Perceptions of Terms Used to Describe Automation in Vehicles: A Multidimensional

Scaling Study

Michael A. Nees

Lafayette College

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Corresponding author:
Michael A. Nees
Lafayette College
Department of Psychology
neesm@lafayette.edu

Abstract

Concerns have arisen that the functionality implied by some of the terms used to describe automation in vehicles does not align with the actual capabilities of automated systems. An exploratory study examined perceptions of a sample of 39 words, phrases, or names used to describe automation in vehicles using similarity ratings analyzed with multidimensional scaling (MDS). Participants rated the extent to which they perceived that pairs of terms indicated similar or dissimilar functional capabilities of vehicles. The model with two dimensions was selected as the most appropriate model for interpretation; the model produced a stress value of .26 and $R^2 = .80$. The first dimension clearly corresponded to the perceived level of automation. In some instances, the model suggested that participants' perceptions of the terms did not align with the capabilities associated with the technical definitions of the terms. Instances of both under- and over-estimation of capabilities were suggested by the model.

Perceptions of Terms Used to Describe Automation in Vehicles: A Multidimensional Scaling Study

Concerns have arisen about the vocabulary that has been used to describe automation in vehicles. In particular, Tesla has been criticized for using terms like “Autopilot” and “full self-driving,” because these terms seem to imply functionality beyond the current capabilities of the systems they describe. Research has suggested that perceptions of the functionality implied by some of the terms used to describe automation in vehicles do not align with the actual capabilities of automated systems (Abraham, Seppelt, Mehler, & Reimer, 2017; Nees, 2018). This exploratory study examined perceptions of a sample of terms used to describe automation in vehicles using similarity ratings analyzed with multidimensional scaling (MDS). MDS permitted the simultaneous comparison of automation terms within a geometric space where plotted distances showed perceptual similarity. This study sought to find an MDS solution for which one dimension corresponded to the attribute “level of automation.”

Method

Participants. Participants ($N = 303$) were recruited online via Amazon Mechanical Turk (AMT). AMT workers were required to be located in the United States, to have a task approval rating of greater than 95%, and to have at least 1000 previously approved tasks. The study description also indicated that the research was only open to licensed drivers. Participants were paid \$1.00 for their time.. Twenty-six participants failed attention check questions (described below), so the final sample analyzed was $N = 277$ (130 females, 145 males, and 2 people who chose “other/prefer not to respond”). Participants reported a mean age of $M = 34.69$ years ($SD = 10.34$, $mdn = 33$, minimum = 18, maximum = 70). Self-reported racial/ethnic backgrounds were white ($n = 223$), Asian ($n = 14$), black or African American ($n = 32$), Hispanic or Latino ($n = 14$),

American Indian or Alaska Native ($n = 4$), and Native Hawaiian or Pacific Islander ($n = 1$).

Three participants selected “prefer not to answer.” Participants were allowed to select more than one category, so these numbers sum to a number greater than the sample size. Participants reported $M = 17.63$ years of driving experience ($SD = 10.85$, $mdn = 16.00$, minimum = 1.00, maximum = 60.00). Participants reported driving $M = 9.30$ hours per week ($SD = 11.52$, $mdn = 7$, minimum = 0.00, maximum = 150.00). Participants reported the scenario that best described where they drive most often as urban/city driving ($n = 157$), rural/small town driving ($n = 95$), distance/interstate/freeway driving ($n = 22$), and other ($n = 3$).

On scale from 1-7, participants rated their familiarity with the current state of technology related to vehicle automation and self-driving cars as $M = 3.83$ ($SD = 1.39$, $mdn = 4.00$).

Participants reported having read $M = 5.18$ articles about self-driving cars in print or online ($SD = 30.37$, $mdn = 2.00$, minimum = 0.00, maximum = 500.00). Fifty-one participants reported owning or using a vehicle that had one or more of the automated features described by the words rated in the study, including cruise control ($n = 49$), autobrake or forward collision assist ($n = 6$), steering or lane keeping assist ($n = 5$), adaptive cruise control ($n = 2$), and one instance each of Autopilot and forward collision warning.

Survey Questions

Survey questions asked participants to rate the similarity of pairs of terms that have been used to describe automation in vehicles. Pairs were constructed from 39 different terms. Table 1 lists the terms used in the study and their source or rationale for inclusion. For each pair, participants rated the extent to which they perceived that the terms indicated similar functional capabilities of the vehicle. Terms that could be used as an adjective to modify “vehicle” were

presented as such; all other terms were presented as the object of the phrase “a vehicle with” (see Figure 1).

Figure 1. Example question.

Attention Check

As part of the demographic battery, participants responded to the question, “I followed the instructions for this study and answered all questions to the best of my ability” on a scale from 1 (“strongly disagree”) to 7 (“strongly agree”). Participants who selected a response lower than “6” were deemed to have failed the check.

