

ECONOMICS

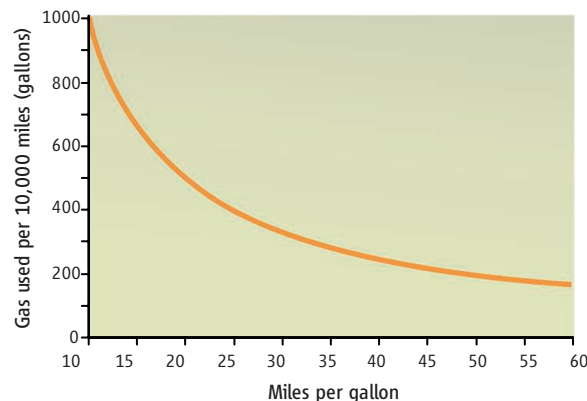
The MPG Illusion

Richard P. Larrick* and Jack B. Soll

Many people consider fuel efficiency when purchasing a car, hoping to reduce gas consumption and carbon emissions. However, an accurate understanding of fuel efficiency is critical to making an informed decision. We will show that there is a systematic misperception in judging fuel efficiency when it is expressed as miles per gallon (MPG), which is the measure used in the U.S.A. People falsely believe that the amount of gas consumed by an automobile decreases as a linear function of a car's MPG. The actual relationship is curvilinear. Consequently, people underestimate the value of removing the most fuel-inefficient vehicles. We argue that removing the most inefficient vehicles is where policy and popular opinion should be focused and that representing fuel efficiency in terms of amount of gas consumed for a given distance—which is the common representation outside of the United States (e.g., liters per 100 kilometers)—would make the benefits of greater fuel efficiency more transparent (1–3).

To illustrate these issues, consider the criticism that has been directed at adding hybrid engines to sport utility vehicles (SUVs). In a *New York Times* Op-Ed column, an automotive expert (4) has said that hybrid cars are like “fat-free desserts”—they “can make people feel as if they’re doing something good, even when they’re doing nothing special at all.” The writer questions the logic of granting tax incentives to buyers of “a hypothetical hybrid Dodge Durango that gets 14 miles per gallon instead of 12 thanks to its second, electric power source” but not to a “buyer of a conventional, gasoline-powered Honda Civic that gets 40 miles per gallon.” The basic argument is correct: The environment would benefit most if all consumers pur-

chased highly efficient cars that get 40 MPG, not 14, and incentives should be tied to achieving such efficiency. An implicit premise in the example, however, is that an improvement from 12 to 14 MPG is negligible. However, the 2 MPG improvement is



Gas consumed driving 10,000 miles. Gallons of gas used per 10,000 miles driven as a function of fuel efficiency of car (expressed in MPG).

Perceived and actual benefits of improving gas mileage

Change in vehicle pairs* (old vehicle to new vehicle)	Perceived rank in gas savings (mean)	Actual rank in gas savings	Actual reduction in gas consumption per 10,000 miles
34 MPG to 50 MPG	1.18	3	94.1
18 MPG to 28 MPG	1.95	1	198.4
42 MPG to 48 MPG	3.29	5	29.8
16 MPG to 20 MPG	3.73	2	125.0
22 MPG to 24 MPG	4.86	4	37.9

*Vehicle pairs are listed in order from largest linear change (34 to 50) to smallest linear change (22 to 24). Participants did not see the actual rank in gas savings or the actual reduction in gas consumption when they gave their answers.

actually a significant one in terms of reduction in gas consumption. The amount of gas used by a vehicle to drive 10,000 miles at different levels of MPG is shown in the graph above. A car that gets 12 MPG consumes 833 gallons to cover that distance (10,000/12); a car that gets 14 MPG consumes 714 gallons (10,000/14). The roughly 120-gallon reduction in fuel used is larger than the reduction achieved by replacing a car that gets 28 MPG with a car that gets 40 MPG over that distance.

We conducted three experiments to test whether people reason in a linear, but incor-

rect, fashion about gas mileage. In study 1 (5), 77 college students were asked to “assume that a person drives 10,000 miles per year and is contemplating changing from a current vehicle to a new one.” They were asked to rank-order five pairs of old and new vehicles in order of “their benefit to the environment (i.e., which new car would reduce gas consumption the most compared to the original car)” using 1 for the most beneficial change and 5 for the least beneficial change.

