Evaluating the Impact of Decals on Driver Stereotype Perception and Exploration of Personalization of Automated Vehicles via Digital Decals

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ABSTRACT

Traffic behavior and its perception is shaped by various factors such as vehicle color or size. Decals are used to express information about the owner's beliefs or are intended to be funny. In the future, with external displays on (automated) vehicles, individualized customization could be even more pronounced. While some research looked at the messages these decals convey, it is unclear how these decals influence the perception of surrounding drivers on the operator of the vehicle. We gathered data on decals in 29 cities in 8 countries. A thematic analysis unveiled 17 dominant themes among decals. Subsequently, we investigated effects of decals of 9 supra-regional common themes in an online study (N=64) finding that participants attributed different characteristics to the driver of a vehicle with a decal based on the type of decal and the participants' country of origin. Additionally, a Virtual Reality study (N=16) revealed diverse opinions on future usage of such personalization options.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; *Interaction techniques.*

KEYWORDS

External communication; decals; decals; personalization; shared mobility; interface.

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1 INTRODUCTION

Humans tend to create emotional bonding with objects such as their vehicles [27, 29, 45]. This leads to the individualization both inside and outside the vehicle, e.g., via decals. In 2016, in a survey among 6000 Americans, 8.4% reported to own patriotic decals [16]. The vehicle appearance leads to the formation of expectations on the driving behavior and even attribute person-like traits [64, 65]. It was found that model [15], shape [2, 64], and color [15] influence these expectations. However, people are accurate in estimating the real speed of vehicles despite these expectations [32]. This is important as it provides clues to other traffic participants and, therefore, helps to adjust their driving style. While some research has looked into the messages conveyed by some of the exterior individualization options such as decals [13, 20, 21], the impact these have on the expectations of other traffic participants is unexplored. It is also unexplored whether such a personalization option would be desirable with automated vehicles in the future through possibly attached displays. Therefore, we employed a three-step approach as follows: To determine the relevance of today's personalization, we first gathered data on decal usage. Then, we determined the effects of these decals on stereotype association in an online study. Finally, to determine whether such decals could still be relevant with automated vehicles, we conducted a Virtual Reality (VR) study where participants were able to employ static and moving "digital decals" to the attached displays.

We collected data on decal usage in **29** cities in **8** countries. Based on this data, we categorized decals into **17** categories. We conducted a user study via MTurk in Germany, India, and the USA (N=64) to investigate associations between decals and the expectations the human drivers have based on these. Participants attributed different characteristics to the driver of a vehicle with a decal based on the attached type (e.g., in the USA, lower age was attributed with a "My Family" decal compared to no decal). Additionally, effects were

not uniform across countries and the same decals led to different attributions in the German, Indian, and US samples.

In the future, ownership and usage of (automated) vehicles could change from personal ownership to ride-sharing models. Therefore, personalization options such as decals could become unfeasible. To evaluate potential usage patterns and preferences, we let *N*=16 people explore possibilities of a vehicle with attached displays and alter the shown "digital decals" in a VR study and asked them about their thoughts on personalization possibilities arising from externally attached displays. This concept leans on the scenario "Allowing Social Expression" of the "social car"' concept, for example, by Schröter et al. [54, 55] who compared the social car with the web where "users of today willingly and joyfully share personal information such as current mood, trip destinations, etc" [54, p. 109]. Most participants stated some doubts about the relevance and usefulness of such "digital decals", however, six participants clearly stated wanting to use this personalization possibility. Such personalization could become a contributing acceptance factor for shared-mobility.

Contribution statement: This work contributes findings regarding the prevalence of decals in 29 cities in 8 countries. Additionally, insights into associated stereotypes in the USA, India, and Germany are provided. For example, in the USA, a driver with a "My Family" decal is rated significantly younger, more cautious, more feminine, more dawdler, and safer than without the decal. In a subsequent VR study (*N*=16), the idea of "digital decals" as a potential replacement for decals in shared-ride automated mobility was explored, and first insights on potential future usage of these are provided. While all participants found that such decals can be distracting, approximately half still definitely wanted to employ them in the future.

2 RELATED WORK

We present an overview of the small research field on decals and look into factors that influence the perception of vehicles and the stereotypes associated with specific vehicle characteristics.

2.1 Decals

Noble and Baldwin [49, p. 87f.] suggest that "in appropriating objects, we are not simply personalizing them, [...] we are personalizing and subjectifying ourselves, pursuing our own 'distinction'."This statement is transferable to decals as a means to personalize vehicles. Doyle and Tranter [20] split the work of the decal research field into three foci: (1) Identification of groups [66], (2) focus on slogan and support decals (with special emphasis on national decals [4, 7, 36]), and (3) a focus on emotional, humorous or offensive decals [46, 57]. Doyle and Tranter [21] also examined decals at the Gold Coast, Australia in 2014, focusing on visual jurisprudence. In addition to being a mode of individualization, they claim that decals are *lawful* through expressing formal (flags) and other core jurisprudential concepts (friends and enemies; ouroboros of rights; critique). Our work builds upon the 16 categories employed by Doyle and Tranter [21]: Aggressive nationalism, nationalism, assertive female, flower, animal, consumer brand, hobby/sport, humorous, media station, my family, nonsense, offensive, political, religious/spiritual, school, and sexual. A search on Google with the keywords `bumper sticker fine` (bumper sticker being a synonym of decal) on the 25th of November 2019 revealed that more such incidences happened [31, 47]. Finally, Turner et al. [60] summarize their naturalistic studies that aggressive stimuli (such as aggressive decals) could provoke aggressive responses such as increased horn-honking.