Procedure

This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at Lafayette College. Data were collected in July, 2017. Informed consent was obtained from each participant. Participants were instructed to rate the terms based on the capabilities of the vehicles they described (see Appendix A). There were 741 possible pairings of the terms (ignoring the order of the terms within the question). For each participant, the Qualtrics survey presented 50 of the possible pairings of the terms, and pairs were pseudo-randomly selected to approximately balance the overall number of times a given pair of terms was presented across all participants. Thus, each participant provided similarity ratings for 50 pairs of terms; across all participants each pair of terms was rated $M = 18.69$ ($SD = 4.17$) times. The order of the appearance of the terms in the question (i.e., first or second) was

randomly determined for each pair of terms for each participant. After the ratings were finished, participants answered demographic questions and were debriefed.

Table 1
Terms Used in Study 2

Term	Source and/or rationale
Self-driving	Ubiquitous
Automation	Ubiquitous
Automated	Ubiquitous
Autonomous	Ubiquitous
Semi-autonomous	Ubiquitous
No automation	SAE Level 0 (SAE International, 2016)
Driver assistance	SAE Level 1 (SAE International, 2016)
Partial automation	SAE Level 2 (SAE International, 2016)
Conditional automation	SAE Level 3 (SAE International, 2016)
High automation	SAE Level 4 (SAE International, 2016)
Full automation	SAE Level 5 (SAE International, 2016)
Function-specific automation	NHSTA Level 1 (National Highway Traffic Safety Administration, 2013)
Combined-function automation	NHSTA Level 2 (National Highway Traffic Safety Administration, 2013)
Limited self-driving automation	NHSTA Level 3 (National Highway Traffic Safety Administration, 2013)
Full self-driving automation	NHSTA Level 4 (National Highway Traffic Safety Administration, 2013)
Autopilot	Tesla ("Autopilot," n.d.)
Drive Pilot	Mercedes-Benz (previously, see McCowen, 2017)
Copilot	BMW ("BMW ConnectedDrive," n.d.)
Pilot Assist	Volvo ("Pilot Assist," n.d.)
ProPilot	Nissan (Abuelsamid, 2017)
Traffic Jam Assist	Kia ("Kia Motors Worldwide," n.d.)
Traffic Jam Pilot	Audi (McCormick, 2017)
Supervised Driving Mode	Volvo ("Autonomous Driving," n.d.)
Unsupervised Driving Mode	Volvo ("Autonomous Driving," n.d.)
Super Cruise	Cadillac ("Cadillac Super Cruise Sets the Standard for Hands-Free Highway Driving," 2017)
Advanced driver assistance	Ubiquitous
Adaptive cruise control	Ubiquitous
Lane keeping assist	Ubiquitous
Lane-centering Steering	Ubiquitous
Lane Trace Control	Toyota (Read, 2013)
Forward collision warning	Ubiquitous
Collision Mitigation Braking	Honda ("Collision Mitigation Braking System," n.d.)
Lane departure warning	Ubiquitous
Road Departure Mitigation	Acura ("Road Departure Mitigation," n.d.); Honda ("How does Honda's Road Departure Mitigation System work?," 2017)
Steering assist	Ubiquitous
Manual driving	Ubiquitous/control
Autosteer	Ubiquitous
Autobrake	Ubiquitous
Cruise control	Ubiquitous

Results and Discussion

Data quality screening. Nine participants were excluded from the analyses for finishing the experiment in less than 190 seconds (range = 150 to 188 seconds), which suggested that they did not read each question. These 9 participants clustered at the low end of the distribution of completion times, and a 26-second gap separated these 9 participants from the rest of the distribution. Five of these participants also failed one of the other checks. Eleven additional participants were excluded for failing the attention check question. Two additional participants were excluded for self-reporting having searched for definitions of words online during the study, and four additional participants were excluded for self-reporting that they were not licensed drivers.

Pre-processing of data to construct dissimilarities matrix. Ratings for each pair of terms were averaged across participants and across order of presentation (i.e., whether the term appeared first or second in the question) to form a symmetric matrix of aggregate similarity ratings. Since dissimilarity ratings are desirable as the raw input for MDS (Giguère, 2006), the averaged similarity ratings (scaled from 1-7) were subtracted from 8 to re-scale the ratings as dissimilarities.

MDS solution, dimensionality, and model fit. The matrix of averaged dissimilarity ratings was modeled with classical MDS using the non-metric (ordinal) ALSCAL procedure in SPSS, which was set to untie tied ratings and to produce models with dimensionalities from one to six. The model with two dimensions was selected as the most appropriate model for interpretation. Selection and interpretation of dimensionality in MDS solutions is subjective and ambiguous. Factors to consider include stress (a measure of lack of fit), R^2 (a measure of the proportion of variance in actual distances of ratings accounted for by the model), and the

interpretability of the dimensions obtained (Borg & Groenen, 2005; Jaworska & Chupetlovska-Anastasova, 2009; Kruskal & Wish, 1978).

