LETTER

Questionable association between front boarding and air rage

Marcus Crede[a,1], Andrew Gelman[b,c], and Carol Nickerson[d]

DeCelles and Norton (1) conclude that physical inequality (the presence of a first-class cabin) on airplanes is associated with a greater number of air rage incidents in economy class, and that situational inequality (boarding from the front rather than the middle of the airplane) is associated with a greater number of air rage incidents in both economy class and first class. Their study has many flaws that invalidate their conclusions, but we focus on just one, their failure to recognize a statistical artifact in their analyses.

Decelles and Norton's (1) table S2 shows that the correlation between front boarding and economy class incidents equals −0.035 (odds ratio 0.1954), and the correlation between front boarding and first class incidents equals −0.019 (odds ratio 0.1498); that is, the association between front boarding and air rage is moderately sized and negative. In table 2 of ref. 1, however, the odds ratios predicting economy class incidents and first class incidents from front boarding and several covariates equal 2.1754 and 11.8594, respectively, indicating that the association between front boarding and air rage is moderately sized and positive.

What has happened here? The surprising reversal of the direction of the association between front boarding and air rage is an example of a statistical phenomenon known as "negative suppression" (2) in psychology and as "qualitative confounding" (3) in epidemiology. Consider a least-squares regression analysis with a criterion Y and two correlated predictors X_1 and X_2 (all variables standardized). Score X_1 and X_2 so that the correlations between Y and X_1 and between Y and X_2 are nonnegative, and so that the correlation between Y and X_1 exceeds the correlation between Y and X_2. Ordinarily, when X_2 is added to the regression containing only X_1, the partial regression coefficient for both X_1 and X_2 has the same sign as, and a magnitude less than, its corresponding simple regression coefficient.

However, if the correlation between X_1 and X_2 is greater than the ratio of the correlation between Y and X_2 and the correlation between Y and X_1 ($r_{X_1X_2} > r_{YX_2}/r_{YX_1}$), then negative suppression occurs. The partial regression coefficient for X_2 reverses sign; the partial regression coefficient for X_1 keeps the same sign but increases in magnitude. For example, if r_{YX_1} equals 0.44, r_{YX_2} equals 0.10, and $r_{X_1X_2}$ equals 0.60, then $r_{YX_1.X_2}$ equals 0.59 and $r_{YX_2.X_1}$ equals −0.26.

DeCelles and Norton (1) used logistic rather than least-squares regression (producing odds ratios rather than standardized regression coefficients), and used multiple predictors rather than just two, but something akin to negative suppression must have occurred. Without the data, however, it is not possible to determine which variables were responsible for the association reversal and exactly how that reversal occurred.

So, does front boarding have a negative association with air rage, or a positive association, as DeCelles and Norton (1) claim? It is impossible to know, given the information provided. Suffice it to say that, generally, suppression effects are considered statistical artifacts unless there is a strong theoretical explanation for their occurrence (4). No such explanation is provided by DeCelles and Norton (1).

1 DeCelles KA, Norton MI (2016) Physical and situational inequality on airplanes predicts air rage. *Proc Natl Acad Sci USA* 113(20): 5588–5591.

2 Tzelgov J, Henik A (1991) Suppression situations in psychological research: Definitions, implications, and applications. *Psychol Bull* 109(3):524–536.

3 Szklo M, Nieto FJ (2014) *Epidemiology: Beyond the Basics* (Jones & Bartlett Learning, Burlington, MA), 3rd Ed, pp 174–176.

4 Bobko P (2001) *Correlation and Regression: Applications for Industrial Organizational Psychology and Management* (Sage, Thousand Oaks, CA), 2nd Ed, pp 254–255.

[a]Department of Psychology, Iowa State University, Ames, IA 55011; [b]Department of Statistics, Columbia University, New York, NY 10027; [c]Department of Political Science, Columbia University, New York, NY 10027; and [d]Champaign, IL 61820

Author contributions: M.C., A.G., and C.N. wrote the paper. The order of authors is alphabetical.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. Email: mcrede@iastate.edu.

www.pnas.org/cgi/doi/10.1073/pnas.1611704113