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How small sample size and replication can increase accuracy in experiments: Lessons that marketing may learn from agricultural scientific method

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ABSTRACT

This paper examines the use of small sample sizes and replication in marketing experimentation, including full factorials, fractional factorials, Latin squares and their derivatives such as conjoint analysis. It is well understood within agricultural research that the sample size used within these experiments should be kept to a minimum if maximum reliability is to be achieved. This understanding, which underlies the massive success of agricultural research in the last century, does not appear to have been transferred to marketing. This article explains the logic behind this counterintuitive claim. It then discusses the links between the use of small sample size and replication in experimental research. It concludes that the current very low level of replication in marketing can be related to a very basic mismatch between academic marketing's theoretical expectations of replication outcomes and the degree to which these expectations can be meaningfully achieved by replication within any living environment.

1. Introduction

This article examines the apparently counter-intuitive claim that smaller sample sizes give more accurate results when combined with certain experimental techniques that are very popular in academic marketing.

The advantages of a small sample size are well understood in agricultural science, where these techniques originated, and this realisation forms a basic tenet of agricultural science research method. The article uses agricultural research situations to demonstrate why this tenet is both valid and important. It also demonstrates how the philosophy, assumptions and methodologies that underlie this tenet also lead to a greater requirement for replication as a routine part of hypothesis testing, both within individual research exercises (intra-research replication) and between them as part of subsequent published discourse (inter research replication).

There appears to be no significant understanding of this crucial methodological tenet within the academic marketing literature, which displays no recognition of the advantages of small sample sizes, but does display a recognised deficiency in its rate of replication (Easley and Madden, 2013; Easley et al., 2000). The means by which small sample size tenet can then be effectively applied to marketing research are therefore demonstrated with a short theoretical discussion and a single worked example.

The article concludes with a discussion on the relationship between the use of small sample sizes and the use of replication in research. It is proposed that the widely reported lack of replication in research is significantly associated with a single underlying epistemological cause: namely academic marketing's general aversion to the use of small samples, and to the related lack of a widespread realisation as to why the research environment within which the discipline operates makes it advantageous to use large numbers of small sample intra and inter research replication exercises when using some of its most popular experimental techniques.

Previous commentaries on replication in marketing have focussed upon the distinction between replication practice within marketing as a 'social' science and replication within the 'natural' or 'life' sciences (Easley et al., 2013). Agricultural science and the approaches that have led to its remarkable success over the last eighty years have received little attention. This is unfortunate because agricultural research is a 'hybrid' discipline with a strong commercial and applied emphasis, which shares many similarities with both the natural and marketing sciences. It has also historically been a major technical donor to the social science research toolbox. The pragmatic solutions that it has discovered and successfully applied to its research processes as it continues to feed the World are highly applicable to the research issues that marketing faces.

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2. Agricultural science's contribution to marketing experimental technique and method

Marketing utilises a variety of experimental designs that were initially developed for use in agricultural research (Banks, 1965; Brunk and Federer, 1953a, 1953b; Cox, 1964). These designs have come to Marketing either directly by transfer (Latin square, fractional factorial, full factorial) or by subsequent development of these initial designs (conjoint analysis) (Hamlin, 1997, 2005). With one or two caveats, the transfer has been a happy one (Hamlin, 2005). However there are several important insights derived from their development and widespread successful application within Agriculture that do not seem to have been sufficiently widely disseminated within the marketing research literature.

Exactly why these insights have failed to transfer between the disciplines can only be a matter of historical conjecture. However, the author's own extensive experience as both a commercial/academic agricultural researcher and an academic marketing researcher may provide a possible cause. Agricultural researchers tend to apply only a very small and stable suite of closely related experimental techniques that have been formalised for a very long time. The nature of the research environment means that they also execute them at a very high volume and either apply or publish the results very quickly (Gomez and Gomez, 1984; Sunding and Zilberman, 2001). This creates a 'density' of experience within the community that academic marketing, with its larger toolbox, greater diversity and slower research cycle rate, simply cannot match.

