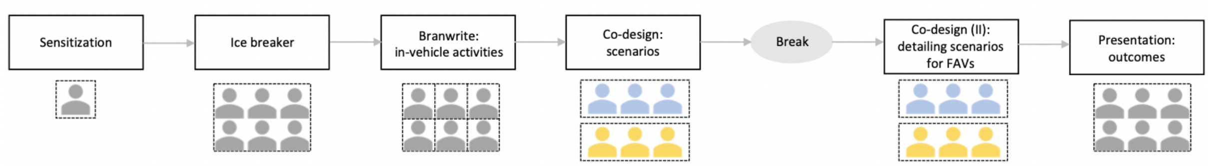

Figure 1. Workshop route and participant arrangements.

Prior to the workshops, we organized a pilot session with six additional participants. Based on the feedback received in the pilot (e.g., regarding the time allocated to each exercise, materials used, or the explanations given), we iterated the workshop route. Figure 1 illustrates the resulting workshop design. Below, we elaborate on the brainwrite and co-design activities, which constituted the fundamental components of the workshop:

- **Brainwrite on in-vehicle activities:** We handed out white, A4 sheets to the participants, with a fundamental need and its definition written. We asked them to think about different activities that can emerge in AVs in connection to every fundamental need. The brainwrite format meant that every participant, individually, allocated some time to write their ideas on every sheet, which they would later pass on to the next participant. This exercise favored an immersion in the topic, generated a vast number of ideas, and inspired participants with the ideas of others. The NDRTs that were elicited in this exercise were the base of the next activity.
- **Co-design of scenarios:** Participants were divided into two groups. Every group was given two fundamental needs and was asked to design a scenario for each of them. We provided drawing materials (e.g., markers, papers, etc.). The NDRTs that were generated in the brainwrite were used as a trigger. Scenario building is a useful method to visualize design goals, narratives, and interactions (Ebbesson, 2022), which reflect the discussions, assumptions, and preferences of participants.
- **Co-design (II):** We asked participant groups to adapt their two scenarios to three user interfaces (UIs) that could be used inside AVs for the provision of passenger experiences (i.e., ambient, graphical, and tangible UIs). Our goal was to obtain more concrete scenarios by encouraging them to further think about how their scenarios could be materialized in an in-vehicle environment.

3.3 Data collection and analysis

We collected data through three iterations of the 90-minute co-design workshops, which we conducted with a total of 18 participants. Eight novice designers participated and were evenly distributed among the sessions (Table 4). No other demographic or personal data were collected.

Workshop	Participants (Potential users; novice designers)	Fundamental needs
A	3; 3	Beauty, Competence, Security, and Fitness
B	4; 2	Morality, Relatedness, Stimulation, Purpose
C	2; 4	Comfort, Impact, Recognition, Autonomy, Community

Table 4. Overview of workshops and participants

Datasets belong to the brainwrite and co-design activities, including the physical outcomes of the exercises (i.e., the brainwritten in-vehicle tasks and the posters containing the scenarios) and the audio recording of the final presentations, that we used to keep track of the descriptions that the participants gave about their scenarios. We exported all ideas in the brainwritten materials to an Excel file; all audio recordings were transcribed, anonymized, and reviewed by one researcher.

We qualitatively analyzed the outcomes of the brainwrite through a thematic analysis-inspired approach (Braun & Clarke, 2012), meaning that, for every fundamental need, we clustered the activities in similar topics or attributes, which revealed patterns regarding the activities that the participants listed. A total of 346 constructs were generated, which resulted in 51 themes. Note that three to five clusters belonged to each fundamental need.

4 Results

Participants were engaged in the design and conceptualization activities that we proposed and collaborated closely with the groupmates that they were assigned. Some of them showed more hesitation at the beginning of the workshop, but we achieved an overall creative atmosphere once the participants familiarized with the typology of thirteen fundamental needs and embraced the creative tasks through vivid discussions, sketches, or text-based outlines. The novice designers that we included in the sessions favored this environment and sometimes led their groups in the co-creation tasks.

From the workshops, we identified new themes regarding non-driving-related activities. Participants focused on some of those themes and proposed concrete scenarios that were aimed at satisfying each of the associated fundamental needs.

4.1 Non-driving-related tasks

As a result of the brainwrite exercise, Table 5 condenses the themes of non-driving-related tasks that emerged as a manifestation of each fundamental need. Activity clusters are illustrated with some examples; note that, apart from activities, vehicle features were also listed by the participants.