Several works target certain countries such as the USA [46], Lagos and Ota [7], Israel [4], Kuwait [13], Jordan [34], and Turkey [59]. Newhagen and Ancell found in the suburbs of Washington D.C. that decal usage and tone varied with social status, race, and income [46]. Decals were mostly used in low-income households regardless of race. For high-income, the race affected the decal's tone with white households having a more positive tone. Chiluwa [7] collected 73 religious vehicle decals in Lagos and Ota, between 2006 and 2007 (97% Christian, 3% Muslim). Three categories of decals were found: *Social vision*, *Individual/group identity*, and *Reaffirmation of faith*. In Nigeria, decals seem to act as "a significant medium for expressing their loyalty and commitment to institutional assumptions and practices" [7, p. 384]. Bloch [4] reviewed political decals in Israel. She claims that in today's society, the individual has little chance to display one's opinions via a mass medium. She stresses the importance of vehicles in Israel's culture and mentions the high taxes as a factor in making the vehicle a status symbol. She cites Fiske, who claimed "A car is not just transport, but a speech act" [24, p. 34]. Dashti [13] investigated general attitudes towards decals of Kuwaitis. For this, they developed a questionnaire including 17 items. In general, Kuwaitis displayed a dislike of decals. Kuwaitis believe such decals not to be useful in any sense or to cause car accidents. Jaradat [34] focused on the themes of decals in Jordan and found no political decals, constituting a taboo in the country. Themes found were: lessons of life, challenging or warning other drivers, funny notes about social issues, religious sayings, treating the car as a female, the driver's low economic status, love and treachery, the prestigious status of the car, envy, nicknames for the car or the driver, irony, and English sayings. Tekeş et al. [59] used decals to elicit whether group membership shape evaluations of other traffic participants in Turkey. For this, they equipped a Renault Megane 2007 with decals on the rear bumper, on the windshield, and one hung on the rear-view mirror. Photographs were taken to show the participants. The authors used decals to demonstrate in-group and out-group affiliation. *No decals* were used as control condition. After showing the photographs, participants had to rate the driver of the shown vehicle on various dependent variables (e.g., on the Mini Driver Behavior Questionnaire (Mini-DBQ) [42]). Visualization of belonging to the in-group resulted in favorable assumptions of the driver, whereas belonging to the out-group led to being rated as being significantly worse in various variables, e.g., in driving more aggressively and with more errors.

2.2 Factors Influencing the Perception of Vehicles

Giblett suggested that the vehicle is a communication medium [28]. Some research in the field of *Legal and Criminological Psychology* has looked into the perception of vehicles and the associations thereof. Stereotypes of people who own the vehicle and their driving behavior are associated with the appearance of the vehicle itself [14, 15]. In their first experiment, Davies and Patel [15] found

driver, *vehicle*, and *colour* to be aspects constituting motoring stereotypes. The Citroen 2CV was rated the least aggressive while the Ford Escort XR3i was rated most aggressive (followed by the BMW 3). For the color, beige (followed by green) was rated least aggressive. Red and black were rated most aggressive. In terms of driver, older adults were rated least aggressive, the older female adults being reported less aggressive than the older male adults. Young males were rated most aggressive, followed by middle-aged males. Davies and Patel [15] also report that in their second experiment, the speed estimation varied significantly between the green Citroen 2CV driven by an older man and the red Ford Escort XR3i driven by a young male, the latter was rated faster despite both vehicles drove equally fast. In the constructed scenario of a crash between a young man driving a red Ford Escort XR3i (perceived as highly aggressive) and an older male adult in a green Citroen 2CV (perceived as little aggressive), it was objectively unclear as to who was to blame for this accident. Judges still attributed blame of the crash significantly more to the red Ford Escort XR3i driven by a young male. The authors conclude in their discussion that their experiments "appear to demonstrate that, first, men and women, drivers and non-drivers, share stereotypical notions about the relative aggressiveness of different drivers and the colors and types of car they drive" [15, p. 58]. In the following experiments, Davies [14] found that actual speed estimation is accurate when watching videos of cars being driven and stereotypes are not influencing this estimation. However, asked about the video one day later, the stereotypes seem to influence the recalled speed estimation, letting a red car being estimated faster.

3 OBSERVATIONAL STUDY

We used manual data collection in 29 cities around the world to collect data in parking lots. The collected data were: number of vehicles with decals and photographs thereof. We reached out to numerous colleagues and friends for help. We sent an e-mail including a description of our research goal and the data collection method. This description instructed them to, when on a parking lot, count 100 vehicles and take a picture of the rear side when one or more decals are present. No constraints regarding types of parking lots (e.g., supermarket, university, residential) were imposed. As only known colleagues and friends contributed data, we were confident in the submitted data and could rule out image submissions from sources like the Internet. In total, we were able to collect data in **29** cities in **8** countries (see Table 3). To find categories within the collected photos of decals and to gather information about their sizes and position, we analyzed each picture.

3.1 Procedure

We used Open and Axial Coding for the analysis. The coding was done by the first and third author. As a starting point, we used online retailers' categories of decals and categories found in the literature.

To find categories used in online stores selling decals, we employed the term `car decals shop` in the Google-search. The first three websites were then screened for decal categories in 2020. The websites are https://www.carstickers.com/products/stickers/ (80 categories), https://www.topdesignshop.de/AUTOAUFKLEBER-auto-aufkleber/ (7 categories) and https://autoaufkleber24.de/ (28 categories).

In a semi-structured process, the first and third author assessed the categories with regards to similarities and distinction. The found distinctions and similarities were then used to combine or split previous categories. We argue, for example, that aggressive nationalism and nationalism are a subset of a political view, therefore, we combined these. Through discussions, we ended up with a first draft of **19** categories. The found decals were then categorized with these. We found no decals for the categories *sexual* and *military*, therefore, we excluded these, resulting in **17** categories.