As a consequence published and thus visible experimental 'techniques' are supported by a much larger, unpublished, orally transmitted, invisible, but nonetheless highly critical body of experimental 'method' within agricultural research. This detailed experimental method is rarely written up for publication as it is bulky and common inter-researcher expertise is assumed. It thus cannot be easily referenced by an 'outsider', and therefore can only be transmitted to another discipline by a significant transfer of personnel. Thus its absence within academic marketing is understandable.

This article examines the nature and implications of just one of these agricultural research method-derived insights: That it is a key requirement of experimental reliability that results are derived from individual samples that are as *small* as possible. Small size is achieved by using an experimental pattern that has the highest efficiency with regard to the individual treatment conditions that are required, and by using the smallest possible sample size within each treatment condition. The stability and generalisability of any conclusion is tested by systematic replication of these small exercises. These replications are commonly both intra-study (to test stability) and inter-study (to test generalisability) to the method and conclusions of any one published report.

3. The economic and practical advantages of small sample size

High efficiency in an experimental design has the obvious attraction that a result can be obtained after a much lower expenditure of time, money and other research resources. The same comments can be made with regard to a small individual sample for each treatment condition within any such design. A further benefit of both of these features is that any experiment that possesses them may be administered with a very much lower degree of disruption of the environment in which it is undertaken.

This is important as much of the research work using agricultural designs since their introduction to marketing in 1953 has been administered in difficult to access field environments, such as retail stores or supermarkets (Brunk and Federer, 1953a, 1953b; Cox, 1964; Dodds et al., 1991; Kennedy, 1970; Montaguti et al., 2015; Orth and Malkewitz, 2012; Rui and Meyers-Levy, 2009). Under such circumstances, where the co-operation of a commercial partner is required, the efficiency of the experimental design may determine if consent to conduct field research is granted at all.

4. The technical advantages of small sample size – Fisher's two principles

Beyond these advantages there is a much more subtle, yet highly important benefit endowed by high efficiency. Nearly all the experimental designs sourced from agriculture are instruments of *parallel* comparison, which rely on the controlled application combinations of the independent variables to *equivalent* experimental units. The mean responses of these individual units are then compared to the mean response of the entire experimental population, or to a single nominated 'control' condition if a partially confounded (fractional factorial) design is being used. The main and non-additive effects of the controlled independent variables are then deduced algebraically from the deviations of individual conditions from the population mean or a nominated control condition. Simple statistical tests such as ANOVA are then used to test the stability of these algebraic manipulations.

The larger the experiment becomes in terms of the number and/or size of the individual experimental units deployed, the harder it becomes to either ensure or reasonably assume that these units are all either internally homogeneous or equivalent to each other for the purposes of these comparisons. The effects of the controlled independent variables will be increasingly moderated by other non-controlled variables that are unavoidably present within the sample environment. As the sample environment increases in size, the greater the chance becomes that effects of these non-controlled external variables will not be uniform, either within or between individual samples.

The less certain the equivalence of the treatments is, then the less reliable the results of the overall experiment will be. It is for this reason that Sir Ronald A. Fisher, the initial developer of nearly all these experimental designs and related statistical tests for agricultural purposes (Fisher, 1925, 1935), made the following direct comment on experimental method in the form of two principles:

> "… the problem of designing economical and effective field experiments is reduced to two main principles (i) the division of the experimental area into the plots as small as possible …; (ii) the use of [experimental] arrangements which eliminate a maximum fraction of soil heterogeneity, and yet provide a valid estimate of residual errors."
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> (Fisher, 1950, p. 510)

As Fisher does not do so, and because the issues relating to them are easier to demonstrate in this way, it is necessary to elaborate upon and demonstrate these two principles in their original agricultural experimental method context before their significance for marketing situations can be discussed. It is acknowledged within agriculture that there is no such thing as an entirely homogeneous environment, outside of a hydroponic cell. While experiments can be conducted within hydroponic cells, the conditions within them are so far removed from the reality 'in the ground' that attempts to extrapolate results from them into the more general environment have to be treated with considerable caution. The situation is a close analogue to the lab experiments that are frequently published in the marketing literature (Calder et al., 1981; Koschate-Fischer and Schandelmeier, 2014).

As a consequence most agricultural field experiments are exactly that; they occur in a field, and that field, even if it is an open flat block in Kansas, will have a range of uncontrolled environmental conditions existing within it (Fig. 1). The precise nature of these

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