Stress and R^2 for models with one to six dimensions are plotted in Figure 2. The two-dimensional model produced a stress value of .26. Although early texts indicated stress less than .15 as a cutoff for minimum acceptable fit, this criterion is problematic with a large matrix like the one used here, because stress increases with the number of items rated and with noisiness in ratings (see Borg & Groenen, 2005; Mair, Borg, & Rusch, 2016). A different approach is to compare the obtained stress against the expected stress of random responses for a given number of items (Spence & Ogilvie, 1973). The two-dimensional model met this minimal fit criterion (see Mair et al., 2016). For the two-dimensional model, $R^2 = .80$ (see Figure 2). There is no accepted criterion for acceptable fit based on R^2 for MDS model, although Jaworska and Chupetlovska-Anastasova (2009) have advocated for .60 or greater as a cutoff. Examples in the published literature have described $R^2 = .64$ as “fairly acceptable fit” (Chuang & Ma, 2001) and $R^2 = .79$ as “acceptable” fit (Cavanagh, Caputi, Wilson, & Kavanagh, 2016) for MDS solutions. Yet another consideration in evaluating the dimensionality of a model is the interpretability of the meaning of the dimensions (Giguère, 2006; Hout, Papesh, & Goldinger, 2013; Kruskal & Wish, 1978). In the two-dimensional MDS model (shown in Figure 3), the first dimension clearly corresponded to the perceived level of automation, with terms toward the left side of the space corresponding to lower levels of automation.

Figure 2. Stress and R2 values for MDS models with one to six dimensions.

The model showed that the terms that were included as controls—“no automation” and “manual driving”—were perceived as very different from all other terms examined in the study, especially with respect to perceived level of automation (Dimension 1). At the other end of the Dimension 1 continuum, “full self-driving automation,” “self-driving,” and “full automation” were perceived to entail the highest levels of automation.

Regarding the terms used to describe SAE levels, “partial automation” was perceived to indicate a lower degree of automation than “driver assistance,” which is the reverse of their order in the standard. “No automation,” “conditional automation,” “high automation,” and “full automation” occupied the correct ordinal positions for the level of automation indicated by their SAE technical definitions.

In some instances, the model suggested that participants’ perceptions of the terms did not align with the capabilities associated with the technical definitions of the terms. “Autopilot” was

rated as relatively similar to “autonomous” and “self-driving.” For other terms, participants underestimated the capabilities of the vehicle according to the technical definitions.

“Unsupervised driving mode,” for example, is described by Volvo to mean “the vehicle does all the driving” (“Autonomous Driving,” n.d.), yet this term was perceived to be similar to “function-specific automation” and “driver assistance.” Further, “unsupervised driving mode” was rated as similar to—but entailing a slightly lower level of automation than—“supervised driving mode.” Participants apparently were unclear on whether the term implicated the driver or the vehicle as the supervisor. “Traffic Jam Pilot,”—the term for Audi’s soon-to-be-released, first-to-market L3 system (“Piloted driving,” n.d.) was perceived to entail lower levels of automation than traditional “cruise control” and was rated most similar to “lane trace control” and “lane centering steering” on Dimension 1, which suggested that the term is perceived to imply less functionality than the actual capabilities of the system.

Dimension 2 was more difficult to interpret than Dimension 1. The range of values assumed on Dimension 2 was smaller. The anchors suggested that Dimension 2 might represent functions that apply to braking (with “autobrake” as one anchor) versus accelerating (with “cruise control” toward the other anchor), yet some of the positions of terms along Dimension 2 do not fit neatly into these categories. This raises an important qualification of the interpretation of this model, namely that the MDS procedure is exploratory, and the stress and R^2 values indicate that the model obtained offered a noisy and incomplete description of perceptions of terms related to automation. This is not surprising given the presumably high degree of variability in participants’ impressions of what the terms mean.

Figure 3. Two-dimensional scaling solution for perceived similarity of automation terms. Circles (not labels) indicate the position of the term in the model.

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Appendix A

Verbatim Study Instructions

In this study, you will be asked to compare the similarity of words that might be used to describe vehicle automation or automatic functions in vehicles. For each question, you will be given a pair of words and asked to rate the similarity of the vehicles described by the words. You can see an example question below. If you choose "1-extremely dissimilar" it means you think the vehicles described by the terms have very different capabilities. If you choose "7-extremely similar" it means you think the vehicles described by the terms have the same capabilities. Numbers in between "1" and "7" on the scale should be used to rate the extent to which you think the vehicles described by the terms have the same capabilities.