Perceptions of improvement corresponded directly to the linear change in MPG and not to the actual reduction in gas consumption (see table below). Sixty percent of participants ordered the pairs according to linear improvement and 1% according to actual improvement. A third strategy, proportional improvement, was used by 10% of participants (5).

Study 2 tested whether the price that people would pay for more efficient vehicles would also show a linear relationship to MPG. College participants ($n = 74$) were told they had several vehicles from which to choose that were identical except for the efficiency of the engine (5). Participants were told to assume “you drive 10,000 miles per year for work, and this total amount cannot be changed. The baseline model gets 15 miles per gallon and costs \$20,000.”

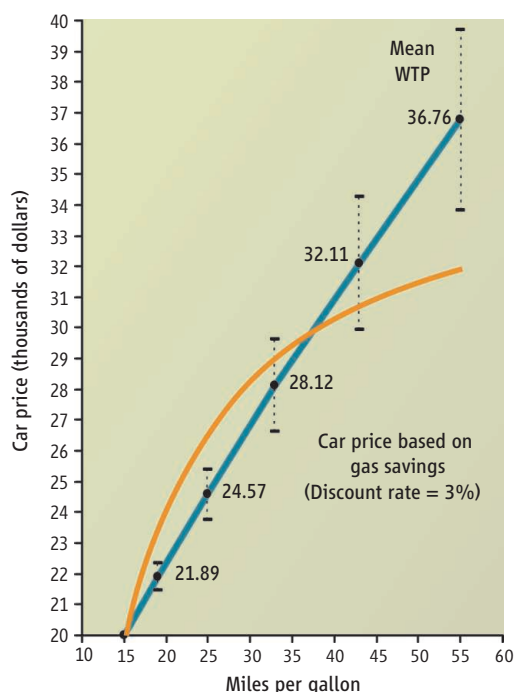
Participants were then asked to state the highest price they would be willing to pay for five vehicles that varied only in the MPG of their engines. Mean willingness to pay (WTP) showed a clear linear relationship with MPG improvement (see figure, page 1594). The best-fitting strategy for the majority of participants was a linear strategy (62%) followed by a proportional strategy (18%); the actual savings was the best-fitting strategy for only 15% of participants. Participants gave mean WTP values that, compared with expected gas savings,

Fuqua School of Business, Duke University, Durham, NC 27708, USA.

*Author for correspondence: larrick@duke.edu

significantly undervalued the improvements to 19 and 25 MPG and overvalued the improvement to 55 MPG (6).

Study 3 was designed to test whether the MPG illusion could be decreased if fuel efficiency were framed in terms of gallons per 100 miles (GPM) instead of MPG. The study was presented in an online survey to 171 participants who were drawn from a national subject pool. Participants ranged in age from 18 to 75, with a



How much will you pay for gas savings? The straight blue line plots the mean willingness to pay for the different engines (95% confidence intervals are plotted for each mean). The curved orange line plots the value of the car, based on future gas savings [calculated using a 3% real discount rate, a 10-year life of the car, and a Spring 2007 gas price of \$2.80 per gallon (5)].

median age of 35. All participants were given the following scenario (5): “A town maintains a fleet of vehicles for town employee use. It has two types of vehicles. Type A gets 15 miles per gallon. Type B gets 34 miles per gallon. The town has 100 Type A vehicles and 100 Type B vehicles. Each car in the fleet is driven 10,000 miles per year.” They were then asked to choose a plan for replacing the original vehicles with corresponding hybrid models if the “overriding goal is to reduce gas consumption of the fleet and thereby reduce harmful environmental consequences.”

One group of 78 participants was randomly assigned to a policy choice framed in terms of MPG. They were asked to

choose between two options: (option 1) replace the 100 vehicles that get 15 MPG with vehicles that get 19 MPG and (option 2) replace the 100 vehicles that get 34 MPG with vehicles that get 44 MPG. Note that town fuel efficiency is improved more in option 1 (by 14,035 gallons) than in option 2 (by 6,684 gallons). As expected, the majority (75%) of participants in the MPG condition chose option 2, which offers a large gain in MPG but less fuel savings [95% confidence interval (CI) = 65 to 85%].