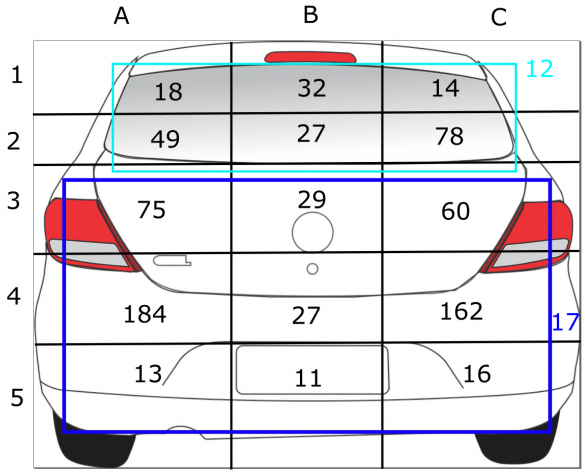


Figure 1: Visualization heatmap points for decal location.

We also categorized the found decals with respect to *size*, *position on the vehicle*, and *number of decals per vehicle*. For the size, we chose the levels *small* ($<\approx 10cm^2$), *medium* ($>\approx 10cm^2 and <\approx 100cm^2$), and *large* ($>\approx 100cm^2$). For the position on the vehicle, we employed a grid as depicted in Figure 1, resulting in 15 locations. We added the three locations *window* (turquoise), *lower body* (blue) and *complete* as some decals cover the entire rear or window. The categorization was done by the first author. When categorization was unclear due to unknown symbols or text, the third author was consulted and a *Google reverse image search* was employed.

3.2 Results

In total, we evaluated 3970 vehicles and categorized **842** decals on **664** vehicles (see Table 3).

Size of decals: Most decals were of medium size (419; 49.76%). Small decals were the second most common (313; 37.17%). 110 decals were coded as large (13.06%). The visibility of small and medium-sized decals is rather low in a high-speed traffic scenario. However, common decals such as "Baby on board" are highly visible due to their characteristic shape.

Number of decals per vehicle: A large majority of vehicles had one decal (540, 81.3%). 85 vehicles (12.8%) had two, 30 (4.5%) had three decals. Two vehicles had four, four had five, and two had seven decals (M=1.27; SD=0.68).

Position on Vehicle: The distribution of decals on the rear side of the vehicle can be seen in Figure 1. Most decals are located in the squares A4 and C4. These are especially *Brand* decals of the retailers.

Decal categories: We used a final set of **17** categories shown in Table 1 with at least one example. Most of these categories have some kind of **affiliation** as a major theme (e.g., sports, religion, nationalism). We distinguish *Brand*, *Fandom*, and *Advertisement* as follows: *Fandom* is, for example, about brands which are not about cars. *Advertisement* clearly provides contact information of the company. *Brand* combines the remaining company-related decals, including the decals displaying information about the retailer of the vehicle.

Ambiguity: Some decals were ambiguous. For example, a decal of an elk (see Table 1) was categorized into the category *wildlife*, however, one could also express affection towards Scandinavian countries [23].

4 STUDY ON DECAL-BASED PREJUDICE

To evaluate the impact of the decals on the perception and expectations of other road users, we conducted an online study in **3** countries (USA, Germany, and India). We chose the most frequent decal of each category as a representative (see Table 1). This study was guided by the research question (RQ): *RQ1: How do decals influence the perception and expectations of car drivers regarding the MDSI factors [58]?*

4.1 Procedure

First, a demographic questionnaire was conducted. Each participant was then asked to rate an imagined driver of a black VW Golf on various factors described in Section 4.3. Afterward, the representative of each decal category was shown along with the message "Please describe your impression of an (imaginary) black VW Golf with this decal on the back by selecting the appropriate options." A VW Golf was chosen based on its high perceived correspondence with demography in Germany [44]. A VW Polo, a somewhat similar-looking model, was also rated with medium aggressiveness [15]. The color black is highly prevalent in Germany [17] and associated with a medium risk of crash [26]. For internal validity and due to the lack of similar medium aggressive models, the black VW Golf was used in all three countries. The order of the decals was randomized. After all **9** categories, participants were asked to fill out the Mini Driver Behavior Questionnaire (Mini-DBQ) [42]. A session lasted approximately 15 min. Participants were compensated with € 2.

4.2 Driving Style

Taubman-Ben-Ari et al. [58] constructed and validated the multidimensional driving style inventory (MDSI)—scale. They found eight distinguishable factors: dissociative, anxious, risky, angry, high-velocity, distress-reduction, patient, and careful driving styles. West et al. [63] developed the Social Motivation Questionnaire, which included two aspects of driving style: *driving speed* and *driving deviance*. More technically, driving style was described using factors such as acceleration profiles, jerk, speed, engine rotational speed, distances to other cars, speed during lane changes make up the driving style [33, 37]. Eboli et al. [22] and Johnson and Trivedi [35] described the driving style more abstractly: they only differentiate between aggressive vs. cautious [22] or aggressive vs. non-aggressive [35]. Jachimczyk et al. [33] propose to use the measurements of acceleration and deceleration to assess the driving style. Based on these, the driver is classified into the classes calm, ordinary, or aggressive. More generally, the two main dimensions of interpersonal relationships are *friendly–hostile* and *submissive–dominant* [1]. This is also reflected in the described driving style assessments (e.g., patient, careful, aggressive).

