Transportation Research Part F 23 (2014) 15–31

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

How consumer drivers construe vehicle performance: Implications for electric vehicles

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ARTICLE INFO

Article history:
Received 8 March 2013
Received in revised form 23 October 2013
Accepted 5 December 2013

Keywords:
Electric vehicle
Performance
Driver
Repertory grid
Acceleration
Smoothness

ABSTRACT

Electric vehicles (EVs) have emerged as potentially important contenders as low carbon vehicles. However from the perspectives of consumer (non-commercial) drivers, all types of EVs have limitations such as short range and higher cost that are significant barriers to widespread uptake. To displace a significant fraction of conventional vehicles, they may need to offer consumer drivers specific advantages that offset these limitations. Better performance might be such an advantage, since electric powertrains can offer performance benefits such as quieter operation and higher torque at low speeds. This qualitative study explored how vehicle performance is construed by consumer drivers, using a repertory grid approach to elicit drivers' personal constructs. Drivers were found to construe performance in terms of two main dimensions, both situationally specific: dynamic performance (involving acceleration, power, and responsiveness during pulling away, overtaking and hill climbs) and cruising performance (involving smoothness and low noise, during high speed cruising on highways). Users of gasoline fuelled cars emphasised dynamic performance more than did users of diesel fuelled cars, but the opposite was the case for cruising performance. A conceptual model based on the findings could help focus design efforts on those aspects of performance that are most directly salient to drivers.

1. Introduction

1.1. Could performance benefits offset some of the perceived disadvantages of electric powertrains?

Transport accounts for some 23% of current global energy-related carbon dioxide emissions, of which nearly three-quarters come from road transport (International Energy Agency, 2009). Large reductions in road transport carbon dioxide emissions will be needed if the sector is to make a proportionate contribution to limiting global warming. The situation appears even more challenging when emissions are considered on a cumulative basis (Skippon, Veeraraghavan, Ma, Gadd, & Tait, 2012).

The automotive and fuels industries are responding to this challenge by developing a range of low-carbon vehicle and fuel technologies, including vehicles powered by hydrogen (Ehsani, Gao, & Emadi, 2009; Koca, 2010; Rifkin, 2002), electricity stored in batteries (Ehsani et al., 2009; Sperling, Delucchi, Davis, & Burke, 1994), liquefied natural gas (LNG), compressed natural gas (CNG) (Bechtold, 1997), methanol (Olah, Goeppert, & Prakash, 2006), and biofuels (OECD, 2004; Reijnders & Huijbregets, 2009; Worldwatch Institute, 2007). The success of these new technologies in reducing road transport carbon dioxide emissions will depend on their uptake by consumers (individuals using vehicles privately, rather than commercially or

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1369-8478/$ - see front matter © 2014 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.trf.2013.12.008

professionally). This will depend on how far they meet consumers' needs. Uptake by commercial fleets will also depend, indirectly, on consumer responses, since fleets need to dispose of their vehicles ultimately into the consumer used-car markets.

Electric vehicles (EVs) including pure Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Extended-Range Electric Vehicles (E-REVs), have emerged as important contenders as low carbon vehicles. At present, mainstream consumers (as opposed to those especially favourably disposed towards early adoption of EVs) have tended to see the short range of BEVs, and their extended down-time while recharging, as significant barriers to uptake (Graham-Rowe et al., 2012; Skippon & Garwood, 2011). PHEVs and E-REVs, which do not have these disadvantages, may have greater appeal. However, the need for two powertrains in the same vehicle means that they carry a cost premium over conventional Internal Combustion Engine (ICE) vehicles. To displace a significant fraction of ICE vehicles, they may need to offer consumer drivers specific advantages that offset this cost disadvantage.

