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Assessing shortened safety climate measures: Simulating a planned missing data design in a field setting

Huw Flatau Harrison[a,*], Mark A. Griffin[b], Marylene Gagne[b], Daniela Andrei[b]

[a] School of Psychology, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[b] Business School, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

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ABSTRACT

Safety researchers are frequently faced with a dilemma in field research: whether to increase both participant engagement and the efficiency of their data collection by using brief construct measures, or to instead use exhaustive and thorough measures to capture the full range of statistical variance in relationships of interest. Using a safety climate questionnaire, this study simulated and evaluated a novel method that can be used by safety researchers to reduce the length of surveys. The method involves using a planned missing data design to randomly allocate participants a reduced selection of items using multiple imputation to replace the missing data and produce a complete dataset, thus retaining the full range of items across the studied population. Results from the study indicate that the method provides safety researchers and practitioners with acceptable levels of model fit, and is able to demonstrate predictive validity. Advantages and disadvantages of the planned missing data design method in field research are discussed.

1. Introduction

Safety researchers are often confronted with two competing requirements in field settings: whether to pursue research constructs in as exhaustive a fashion as possible, or to encourage participant engagement with short and concise questionnaires. These concerns are increasingly relevant within a modern research context of time-poor participants and changing technology. Research has successfully addressed the problem of creating a valid and brief assessment across a range of different constructs, including personality (Gosling et al., 2003; Rammstedt and John, 2007), self-esteem (Robins et al., 2001), job satisfaction (Dolbier et al., 2005; Nagy, 2002; Wanous et al., 1997) and safety climate (Hahn and Murphy, 2008). The aforementioned approaches have, however, tended to create shortened construct measures *a priori,* through hypothesis formation, data collection and data analysis, thereby reducing the breadth of data initially collected and subsequently analysed. The aim of this study is therefore to evaluate a novel and practical approach to shortening safety climate questionnaires which is able to provide safety researchers with a wider range of complete data from which to draw statistical inference.

The use of safety climate measures are vital to organisations in managing their safety climate and by virtue of their capacity to act as an early warning for potential incidents (Cooper and Phillips, 2004; Lutness, 1987), assess the overall safety functioning of the company before any negative events are encountered. Ensuring that safety practitioners and researchers have access to statistically valid measures which are also able to be frequently deployed and quickly assessed in this context is therefore crucial. To this end the feasibility of an alternative approach in which individual respondents are presented with different subsets of items from a larger questionnaire was investigated. The approach involved simulating the allocation of items to individuals in a randomised pattern such that unanswered items (those not included in the distributed questionnaire and thus considered to be missing data) could be imputed *ex post facto* from responses by individuals who were allocated those items. The goal of this approach was to create both a convenient and statistically rigorous approach to reducing the length of questionnaires, whilst simultaneously retaining a wider range of statistically valid information about relationships at hand. Such an approach has been termed a 'planned missing data design' (Graham et al., 2006), and has been used to investigate the effect of smoking on health (Graham et al., 2006), with variations used in contexts such as family (Johnson and Young, 2011) and school research (Baraldi and Enders, 2010).

To our knowledge, the approach has not been used in safety climate research, but is particularly relevant for this context. This is because organisations often require efficient and reliable assessments of their

* Corresponding author.
E-mail addresses: huw.flatauharrison@research.uwa.edu.au (H. Flatau Harrison), mark.griffin@uwa.edu.au (M.A. Griffin), marylene.gagne@uwa.edu.au (M. Gagne), daniela.andrei@uwa.edu.au (D. Andrei).

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safety functioning, with instruments that can be quickly deployed and accurately predict safety behaviours and outcomes. Instruments measuring constructs such as safety climate serve this purpose by assessing a range of different aspects of an organisation's safety functioning.

1.1. Study structure

In this study we begin by introducing the problem faced by safety researchers during the normal course of collecting data for a construct measure. We then provide an introduction to the proposed approach, including a general discussion of the phenomenon of missing data and the underlying mathematical operations used in imputation to replace missing data. Discussion of the substantive application of the article, namely the concept of a safety climate, follows and includes a theoretical introduction to the concept of safety climate and a description of its practical relevance to the approach tested here. Safety climate has been identified as a useful lead indicator of the safety functioning of an organisation, and has demonstrated predictive validity with respect to safety behaviours and incidents in a range of contexts. Due to the rich research history investigating its content and strong predictive relationships with respect to behaviour it is used as the demonstration data for the simulation conducted in the present study.

We then present the outcomes of using the multiple imputation method within the context of a safety climate questionnaire in two different samples. To this end a series of simulated alternative datasets were created by randomly removing items from the original questionnaire in order to model a scenario in which data was *Missing Completely At Random* (MCAR) by design (i.e. where participants received different versions of the same questionnaire). The datasets comprised safety climate responses from employees working within an Australian hospital and within international mining/oil and gas workplaces. The utility of the approach is evaluated within the analytical context of a confirmatory factor analysis (CFA) and the prediction of relevant dependent variables of interest. Implications and uses for safety practitioners and researchers are discussed alongside limitations of the method.