4.3 Measurements

For **9** categories (excluding *Sports*, *Education*, *Places*, *Associations*, *Humorous*, *Advertisement*, and *Other* as these are inherently different based on geographical location; e.g., local sport teams are probably unknown in other countries), a representative was chosen based on the frequency of occurrence (first example in Table 1) and the unambiguity of the classification. According to the Section 4.2, we asked participants for their estimation of the MDSI factors [58]: Distraction (1=*distracted*; 7=*attentive*), Anxiety (1=*anxious*; 7=*confident*), Risk-taking (1=*risky*; 7=*safe*), Anger (1=*hostile*; 7=*friendly*), Speed (1=*Speeder*; 7=*Dawdler*), Stress (1=*stressed*; 7=*relaxed*), Patience (1=*inconsiderate*; 7=*polite*), and Carefulness (1=*reckless*; 7=*careful*). Additionally, we asked for their estimation on the additional items: Interpersonal relationship (1=*submissive*; 7=*dominant*), Aggressiveness (1=*aggressive*; 7=*non-aggressive*), Law-abidingness (1=*non law-abiding*; 7= *law-abiding*), Eco-friendliness (1=*non eco-friendly*; 7=*eco-friendly*), Driving experience (1=*inexperienced*; 7=*experienced*), Age (1=*old*; 7=*young*), and Gender association (1=*masculine*; 7=*feminine*).

4.4 Participants

We recruited N=109 participants. 44 responses had to be eliminated due to wrongly answered attention checks and one participant was excluded due to not being from either the USA, Germany, or India. Additionally, for participants' gender the non-binary group was excluded since it consisted of only one participant in our sample. Thus, we included N=63 people (31 male, 32 female) aged 20-55 (M=28.44, SD=7.47) in the analysis. We used Amazon's MTurk [50] together with LimeSurvey [38]. 19 participants were recruited from the USA (7 male, 12 female), 14 from India (6 male, 8 female), and 30 from Germany (18 male, 12 female). While the Indian subsample did not strongly differ from the overall sample concerning age (M=28.93, SD=6.28), the German subsample was slightly younger on average (M=25.30, SD=5.57) and the US subsample was older on average (M=32.80, SD=8.61). Out of these 64 participants, 52 reported to own a car and of those, 9 participants had one or multiple bumper decal(s) on their vehicle. Decals used by participants were from the following categories: eco-friendly (2), education (3), religion (1), political (1), brand (1), and other (3). When asked whether participants recently noticed decals on other cars, 50 responded with yes, 10 with no, and 4 participants were not sure.

4.5 Results

4.5.1 Model specifications. As every participant rated all decal types, data was of hierarchical nature (measurements nested within participants). This was accounted for by fitting hierarchical linear

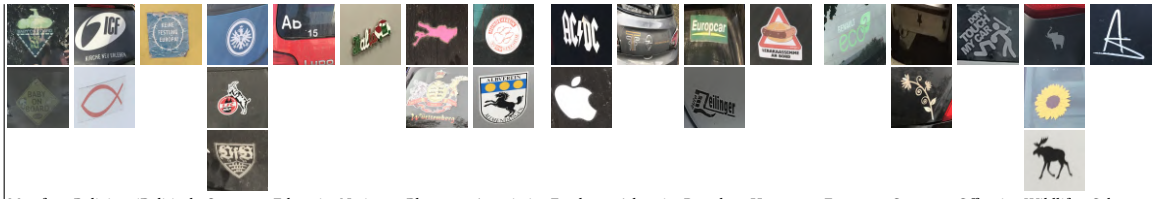
Example																		
Category	My ily	fam-	Religious/ Spiritual	Political	Sports	Education	Nation	Places	Association	Fandom	Advertis- ement	Brand	Humorous	Eco- friendly	Ornamen- tal	Offensive	Wildlife	Other /Misc
Freq.	28 (3.3%)		11 (1.3%)	23 (2.7%)	53 (6.3%)	4 (0.5%)	56 (6.7%)	42 (5.0%)	42 (4.9%)	37 (4.4%)	83 (9.9%)	319 (37.9%)	23 (2.7%)	12 (1.4%)	35 (4.2%)	4 (0.5%)	29 (3.4%)	22 (2.6%)

Table 1: Final categories of found decals.

models (HLMs) with a random intercept for participants for each dependent variable. This approach was tested and found reasonable since the intraclass correlation coefficient was above 0.05 for all models. Predictors in each HLM were the following: country (dummy coded with the US being the reference category), decals (dummy coded for each of the 9 decals with no decal being the reference category), all interaction terms for countries and decals, as well as participants' gender (effect coded), participants' age (with zero set to 20 years to allow for a meaningful interpretation) and interaction terms between participants' gender and participants' age with the country. Neither participants' gender nor participants' age nor any interaction terms of these two with country became significant in any of the calculated models, so due to parsimony, they are not reported here. Furthermore, due to lack of space, we only report 6 of the 9 decal predictors (for the complete models, please refer to the supplementary materials). Results can be seen in Table 2. Dependent variables were standardized (z-scores), and regression weights are interpreted in standard deviations accordingly. Analyses were conducted with R (version 4.0.4) using the "lme4" and "lmerTest" packages.

4.5.2 Effects of countries for vehicle without decals. Comparing countries, the Indian sample did not differ significantly from the US sample in rating the vehicle without any decal on any of the dependent variables. The German sample, however, rated the driver of the vehicle without any decal as significantly more aggressive and significantly more inexperienced than the US sample.