Performance is a key attribute of cars for some drivers. In principle, electric powertrains can offer performance advantages over ICE powertrains, such as quieter operation and higher torque at low speeds. Thus meeting consumers' needs for vehicle performance better than a conventional ICE vehicle is potentially such an offsetting advantage. Emphasis on performance is not restricted to a few highly car-oriented drivers, but is also a factor in mainstream car choice: in the product reviews in a popular buyers' guide for used cars in the UK, "Driving and Performance" heads the list of five assessment categories. Even car buyers who do not specifically prioritise performance must balance factors such as size, purchase cost and fuel economy with sufficient performance for their driving style and usage patterns. However to understand how far performance benefits from electric powertrains might affect their uptake, we need first to have a clear picture of what precisely "performance" means to consumer drivers. The automotive industries have tended to make their own assumptions about how drivers construe performance, rather than eliciting consumers' own constructs; and while there are some commonalities, there is surprisingly little consensus about what exactly contributes to drivers' subjective perceptions. This study was intended to investigate how drivers themselves construe performance.

1.2. Research literature on how vehicle performance is construed

In the automotive industry it is common to define powertrain performance in terms of objective engineering variables that can be measured directly. For example Wei, Pisu, Rizzoni, and Yurkovich (2003) and Wei and Rizzoni (2004) identified the variables acceleration (over the speed ranges 0–60 mph, 30–50 mph and 50–70 mph); top speed; gradeability limit (the maximum gradient at which vehicle can just move forward); gradeability at fixed speed (the maximum gradient at which that speed can be maintained); and towing capability (how much mass a vehicle can tow under specified conditions) as suitable for the objective characterisation of performance. This approach has the merits of ease of measurement and ability to represent performance straightforwardly in vehicle simulations, but it does not follow that consumer drivers would construe vehicle performance in this way. For example, it seems unlikely that many consumers engage, during their normal driving, in finding the maximum gradients at which their vehicles will just move forward.

The industry has also attempted to compare objective measures with drivers' subjective evaluations of aspects of vehicle performance. For example, Passmore, Patel, and Lorentzen (2001) reported an experimental study in which expert drivers' subjective ratings of performance were compared with measured performance. Their subjective response variables were: "overall performance"; "responsiveness to accelerator depression"; "smooth acceleration"; "quick off the mark"; "good acceleration through the gears"; and "ease of control of available power". Since the rating variables and scales were supplied by the researchers, they do not offer a direct window onto how consumer drivers themselves construe performance.

To the extent that vehicle performance matters to consumer drivers, we might expect that the ways they construe performance might figure in their accounts of why they use cars. Mann and Abraham (2006) and Gardner and Abraham (2007) found that affective and symbolic factors, such as independence and personal freedom, personal control, personal space, and enjoyment, were very important, and for some drivers, the experience of driving *per se* was pleasurable. Hiscock, Macintyre, Kearns, and Ellaway (2002) and Ellaway, Macintyre, Hiscock, and Kearns (2003) found that Scottish drivers' attachments to cars were related to perceived psycho-social benefits. Redshaw (2008) found that young drivers in Australia associated car use with certain sets of cultural meanings: their car use, and their choices of car, signified aspects of identity, particularly masculinity and sexual maturity. Heffner, Kurani, and Turrentine (2007) meanwhile found that people bought and used the Toyota Prius hybrid electric vehicle specifically because doing so put them in a positive light as intelligent, moral people who care about others. The emphasis in these studies has thus been on wider factors that contribute to the value of car use; and while enjoyment of driving was a motivating factor in several of these studies, they did not explore in detail how enjoyment might be linked to specific aspects of vehicle performance, so they do not illuminate our question.

One remaining approach to is to consider the literature on *driveability*. While performance can be seen as the way a vehicle responds to control actions by the driver, driveability reflects the ability of a vehicle to respond satisfactorily to those control actions without noticeable demerits. Understanding how consumers construe driveability might therefore be an indirect route to understanding how consumers construe performance.

Whereas performance has tended to be viewed as a set of objective properties of the vehicle, driveability is typically defined in terms of the subjective experience of drivers. A vehicle has poor driveability if drivers notice a significant number of demerits, such as hesitation when they depress the accelerator pedal; and it has good driveability if drivers notice no demerits. Table 1 lists various attributes of driveability that have been included in post-1990 papers identified using the search terms "driveability" and "rating" in the SAE and other automotive databases. Variables connected with lack of smoothness