

A decade of mixed models: It's past time to set your contrasts

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In 2008, the field of psycholinguistics was introduced to mixed-effects models as a practical way to analyse data with variability arising from participants and items. Two papers in the same special issue of the *Journal of Memory and Language* have become cornerstones of the field: Baayen, Davidson, & Bates (2008), which has been cited over 3,000 times, and Jaeger (2008), which has been cited over 1,500 times. Both papers focus on converting an ANOVA-using audience to the merits of mixed models. Unfortunately, both papers describe analyses using R's default coding scheme: treatment contrast coding (also called 'baseline' or 'dummy' coded contrasts), which is often undesirable in psycholinguistics, and both papers failed to discuss the implications of contrast coding for the interpretation of results.

In models with treatment contrasts – the default in most statistical software – what appear to be 'main effects' (overall effects of one variable) are actually 'simple main effects' (effects of one variable conditional on a specific level of other variables). This means that authors do not always draw licensed inferences from their data: this is something we have noticed in our reading, reviewing, and teaching. To assess the implications of contrast coding choices on the field of psycholinguistics, we have used Web of Science to compile a database of 3684 papers from 700 journals published before 2019 that contain citations to Baayen et al. (2008) or Jaeger (2008).

Each paper was accessed and coded for whether (1) the paper used mixed-effect models in one or more analyses, (2) categorical predictors were present in one or more analyses, and (3) the contrasts used were specified explicitly with a formula or statement such as "We used sum coding for Factor X", "Q was the reference level". We also extracted any keywords if present as a proxy for paper topic.

Preliminary analyses focus on a subset of the database which was selected to represent at least 200 papers per year from 2009 onward (N=2471). Only 27% of these papers explicitly describe which contrasts were used. However, the overall pattern is one of improvement over time, such that by 2018, 34% of papers explicitly described the contrast coding scheme used (Figure 1).

Adoption of contrast coding does differ by journal (Figure 2). For journals with at least 20 papers in the database, we examined how the log odds of explicit contrast mention varies. Using sum coding (with the median-ranked journal, *Acta Psychologica* as reference), we show that *Bilingualism: Language and Cognition*, *Quarterly Journal of Experimental Psychology* and the *Journal of Memory and Language* explicitly describe contrast coding reliably more often than average. Only one journal does reliably worse: *Frontiers in Psychology*. This suggests an important role for editors and reviewers in enforcing good statistical practice.

Finally, adoption of contrast coding also differs by topic (Figure 3). For keywords mentioned at least 20 times in the database, we examined how the log odds of explicit contrast mention varies. Using sum coding (with the median-ranked keyword, *word recognition* as baseline) we show that the keywords *bilingualism* and *reading* are reliably associated with more explicit descriptions of contrast coding than average, while the keyword *language acquisition* is reliably worse. This suggests that some domains have led the way in using best practices.

Failing to fully describe analyses precludes evaluation of conclusions and hinders replication and open science, holding back the field. Accessible tutorials are now available for setting and interpreting contrasts (e.g. Schad, Vasishth, Hohenstein, & Kliegl, 2019). We encourage psycholinguistics to follow this example – and the example set in the bilingualism literature – so that we can be more transparent in our practices together.