Fundamental need	Themes	Examples of activities or vehicle features
Autonomy	*Having control over the driving car*	*"being able to intervene in the car driving"*
	Doing your own thing	*"taking a shower", "singing aloud", "listening to music", "running", "having divisions among passengers"*
	Limitless versatility	*"reconfiguration of space", "car that can go to the sea"*
Beauty	*Aesthetically pleasant interiors*	*"texture play", "mirrors"*
	Self-care	*"being able to prepare yourself"*
	Augmented landscape	*"windows that embellish the landscape", "windows that give descriptions about the landscape"*
	Outside view	*"glass roof to see the sky"*
Comfort	*Catering service*	*"delivery to your car by other cars"*
	Easy-going pastimes	*"gossip", "listen to music", "watch a movie"*
	Entertainment	*"dancing", "board game", "playing video games"*
	Calm and worry-free environment	*"dream, not thinking about anything", "stargazing with top window"*

	Ergonomic in-vehicle comfort	*"adaptable seat to your size", "massage seats", "good temperature, adjustable to person's shape"*
Community	*Fun social activities*	*"parties in the car", "board games"*
	Interacting with others outside the car	*"interacting with pedestrians"*
	Spatial configurations for social gatherings	*"facing each other", "dating", "talking to others in the car", "sofas, so that you can meet friends"*
	Calling others	*"easy to videocall"*
Competence	*Control over FAV*	*"be able to adjust the driving style"*
	Being able to work	*"possibility to isolate to work"*
	Ability to fix or manually drive the car	*"help to fix the car if needed"*
	Mental challenges	*"language practice partner", "car racing games"*
Fitness	*Healthy environment*	*"good air quality"*
	Mental wellbeing	*"meditation"*
	Nourished body	*"eating healthy", "measuring your biometrics", "being hydrated"*
	Avoiding physical fatigue	*"not sitting for too long"*
	Work out	*"working out machines", "fitness instructor"*
Impact	*Creating something*	*"writing a song", "making a company", "writing a blog"*
	Environmental impact	*"traveling in an electric car"*
	Contributing to traffic and the FAV	*"be able to influence car driving behavior", "fixing the car"*
	Contributing to others	*"babysitting", "giving a lecture"*
Morality	*Protecting the environment*	*"green energy"*
	Spiritual values	*"religion"*
	Social impact	*"inclusiveness", "collaborating with NGOs"*
	Transparency and privacy within the FAV	*"cameras for driving but not monitored inside", "no risk to injure other people"*
Purpose	*Reflecting on recent achievements*	*"feedback sessions"*
	Being aware of the FAVs navigation	*"knowing where you are at all times"*
	Using time efficiently	*"save more time and work more"*
Recognition	*Mutual recognition with the car*	*"the car checking in with passenger", "taking care of the car"*
	Being respected by others in the road	*"other vehicles respecting your space"*
	Connecting with people that appreciate you	*"calling your parents"*

Relatedness	*Relationship with vehicle*	*"the car talks to you", "the vehicle can imagine your preferences to make the travels customized"*
	Virtually meeting others	*"see friends on screen", "online blind dating"*
	Building intimacy	*"intimate moments", "not alone in the car"*
	Fun activity together	*"cook", "games", "exercise together"*
Security	*Secure driving*	*"no bumps, steady travel"*
	Protection against potential risks	*"have a direct communication with some service of emergency", "structural safety"*
	Home feeling	*"make you feel at home"*
Stimulation	*Visual stimulation*	*"lighting"*
	Auditory stimulation	*"relaxing audio"*
	Engaging entertainment	*"play instrument", "meditation", "exciting movie"*
	Ambient stimulation	*"temperature changes"*
	Stimulation of body	*"the seat changes position", "exercise", "tickling"*

Table 5. Themes of NDRTs (column 2) illustrated by some example activities and vehicle features (column 3)

4.2 Thirteen meaningful scenarios

Based on the final presentations by the participants, an overview of the scenarios is summarized in Table 6, which participants designed in two consecutive design rounds.