4.5.3 Effects of decals and countries. In the American sample, a driver with a "My Family" decal (compared to a driver without a decal) was rated as significantly younger, more cautious, more feminine, more dawdler, and safer. In the German sample, a driver with a "My Family" decal (compared to a driver without a decal in the American sample) was rated as older, more friendly, and more experienced. In the Indian sample, a driver with a "My Family" decal (compared to a driver without a decal in the American sample) was rated as older. In the American sample, a driver with a religious decal was rated as being more of a dawdler. In the German sample, a driver with a religious decal was rated as older, more cautious, more friendly, more careful, more attentive, more eco-friendly, more experienced, more submissive and more polite. In the Indian sample, a driver with a religious decal was rated as more cautious. A driver with an eco-friendly decal was rated as younger, more eco-friendly, and more of a dawdler by the American sample. The German sample rated this driver as older, more cautious, more careful, more eco-friendly, and more experienced. No significant effects were found for the Indian sample. The ornamental decal made American participants rate the driver as younger, more distracted, more inexperienced, and more feminine. In the German sample, the driver was also rated as more feminine, and in the Indian sample, the driver was rated as older. In the American sample, a driver with an offensive decal was rated as more aggressive, more hostile, more anxious, more reckless, more distracted, more stressed, less eco-friendly, less experienced, more masculine, more of a speeder, less law-abiding, more inconsiderate, and riskier. In the German sample, a driver with this decal was rated as more confident, more experienced, and more dominant. In the Indian sample, the driver with this decal was rated as older. No significant effects were found for a driver with a wildlife decal in the American and the Indian sample. In the German sample, a driver with this decal was rated as older, more cautious, more careful, more attentive, more relaxed, more eco-friendly, more experienced, and more polite.

	No decal		My family decal			Religion decal			Eco friendly decal		
Dependent variable	DE	IN	US	DE[1]	IN[2]	US	DE[1]	IN[2]	US	DE[1]	IN[2]
age (old - young)	0.474	0.680	1.165***	-1.840***	-1.253**	-0.155	-1.546***	-0.200	0.582*	-1.014**	-0.538
aggressiveness (aggressive - cautious)	-1.062***	-0.286	0.523*	0.412	-0.053	-0.375	-1.490***	0.757*	0.299	0.662*	0.384
anger (hostile - friendly)	-0.468	0.221	-0.307	0.733*	0.307	-0.153	0.846*	0.416	0.422	0.218	-0.115
anxiety (anxious - confident)	-0.253	0.078	-0.423	-0.166	0.555	-0.115	-0.607	-0.104	0.000	-0.054	0.484
carefulness (reckless - careful)	-0.470	0.085	0.151	0.558	0.237	0.075	0.896*	0.356	0.151	0.847*	0.237
distraction (distracted - attentive)	-0.587	-0.182	0.000	0.118	0.338	-0.467	0.802*	0.467	-0.093	0.626	0.474
stress (stressed - relaxed)	-0.565	0.181	-0.231	-0.492	0.099	-0.039	0.655	-0.006	0.231	0.385	0.077
eco-friendliness (non eco-f. - eco-f.)	-0.579	0.265	0.218	0.161	0.031	-0.109	0.894**	0.192	0.765**	0.856**	-0.057
experience (inexperienced - experienced)	-1.109**	0.634	-0.043	0.842*	-0.055	-0.128	1.134**	0.030	-0.128	1.045**	0.176
gender association (masculine - feminine)	-0.581	0.251	0.723**	0.182	-0.558	0.145	0.384	-0.145	0.325	0.303	0.294
speed (speeder - dawdler)	-0.361	-0.366	0.567*	0.301	0.254	0.567*	0.643	0.167	0.756**	0.480	0.065
interpersonal (submissive - dominant)	-0.350	-0.039	0.169	-0.375	0.169	0.296	-1.060**	-0.103	0.084	-0.613	0.495
law-abidingness (non law-ab. - law-ab.)	-0.151	-0.005	0.351	0.029	-0.084	0.312	0.258	-0.178	0.429	0.059	-0.162
patience (inconsiderate - polite)	-0.529	0.282	0.154	0.007	-0.110	-0.039	0.897*	-0.050	0.424	0.515	-0.028
risk-taking (risky - safe)	-0.325	0.471	0.568*	0.272	-0.203	0.000	0.642	0.162	0.355	0.361	0.051

	No decal		Ornamental decal			Offensive decal			Wildlife decal		
Dependent variable	DE	IN	US	DE[1]	IN[2]	US	DE[1]	IN[2]	US	DE[1]	IN[2]
age (old - young)	0.474	0.680	0.854**	-0.503	-1.076*	0.466	-0.439	-0.821*	-0.039	-1.446***	-0.139
aggressiveness (aggressive - cautious)	-1.062***	-0.286	-0.187	0.161	0.272	-1.418***	-0.036	0.608	-0.149	0.954**	0.021
anger (hostile - friendly)	-0.468	0.221	-0.230	0.230	0.318	-1.456***	-0.143	0.186	-0.153	0.580	-0.328
anxiety (anxious - confident)	-0.253	0.078	-0.269	-0.480	-0.214	-0.731*	0.838*	0.379	-0.269	0.537	0.137
carefulness (reckless - careful)	-0.470	0.085	-0.340	0.340	0.297	-1.057***	-0.203	0.280	-0.302	0.755*	0.129
distraction (distracted - attentive)	-0.587	-0.182	-0.654*	-0.135	0.316	-0.872**	0.478	0.703	-0.343	0.658*	0.343
stress (stressed - relaxed)	-0.565	0.181	-0.039	-0.337	-0.226	-1.233***	0.027	0.396	-0.502	0.929*	-0.116
eco-friendliness (non eco-f. - co.-f.)	-0.579	0.265	0.182	-0.309	-0.348	-0.765**	-0.274	-0.026	0.218	0.643*	-0.343
experience (inexperienced - experienced)	-1.109**	0.634	-0.638*	0.283	0.103	-0.851**	1.295**	-0.024	-0.128	1.519***	-0.602
gender association (masculine - feminine)	-0.581	0.215	0.868**	0.717*	-0.124	-0.976***	0.020	0.439	-0.506	-0.173	0.300
speed (speeder - dawdler)	-0.361	-0.366	0.378	-0.115	-0.032	-0.908**	-0.171	0.562	-0.189	0.478	0.492
interpersonal (submissive - dominant)	-0.350	-0.039	-0.042	-0.369	0.380	0.422	1.047**	0.157	0.338	0.015	-0.193
law-abidingness (non law-ab. - law-ab.)	-0.151	-0.005	-0.390	-0.098	0.212	-0.780**	-0.577	-0.111	0.429	-0.185	-0.697
patience (inconsiderate - polite)	-0.529	0.282	0.116	-0.196	-0.292	-1.080***	-0.101	0.022	-0.116	0.706*	-0.325
risk-taking (risky - safe)	-0.325	0.471	-0.461	0.066	0.177	-1.029***	0.017	0.380	0.035	0.187	-0.360