Participants in the GPM condition ($n = 93$) were given the same instructions as those in the MPG condition. In addition, they were told that the town “translates miles per gallon into how many gallons are used per 100 miles. Type A vehicles use 6.67 gallons per 100 miles. Type B vehicles use 2.94 gallons per 100 miles.” They read the same choice options as used in the MPG condition, including the MPG information, but with an additional stem that translated outcomes into GPM for the hybrid vehicles [(option 1) replace the 100 vehicles that get 6.67 gallons per 100 miles with vehicles that get 5.26 GPM and (option 2) replace the 100 vehicles that get 2.94 gallons per 100 miles with vehicles that get 2.27 GPM]. As expected, the majority of participants (64%) in the GPM frame chose option 1, which offers a small gain in MPG but more fuel savings (CI = 54 to 74%). Overall, the percentage choosing the more fuel-efficient option increased from 25% in the MPG frame to 64% in the GPM frame ($P < 0.01$).

These studies have demonstrated a systematic misunderstanding of MPG as a measure of fuel efficiency. Relying on linear reasoning about MPG leads people to undervalue small improvements on inefficient vehicles. We believe this general misunderstanding of MPG has implications for both public policy and research on environmental decision-making (7–9). From a policy perspective, these results imply that the United States should express fuel efficiency as a ratio of volume of consumption to a unit of distance. Although MPG is useful for estimating the range of a car’s gas tank, GPM allows consumers to understand exactly how much gas they are using on a given car trip or in a given year (10–14) and, with additional information, how much

carbon they are releasing. GPM also makes cost savings from reduced gas consumption easier to calculate.

Although the current work has focused on misunderstanding the curvilinear relationship between MPG and fuel efficiency, other cognitive processes may also lead people to undervalue small improvements for inefficient cars. For example, if the 50 MPG fuel efficiency of popular small hybrids is used as a standard of comparison, small improvements on inefficient cars (e.g., a 5 MPG improvement from 15 to 20) look like “a drop in the bucket” (15, 16).

The issue of translating car efficiency to gas consumption and carbon emissions is a special case of a general policy problem: People need a common metric to compare the consequences of their activities across a range of daily actions (14, 17). Choosing a more efficient car is just one means to reduce greenhouse gas emissions. Arming consumers with information about the relative greenhouse gas emissions of various activities expressed in a common metric can allow concerned consumers to make beneficial trade-offs in their daily decisions.

References and Notes

1. Decision-makers often focus on the surface attributes of a decision problem and fail to recognize the more fundamental structure (2, 3).
2. C. K. Hsee, F. Yu, J. Zhang, Y. Zhang, *J. Consum. Res.* **30**, 1 (2003).
3. D. Kahneman, S. Frederick, in *Heuristics and Biases: The Psychology of Intuitive Judgment*, T. Gilovich, D. Griffin, D. Kahneman, Eds. (Cambridge Univ. Press, New York, 2002), pp. 49–81.
4. J. L. Kitman, *New York Times*, 16 April 2006, §4, p. 12.
5. Materials, methods, and additional examples and analyses are available as supporting online material (SOM) on Science Online.
6. Section IV of the SOM provides additional analyses of WTP versus expected gas savings.
7. J. D. Sterman, L. B. Sweeney, *Clim. Change* **80**, 213 (2007).
8. A. E. Tenbrunsel, K. A. Wade-Benzoni, D. M. Messick, M. H. Bazerman, *Acad. Manag. J.* **43**, 854 (2000).
9. E. U. Weber, *Clim. Change*, **77**, 103 (2006).
10. Section I of the SOM discusses possible GPM measures.
11. Decisions are often improved more by changing the decision context than by trying to improve individual reasoning (12–14).
12. J. Klayman, K. Brown, *Cognition* **49**, 97 (1993).
13. J. W. Payne, J. R. Bettman, D. A. Schkade, *J. Risk Uncertain.* **19**, 243 (1999).
14. R. H. Thaler, C. R. Sunstein, *Nudge* (Yale Univ. Press, New Haven, CT, 2008).
15. J. Baron, *J. Risk Uncertain.* **14**, 301 (1997).
16. C. Heath, R. P. Larrick, G. Wu, *Cognit. Psychol.* **38**, 79 (1999).
17. J. Baron, *J. Public Policy Market.* **23**, 7 (2004).
18. The authors thank D. T. Robinson for advice on discount rate assumptions in study 3.

10.1126/science.1154983

Supporting Online Material

www.sciencemag.org/cgi/content/full/320/5883/1593/DC1