Fundamental need	Scenario
Autonomy	*The car will change its shape and configuration, considering where it is or where it is going.*
Beauty	*Users will be provided with new and exciting virtual views in situations in which outside landscapes are dull and boring.*
Comfort	*A very easy, hassle-free, and simple food delivery service will be created to receive food when traveling in an autonomous car.*
Community	*Users will cook in the autonomous vehicles, to later share their dishes and ingredients with people in other cars.*
Competence	*The car will train users in their driving skills, through a simulator-like environment.*
Fitness	*The car will be a personal fitness tracker, that will be able to track users' biometrics and will provide them with different stimuli to contribute to their health.*
Impact	*The car will be a space for users to spend quality time with their kids while traveling.*
Morality	*The car will be a space where users can pray.*
Purpose	*The car will be a therapeutic space that will help users envision their future objectives.*
Recognition	*The car will include a very advanced and modern in-vehicle video-calling system to allow users to connect with people that appreciate them.*
Relatedness	*The car will allow users to attend meetings virtually when they are not able to attend them in person to support human relations.*

Security	*The car will make users feel safe, welcome and under control inside of the vehicle in situations in which the outside environment is hostile.*
Stimulation	*a) The car will be a party room, where users can have fun by singing and dancing.*
	b) The car will be a meditation room, where users will be mentally stimulated.

Table 6. Meaningful scenarios associated with the thirteen fundamental needs. Note that participants presented two scenarios for the 'Stimulation' category.

As an example, to illustrate the depth of the descriptions given by the participants, we add two scenarios in the following lines:

- **Community:** Cooking was used as an inspiration that often serves to bring people together. In the scenario, users would cook in the autonomous vehicle, to later share their dishes and ingredients with people in other cars. Emphasis was made on the idea of "sharing": "You just end up having a bit of a potluck dinner within your vehicles, and you share ingredients or parts".
  It was suggested that auditory and light notifications could be used to communicate the state of the cooking task and that the car could take over some of those tasks. A robotic arm was considered a possible solution for this idea. The in-vehicle environment would be a changing one, meaning that "You might not have a cooking car the whole time"; popping-out stoves and tables shall be included. Finally, the outside of the vehicle could be used to communicate with other people: "So maybe it pops up red or green if you want to share something".
- **Purpose:** A therapeutic scenario was proposed that would help users envision their future destination through technology. The forward movement of the car would be used as a metaphor for users' life direction and the in-vehicle environment could be equipped with lighting and curtains that would be used to create an intimate environment for the user. Virtual Reality glasses could also be provided so that the user could experience this through a virtual environment. Finally, a massage chair could enhance users' relaxation.

5 Discussion

5.1 Reflection on the approach taken

In this study, we used the typology of thirteen fundamental needs (Desmet & Fokkinga, 2020) to frame the activities of three co-creation workshops, where participants were guided in the design of meaningful experiences for fully autonomous vehicles. Below, we develop reflection on the utility of the approach taken to (1) identify tangible manifestations of the fundamental needs, and (2) conceptualize possible meaningful experiences in autonomous cars.

First, based on the results of the brainwrite activity (Table 5), we demonstrate that the thirteen fundamental needs typology can be used to trigger a deep understanding of need-fulfilment oriented user experiences in FAVs. Participants were guided to consider some of the basic needs that they might not have considered in the context of AVs (e.g., recognition, morality, or impact), thereby identifying potential activities that could be implemented. In sum, those activities appeared more diverse and original than the non-driving-related tasks proposed in prior work (Table 3). For instance, the category Fitness included not only meal, sleep, and personal hygiene tasks (also found in prior work, Table 3) but also "being able to move after some time inside the car", "the car measuring one's biometrics", or "providing silence to passengers" (Table 5). If we compare the thirteen categories, we evidence that some of the activities are mentioned more than one fundamental need (e.g., "meditation" was mentioned in fitness, morality, and stimulation); this might suggest that participants did not adhere to the definitions strictly or that an activity might potentially be able to satisfy more than one fundamental need in a certain context.

Second, by analyzing the thirteen scenarios that were created by the participants, we could say that new meanings were given to the FAV. Rather than depicting ordinary tasks that users could do while being driven, the car was conceptualized as a space that could provide unique experiences (e.g., "the car will be a therapeutic space"). We argue that this was possible because participants were focused on exploring and fulfilling the fundamental need they were designing for, which made other boundaries (e.g., feasibility of the concept) secondary. While prior work identified activities that are linked to how we currently understand cars, our approach allowed users to imagine how their inner needs could be satisfied in such an environment. In this case, the need typology can not only support the participants in redefining the functional use of the car but also broaden the understanding and conceptual framing of the mobility space.