Table 2: HLM Results (regression weights and significance).
Note. **DE: Germany. IN: India. [1]: interaction term for sticker type and Germany. [2]: interaction term for sticker type and India.**
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

5 VISION — ADAPTIVE "DIGITAL DECALS"

We showed that decal usage is prevalent in numerous countries and cities and that stereotypes are associated even with decals that could have been attached by a spouse or even a previous owner. Current research investigates how future (autonomous) vehicles could communicate with other (vulnerable) road users [9–11, 19, 39–41, 48, 51, 53]. Additionally, current concept cars include external displays (e.g., F015 [3]) or other external visual means such as LED strips or projectors [48]. Therefore, we envision the possibility to display a "digital decal" which could alter per or during a journey. Via such a system, the owner or user of an (automated) vehicle could personalize it or signalize information to the other road users such as "I am in a hurry", "Driving with children", or "think about the environment!" This could be altered via an application on one's smartphone resembling wallpaper apps such as Walli [56]. This approach is also related to the video showcase presented by Wang et al. [62]. In this showcase, a Head-Up Display is used to show information about the other drivers and their intentions, e.g., driving to an airport. Additionally, this approach was partly explored by Colley et al. [8]: the authors explored how external displays could act as public displays using projections on vehicles such as navigation cues, advertisement, warnings, or aesthetics (e.g., decals). The authors found that safety-related visualizations were found most useful while there were some privacy issues related to, for example, presenting navigation cues for pedestrians. It also resembles the "social car" approach by Schröter et al. [54, 55]. While they proposed a comparable approach, they state that future work should "design and trial" [54, p. 109] such possibilities.

Based on the prevalence of decals on today's vehicles, we also investigate the possibilities for customization via VR with regard to our found categories, try to quantify the desire to use such a system, and discuss the potential on on-road encounters. We focus on the personalization aspect of such "digital decals". The findings of the attribution of (potentially wrong) stereotypes found in the online study based on an attached decal also are relevant here: such stereotypes could be transferred to an AV when displaying such "digital decals", therefore, forming associations the manufacturer or provider wants to avoid.

5.1 Study on "Digital Decal" Usage

To explore how potential users would use the customization possibilities, we implemented a VR simulation in Unity [61] including a vehicle with external displays on the front and rear side capable of displaying messages, pictures, and animations. Participants were able to change the displayed content with a menu (see Figure 2b). We used VR to immerse participants in the scene and to be able to experience the impact of the "digital stickers". Participants were, therefore, able to assess the look of these at the different locations. This exploratory study was guided by the research question:
RQ2: Will participants want to use "digital decals" and if yes, what will they want to display?

After signing informed consent, participants first answered a demographic questionnaire. Afterward, questions targeted towards their current usage of decals were posed. Finally, we explained our vision as described in Section 5. For this, a video showing a potential future on a highway with such digital decals was shown (see Figure 2a). After being able to customize a vehicle in VR (see Figure 2b), participants were asked the following questions:

- Would you use such a system? (1=*not at all*; 7=*definitely*)
- How much would you be willing to pay additionally to be able to use such digital decals?
- Would such a system aid you in understanding the intentions of other drivers? (1=*not at all*; 7=*definitely*)
- What would you display?
- Do you have any concerns when many people would use such a system?
- Do you see any potential for the abuse of such a system?
- Should autonomous vehicles make use of these displays to communicate their intention? If yes, please describe scenarios in which you believe such communication to be helpful.

The position and the used "digital decal" were logged. We asked open questions regarding the concept, asking for positive and negative feedback. On average, the study took 15 min. Participants were compensated with 3 €.

5.2 Participants

We recruited N=16 (5 female, 11 male) German participants being M=25.50 (SD=2.16) years old. One participant has a decal from a previous owner attached to their vehicle. Ratings regarding the usage of such digital decals were diverse (M=3.81, SD=2.69). 6 participants indicated complete willingness to use such digital decals as indicated by choosing 7 on the 7-point Likert scale while 5 did not want to use such a decal at all (chose 1).