1.2. Survey construction and participant engagement

Researchers, in the normal course of deciding on their questionnaire content, frequently use exploratory factor analytic (EFA) techniques to investigate the plausibility of alternative factor structures within their data, an approach which is frequently misused (Fabrigar et al., 1999). This method, fitting into traditional theory-driven response facilitation approaches (Rogelberg and Stanton, 2007), is regularly used by researchers when identifying the core content of a questionnaire, including which items can be reasonably left out. When completed with a pragmatic mindset, this approach is often the first, and last, step taken by researchers attempting to balance theoretical principles with practical restrictions. In the interest of reducing participant burden, however, it may also lead to the removal of items of potential interest, leading to less information being collected about a research sample.

Particular instances where shortened measurement tools are preferable, however, include situations where participant fatigue and noncompliance may be an issue (Gardner et al., 1998; Robins et al., 2001), and there is a need to maintain employee interest and engagement over an extended period of testing (Nagy, 2002). This is particularly relevant when attempting to retain employee engagement within survey populations that traditionally report higher degrees of noncompliance, such as those that are male dominated and have lower reported levels of education (Rogelberg and Luong, 1998) and those including executives and/or manager subpopulations (Anseel et al., 2010). Additional attitudinal variables, such as degree of interest in survey subject matter, may also affect engagement (Rogelberg and Luong, 1998). Importantly, many of these flagged issues with survey noncompliance would likely be a concern to those involved in traditional safety-critical industries such as mining, oil/gas and construction. A clear rationale for the present research then is to address relevant participant engagement/noncompliance issues that researchers have identified as a potential problem when conducting survey collection (Hinkin, 1995; Podsakoff et al., 2003; Rogelberg and Luong, 1998), which are particularly relevant to research within the safety context.

When attempting to address such engagement issues and balance scientific rigour with practical concessions, the inevitability of decreasing model fit and psychometric properties in the case of item reduction can be academically deleterious. Indeed, it is generally understood as a rule of thumb that successful shortened construct measures should demonstrate convergent and discriminant validity, test-retest reliability and criterion relationships similar to extended assessment tools which measure the same construct (Gosling et al., 2003). Practitioners might indeed argue whether one might simply retain only those individual items expected to correlate with a dependent variable of interest. Recent novel approaches using this extreme method have been moderately successful (Fisher et al., 2016), yet it still remains to be seen whether a better balance might be achieved between the competing demands of science and practice. The use of a planned missing data design appears to possibly address this balance between maximizing information, and minimizing burden. The methodological problem facing safety researchers is thus twofold: (1) how to collect as much data and information as possible to ensure scientific rigour whilst (2) reducing the burden placed on participants.

Recently, Huang et al. (2017) utilised a novel and effective approach to shortening questionnaires using item response theory (IRT) to identify the most useful items in a questionnaire in providing information about a latent trait (in this case safety climate). They were able to reduce the 16 item questionnaire originally used by Zohar and Luria (2005) in two separate ways to address both academic and practical contexts. The former involved retaining only items with a minimum level of discriminant ability (resulting in a 8–11 item version of the questionnaire) and the latter by retaining items with the most information that would retain at least 30% of the information of the original tool (resulting in a 4 item version of the questionnaire). Whilst the paper presents a methodologically rigorous approach to questionnaire shortening within the safety climate context, it is eclipsed by the method introduced in this paper for two key reasons (both theoretical and practical).

Firstly, the approach utilised by Huang et al. (2017) produces shortened questionnaires by *reducing* the overall scale information gathered by *removing* items altogether. Thus instead of the full 100% achieved by the original questionnaire, they achieved solutions which captured between 30.29 and 77.71% of the original questionnaire. This is in contrast to the planned missing data design suggested in the present paper which reduces the burden on individuals, whilst *retaining* the overall scale information by asking *all* items across the entire sample instead of each person. In safety critical contexts, capturing as much information as possible about the environment is crucial when attempting to reduce accidents through the use of a lead indicator tool such as safety climate. Secondly, and more practically, the approach used by Huang et al. (2017) requires very specific knowledge of the utility of each item within a proposed safety climate questionnaire, therefore requiring in depth analysis. By contrast the use of a planned missing data design does not rest on discrimination between items, making the overall process easier and less time consuming when trying to apply to a new questionnaire. This should theoretically make it easier to implement by practitioners or researchers introducing a new questionnaire into a workplace.

The present research is thus concerned with investigating a missing data item reduction strategy (namely multiple imputation) theorised as an acceptable compromise to the participant engagement debate, and the impact of such an approach on overall statistical fit qualities and ability to accurately predict behaviour. Developing a procedure for shortening measures of safety climate whilst retaining model fit and