Furthermore, we propose that people may hold different hierarchies of need gratification for the same activity because the underlying motivations may differ for each individual. This might lead to different degrees of acknowledgment or appreciation of 'meaningful experience' that can be achieved in such context. Overall, we recognized that the theoretical frame that the typology brought was helpful for considering all fundamental needs as equally relevant starting points for design, which fostered creativity and uncovered new opportunities and narratives within the given mobility context.

5.2 Implications: fundamental needs in the design of meaningful autonomous interactions and experiences

Autonomous products introduce new paradigms in the user roles and contexts that surround them and therefore, meaningful user experiences should be created to avoid relegating humans to undesirable tasks, as well as to employ users' newly available time in worthy activities. This is challenging for designers since they oftentimes need to envision future use cases with technology that is not ready yet, which makes understanding human experience or involving potential users in the design process a hard task. In this paper, we explored how using an existing typology of human needs (i.e., typology of thirteen fundamental needs) can support the design of such emerging and untapped experiences.

The results suggested that employing the typology of thirteen fundamental needs in the design of future autonomous experiences could be helpful in considering all categories of fundamental user needs, fostering creative idea generations, and imagining how deep human needs could be satisfied in a proposed design context. Therefore, the typology could support designers in giving new meanings to future technology and ensuring that user needs are also met in new products and functionalities. We acknowledge that other existing basic human need frameworks might also be suitable for alternative contexts (for instance, the business-oriented framework by Diller et al., 2005).

In the context of autonomous driving experiences, the design-focused need typology provides designers with a holistic and nuanced vocabulary to identify challenges and opportunities in two main directions: (1) strengthen the primarily addressed needs in the current use scenario, such as security, comfort, and stimulation; (2) integrate possibly neglected, overlooked, or undermined needs in present use scenario, such as morality, purpose, and impact.

Our main contribution is to experiment with this approach through co-creation workshops. Specifically, we included the typology as a trigger material in a brainwrite activity and as a supporting framework in the co-design of in-vehicle experiences with FAVs. While the brainwrite was an inspirational exercise where considerable amounts of ideas had to be generated, the co-design workshops aimed at detailing those ideas into concrete scenarios; thus, the typology was used as a support for both diverging and converging tasks. For future design practice, we would recommend using the typology as a theoretical guide in the different stages of the design process, either as user research or design material. We suggest that beyond simple design activities with potential users (e.g., brainstorming), including the framework in further qualitative research methods (e.g., interviews, focus groups, or observational studies in simulated environments), will provide more solid and generalizable results on the meaningful experiences to be designed.

5.3 Limitations of the study

From an explorative approach, our research offers preliminary evidence to substantiate how the typology of thirteen fundamental needs could support the design of meaningful experiences with emerging future technology. Yet, there are some limitations to consider. First, the research is limited by the context of fully autonomous vehicles and non-driving-related activities. Future research should also consider other autonomous products or processes that might not offer such versatility to satisfy different fundamental needs. Second, the workshop route that we proposed did not fully cover the entire design process but purposely emulated some design activities of an early conceptualization stage. Future studies could be focused on the usefulness of the approach in a longer-term design challenge. Additionally, it needs to be pointed out that the participants were quite homogeneous and mostly belonged to a young and technology-savvy demographic group. Thus, the results may only reflect the needs of that specific population. Future research might include other types of participants to see if the thirteen fundamental needs serve comprehensive user research purposes.

As a next study, we propose to explore the use of fundamental needs not only to understand users, but also to support designers in designing in a real context; we would like to inquire about the practicality of the tool for designers, design researchers, and innovation managers to understand the implications of automation in the users they are designing for.

6 Conclusion

In this research, we explored ways that a typology of human needs could guide the design of meaningful autonomous experiences. Specifically, our study examined the usefulness of the typology of thirteen fundamental needs by Desmet and Fokkinga (2020) to (1) identify manifestations of deep user needs in future FAV contexts and (2) conceptualize meaningful user experiences.

The outcomes of the study comprise themes regarding NDRTs and a set of thirteen meaningful scenarios for fully autonomous vehicles. The findings shed light on how the design-focused need typology provides designers with a holistic and nuanced vocabulary to identify challenges and opportunities in two main directions: (1) strengthen the primarily addressed needs in the current use scenario; (2) integrate possibly neglected, or undermined needs in present use scenario. The identified thirteen fundamental needs within the future mobility context here can assist designers, researchers, and managers in taking the step to design meaningful user experiences and interactions with AVs.

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