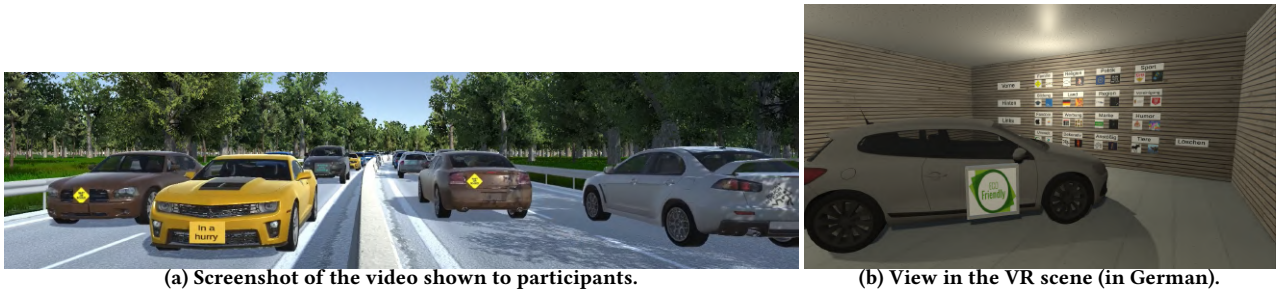
5.3 Results

We logged the decals that were used in the VR part of the study. For each category, a static and an animated decal were provided. Due to technical problems, we had to disregard 3 participants and only report the findings of the logs of the remaining 13 participants. In total, 113 actions were logged (≈ 10 per participant). 14 of these were deleting previous decals. Of the remaining 99 decal interactions, 53 were logged as choosing an animated, 46 showed that a static decal was used. Most decals were chosen for the rear display (56), 23 for the front and left display. Only 11 decals were used for the right display.

The various categories were chosen as follows: Humorous 18 times, fandom 13, brand 9, ornamental 9, offensive 8, places 6, association 5, political 5, advertisement 5, eco-friendly 4, sports 4, wildlife 4 times, nation 2, my family 0, and religion 0 times. We believe that the absence of religion- and family-related decals can be attributed to the sample as these were mostly younger adults.

Participants weren't willing to pay much for such a feature (M=134.38 €, SD=262.40; range: 0 (5 times) — 1000 (2 times)). Participants believed, however, that such digital decals could aid in understanding other drivers (M=5.13, SD=1.71), and 13 out of 16 participants agreed that autonomous vehicles should use such displays to communicate with pedestrians (9 participants).

Regarding concerns for potential abuse or other negative impacts, all participants agreed that the usage of such a feature should be limited as distraction could become a severe problem (e.g., [P6]: "It could be distracting when [there are] too many moving stickers on



(a) Screenshot of the video shown to participants. (b) View in the VR scene (in German).

Figure 2: Screenshot of video shown to illustrate idea and view in VR scene.

the road"). One participant did not want to personalize the vehicle, however, saw the potential of showing advertisement and, therefore, earn money with its display.

6 DISCUSSION

In this work, it was shown that a 16.70% of people use a decal on their vehicle. Our categorization revealed a set of **17** distinct categories which have a high overlap to previous work [21]. Still, decals belonging to the categories of *military* and *sexual* were not detected, indicating that in the cities we collected data, these themes could be less impactful. Our online study showed interesting insights into the stereotypes associated with decal usage and our VR study showed the high diversity of opinions of future digital decals enabled via attached displays.

6.1 Impact of Decals

Through our collection of decal prevalence in 29 cities in 8 countries, a medium prevalence of decals was shown. 16.7% of all vehicles have a decal attached to the rear side. We did not include decals at the side or in the front in our data collection, therefore, even more vehicles have an attached decal. While the data collection primarily focuses on Germany, 7 other countries (CYP, ARE, IRL, AU, DNK, AO, NL) were included. The data collection shows, when including related work on decals in other countries such as the USA [46], Lagos and Ota [7], Israel [4], Kuwait [13], Jordan [34], and Turkey [59], that attaching decals to the vehicle is prevalent at least in large parts of the world.

In the online study, the associated stereotypes were determined. While we can not determine the impact these stereotypes have on one's driving style, we assume that drivers do adjust theirs. Interestingly, the same decal evoked different stereotypes per country.

This could be evoked by demographic differences in the countries. On average, women in the USA have their first child at 26 years of age [43] while, in Germany, this is with 30 years of age [18] and with ≈ 17 years of age in India [67] (data of 2005, since then teenage pregnancy became more scarce [25]). Still, in India, the driver of a VW Golf with a "My Family" decal was rated as older. The reason could be that financially it is only possible to buy such a vehicle in later stages of life in India.

The prevalence of decals could also be a contributing factor for the diverse stereotypes. If a religious decal is more prevalent in the USA, several (contradictory) experiences with drivers of vehicles with such an attached decal could have been made. In other countries, these decals could be less prevalent and, therefore, a stereotype might be more easily developed. Prevalence is related to the distinctiveness of decals. An elk, as used in the reported study, could just be too specific and, thus, not prevalent in some areas of the USA or India.

313 decals were coded as small. These are probably not or only late visible and, therefore, have a small impact on stereotype formation. The others, however, are highly visible at least in low-speed environments such as cities. Therefore, decals potentially have an impact on the traffic on the roads. These findings are in line with previous findings of associated stereotypes by the appearance of the vehicle [14, 15]. Future work should determine how one's driving style is affected by the display of such decals.

