Hidden stimulus effects in crossed effects experiments in marketing-communication

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In marketing-communication, there is a burgeoning interest in experimental approaches (Alhabash & Wise, 2012; Janssens et al., 2011; Krakowiak & Oliver; 2012; Mazodier et al., 2012) which allow to detect more conclusive causal relations than it is generally the case in observational and survey-based research. We will focus on a methodological issue linked to a crossed effects design, where every subject responds once to the same set of stimuli. As a result, the data are grouped both under the subjects, each subject responding to the same set of stimuli, and the stimuli, each stimulus being responded to by every subject, so that the outcomes are correlated. It is common practice to use a Repeated Measures ANOVA (RM ANOVA) to account for the correlation or non-independence of the experimental outcomes.

We will argue that RM ANOVA is not the technique best suited to analyze the results of a crossed effects experiment, since it only to model allows one grouping factor, generally the subjects, discarding the variance caused by the stimuli and hence jeopardizing the generalizability of the results since one source of variance is excluded from the model. We will demonstrate that mixed-effects models (Gelman & Hill, 2007; Bates et al., 2013) are better suited to analyze crossed effects experiments since both subjects and stimuli can simultaneously be included in the model as random effect terms, next to the fixed effect terms representing the experimental condition and treatment factor (Baayen et al., 2008; Quené & Van den Berg, 2008; Richter, 2006).

A mixed-effects model is fitted to reanalyze the outcomes of an experiment where a RM ANOVA was used to analyze the impact of a condition and a treatment factor on the recall of products displayed for a short time on a computer screen and where the within-subject variance was a random effect (Janssens et al., 2011). Although there was no major impact on the fixed effects, the interaction between the experimental condition and the treatment remained significant, the mixed-effects model with two random effect terms outweighs a RM ANOVA with only one random effect term for subject. First, it significantly reduces the overall variance (ANOVA with X^2 as test statistic on the deviance of both models: $X^2 = 251.53$, df = 1, $p < 2.2e-16$). Secondly, the predictive power of the model, measured by the index of concordance (*c* index), is significantly improved: an unsatisfactory score of 0.5933 (95% CI = [0.5915;0.5951]) as opposed to a score of 0.8078 (95% CI = [0.8065;0.8091]). Finally, the intra-class correlation reveals that the random effect term for the stimuli explains 49.14% of the variance compared to only 7.93% for the subjects.

The above-mentioned figures convincingly prove that the stimuli cannot be discarded from the analysis of a crossed effects design and have to be represented in the model together with the subjects. Upon closer inspection of the stimuli, it turns out that 4 of the 6 positions on the computer screen significantly favor the recall of products as opposed to the remaining 2 positions (ANOVA with Tukey HSD as post hoc test: $F_{5,918} = 58.99$, $p < 2e-16$).

In brief, the high intra-class correlation for stimulus clearly proves that the subjects' responses show a high degree of intra-group closeness: observations for the same stimulus are similar on different subjects and simultaneously different from the observations for other stimuli. The mixed-effects model has unveiled a significant effect of the stimuli on the successful recall of products, which pointed to the identification of 4 screen positions favoring and 2 positions disfavoring the product recall.

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