6.2 Considerations for Autonomous Vehicles

The emerging research field on external communication of autonomous vehicles [10] with (blind) pedestrians [9, 11, 41] or cyclists [30] assumes that, for example, displays will be attached to the outside of an autonomous vehicle. Today, there are already possibilities to display various messages via LED displays [12]. With the expected usage of external communication of highly automated vehicles [10, 40], possibilities to enhance such personalization will exist. Colley et al. [8] already defined potential use cases such as being a pedestrian navigation guide or displaying the vehicle's environmental impact in a focus group study. While some negative aspects are mentioned (e.g., privacy), the authors highlight the potential benefits such as increased safety. We contribute to this research by providing data on today's external communication via decals and the stereotypes they encourage. Additionally, participants of the study in VR (N=16) were divided in their agreement to use these "digital decals". Our data indicate that potential users, however, focus more on humorous and fandom-related decals. Additionally, the potential distraction during a journey was highly emphasized. These personalization options have to be considered carefully as blinking or, in general, moving animations could be distracting for the other road users. Still, with external displays attached to an (autonomous) vehicle, the potential for misuse would be existent. This could then pose a security risk both for manual drivers and autonomous vehicles as their perception could be confounded (e.g., by displaying people on the display).

Six of the participants stated that they would definitely use such personalization options despite also worrying about the potential such ubiquitous communication could have on driver distraction.

While today's decals are often small. the displays for such "digital decals" could be large [52] and, therefore, highly visible. We assume that the effect such stereotypes have on one's own driving style would, therefore, be even more pronounced.

6.3 Increased Personalization Through Digital Decals?

It is especially interesting that some participants *definitely* wanted to use such a personalization option as none of these participants ever attached a decal to their vehicle. "Digital decals" could provide higher personalization options and will be, therefore, maybe even more liked and prevalent than current decals. Having to quantify their willingness to pay for such a feature, a relatively low price was named (M=134.38 €, SD=262.40). Due to most of the participants still being in university or in training, little money available. Still, there is some potential for car manufacturers to provide additional personalization mechanisms and, therefore, stand out.

6.4 Potential Benefits and Drawbacks of Digital Decals on Traffic

Besides personalization, such configurable eHMIs could benefit the traffic climate. Sadeghian et al. [53] already explored some eHMI concept and their impact on traffic climate. With the proposed digital decals, communication with other (vulnerable) road users could be enhanced. Also, awareness regarding fuel or, more general, energy consumption could be raised by presenting relevant information to other drivers in mixed traffic. Additionally, Colley and Rukzio [10] name affective messages as a potential communication use case. Affective messages via external displays could humanize the automated vehicles and, therefore, increase acceptance. This approach can also be seen in work by Chang et al. [6] who used simulated eyes to convey awareness of pedestrians. As we found in the Section 4, drivers attribute characteristics to other road users based on decals. Autonomous vehicles could utilize this to display digital decals associated with desirable attributes, therefore, improving their acceptance. This has to be, however, researched in the future as cognitive overload could become a problem.

6.5 On the Need for Personalization in Shared Mobility

This work proposes to enable users of shared automated vehicles to personalise not only the interior but also some parts of the exterior via eHMIs. This proposal is based on the shown need of personalization of current manually driven vehicles via decals in 29 cities in 8 countries. While our experiment shows that some participants would definitely like to use "digital decals", it is unclear whether this would also be the case if the vehicle is shared. Future research should address this.

7 LIMITATIONS

While we tried to gather data on decals in a variety of parking lots, most of our data were acquired in South-West Germany. Other cities vary in the percentages of vehicles with decals. We also had to categorize decals that were not readable for us into the category *other*. This occurred **22** times or 2.6% of all decals. In the study, participants had to imagine a black VW Golf with decals. Other models could have shown different results as the appearance of vehicles does affect stereotypes [14, 15]. The participants of the online study were not evenly distributed across the countries as we had to disregard several data due to failed attention checks. We did not find a lot of significant effects for the Indian subsample which could be due to this sample being the smallest. However, even though samples differed in age and gender distribution, the analysis revealed that the factor gender and age did not have a significant effect on the measurements. The sample size of the VR study was relatively small (N=16) and young (M=25.50 years old, SD=2.16). However, for an exploratory study eliciting first insights for potential usage, the sample size is adequate and higher than the most frequent sample size of 12, for example, for CHI [5]. Therefore, the findings are not transferable to other age groups. It is interesting to study their willingness to use such personalization options.

8 CONCLUSION AND FUTURE WORK

Overall, we report data on the prevalence of decals in 29 cities in 8 countries (16.7%). In an online study, we showed the associated stereotypes with such decals. Our sample (N=64) was recruited in the USA, India, and Germany and stereotypes differed between countries. In a subsequent VR study, we explored, in a VR study (N=16), how potential future external displays on autonomous vehicles could and would be used. We found that our sample had strong and diverse opinions on usage. Still, almost half wanted to use such a possibility.

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A DECAL DATA COLLECTION

City	Country	Vehicles	Decals	in %
Augsburg	GER	100	41	41
Biberach	GER	100	14	14
Bopfingen	GER	100	21	21
Erbach (Danube)	GER	100	24	24
Einsingen	GER	100	18	18
Ehingen (Danube)	GER	300	36	12
Hamburg	GER	100	9	9
Heidenheim	GER	100	18	18
Konstanz	GER	100	10	10
Memmingen	GER	100	24	24
Münsingen	GER	100	22	22
München	GER	200	20	10
Neu-Ulm	GER	250	41	16.4
Regensburg	GER	100	23	23
Stuttgart	GER	100	17	17
Tübingen	GER	100	14	14
Ulm	GER	700	137	19.6
Ulm-Söflingen	GER	100	33	33
Weimar	GER	100	16	16
Würzburg	GER	100	8	8
Akanthou	CYP	100	19	19
Dubai	ARE	200	5	2.5
Dublin	IRL	50	19	38
Hirschegg	AU	100	22	22
Kopenhagen	DNK	100	7	7
Silvretta	AU	70	14	20
Tirana	AO	100	17	17
Utrecht	NL	100	20	20
Vienna	AU	100	2	2
Total		3970	664	16.7

Table 3: Manually collected data per city.