

# Advances in Longitudinal Research Methodology

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**Abstract**

Issues in longitudinal research in geropsychology are identified. Advances in longitudinal research methodology are illustrated by summarizing three symposium contributions. Tjörborn Swensson discussed whether biographical retrospective data can be conceptualized as a longitudinal inquiry, and what the kind of design would be that one would want to apply given a positive answer to the question. Scott Hofer treated the topic of subject attrition in longitudinal studies within the more general framework of contemporary missing data analysis. Christian Rott addressed the issue of variability within and across individuals. Using the example of the Bonn Longitudinal Study (BOLSA), he showed how model misspecifications can circumvent limitations of the designs using age-cohort-period model. He also incorporated adjustments for attrition and substitution of an event definition for calendar time.

## ADVANCES IN LONGITUDINAL RESEARCH METHODOLOGY

### I. Introduction

In summarizing the content of the symposium on "Advances in Longitudinal Research Methodology" I will begin by reminding the reader of the important role of longitudinal inquiry in geropsychology. I will also briefly touch on some of the early issues that are currently being given full attention by researchers designing serious longitudinal studies.

For the content of the symposium I purposively selected a diverse group of contributions. The first (Tjörborn Swensson, Gerontogisk Institute, Lund, Sweden) discusses an important content question, namely whether biographical retrospective data can be conceptualized as a longitudinal inquiry, and what the kind of design would be that one would want to apply given a positive answer to the question. The second contribution (Scott Hofer, Pennsylvania State University, USA) discusses the thorny topic of subject attrition in longitudinal studies. It places this topic within the more general framework of contemporary missing data analysis. This permits illustrating the applicability of modern multivariate methodology to the solution of attrition-related questions. The third paper (Christoph Rott, University of Heidelberg, Germany) deals with the issue of variability within and across individuals. Using the example of the Bonn Longitudinal Study (BOLSA). examples are provided of how model misspecifications can be used to circumvent limitations of the designs currently used to estimate



components of the age-cohort-period model, as well as how the dependency of the time-of-measurement (period) component might be resolved by substituting an event definition for a calendar time definition.

## **II. Some Historical Notes on the Role of Longitudinal Inquiry in Geropsychology**

In the beginning, most psychologists who later on became interested in adult development and aging, started out as child psychologists. Child psychologists soon became interested in the differential developmental paths taken by children. They realized that antecedent-consequent relationships could not be elucidated by comparing different age groups, but that it was essential to follow cohorts of children over the path of their development if one were interested in between individual differences in the intra-individual development occurring in particular children.

Some of the original longitudinal studies in geropsychology began as child studies. Perhaps the best known in this class are the Berkeley Growth and Guidance studies originating in the 1930s [1] or the Terman study of genius [2] which as their subjects aged developed into studies of adult development and aging. Other studies were explicitly designed to follow adults from middle or early old age into advanced old age. Examples of such studies are the Duke Normative Aging studies [3] and the Bonn Longitudinal study [4]. These studies followed one or two cohorts of particular interest in their historical location, while others (such as the Seattle Longitudinal Study



[5] have followed multiple cohorts spaced equally in time. Studies have varied widely in substantive content, but all have been important in increasing our understanding of human aging and in particular being able to appreciate the wide array of individual differences in developmental trajectories that remain quiet pronounced in adulthood [6].

### **III. Early Issues in Longitudinal Methodology**

*a. Understanding the difference between cross-sectional and longitudinal data.* The recognition that longitudinal data were needed to understand development was not necessarily followed immediately by a full recognition of how cross-sectional and longitudinal data were related, and what kind of information could or could not be inferred from one to the other. It was not until 1965 that Norman Ryder [7] in sociology and this author in psychology [8] formal clarified these relationship in what became known as the age-cohort-period model. In short, cross-sectional studies compare groups of individuals at different ages at one point in time. Hence they are useful in describing how population groups differ by age, but they do not inform us how particular individuals will change as they age, unless our observations are made in a completely static context (that is, where cohort and period effects are close to zero). But longitudinal studies are also fraught with methodological problems, the most serious of which have been described by Campbell and Stanley [9] as threats to internal validity common

to all quasi-experiments, that is studies that do not allow completely random assignment to levels of the independent variable.

b. *Threats to the internal validity of longitudinal studies.* The major concerns here for aging studies include the confounding of *historical change* with age-related effects. This problem is generally handled by following more than one cohort over a similar age span. *Experimental mortality* (attrition) involves the typically non-random dropout of part of one's sample (see below). When attrition is due to causes other than death, it is often necessary to estimate what performance levels would have been like in unattrited samples. *Practice effects* (reactivity) may be a function of subjects becoming "testwise" or leading to actual treatment effects in improving performance. Practice effects can be controlled for by adding control groups which have been assessed one occasion less than the target group [10].

#### **IV. Obtaining Longitudinal Data via Introspection**

Although longitudinal studies are generally conceptualized as a sequence of data gathered on the same individuals over a long period of time, it is also possible to conceptualize the reconstruction of events occurring over a person's life by means of autobiographical data as a form of longitudinal inquiry. How this can be done was laid out in Tjörborn Swensson's presentation.

a. *Introspection as a means of revealing the inner self.* As distinct from objectively assessed longitudinal data, the autobiography rather represents a quasi-longitudinal account of the subjects' perceptions of their lives. Nevertheless, it is argued that it is only the life story as told by the individual that can reveal for us the developmental course of the inner self.

b. *The interviewer as a response as a response elicitor.* If biographical data are obtained by means of an interview, then the characteristics of the interviewer are important. Is that person someone to whom intimate details can be safely revealed? Does the subject perceive possible consequences to his revelations in terms of the relationship with others? Is the interviewer in an authority role with the possibility that the data revealed may influence future relationships? All these dimensions are likely to influence the veracity and completeness of information gathered.

c. *Context within which the life story is told.* Reports of the past must be seen in the context of what currently holds meaning in our lives as well as what we expect future to hold. Equally important is the presence or absence of meaningful family, members friends, and others that are part of a person's support system. Since these will shift over time, we can expect that the life story will change as well. Just as objective longitudinal data are influenced by the historical situation during which they are collected, so do biographies shift over time. It is as if we had several "cohorts" of life histories.



*d. Cross-sequential designs for conceptualizing autobiographies.*

Swensson proposes alternate designs for collecting multiple autobiographies on the same persons to understand the confounding factors listed above. First he would assess change in content of the autobiographies as people age (e. g., ask subjects to tell about their life at different ages, say 60, 70 and 80). Second, he would study change in perspective from different ages (e.g., at 70 describe age 60, at 80 describe age 70). Third, he would compare whole life reviews conducted at different ages; and finally he would inquiry into life events only mentioned at later but not at earlier ages

## **V. Longitudinal Attrition as a Missing Data Problem**

Scott Hofer's paper was designed to propose methods for minimizing the effect of missing data and attrition in the study of change over time.

*a. Classical methods for dealing with missing data.* The classical approach has been to engage in listwise or pairwise deletions (the latter often not tractable to multivariate analyses), or to throw up ones hands and decided that certain sets were simply not interpretable because of missing data problems. Also popular means replacement downwardly biases standard errors. Regression imputation underestimates variances and standard error. Both methods assume that data are missing randomly.

*b. Patterns of missing data.* Several types of missing data patterns can be distinguished. The most benign is called sparse missingness (typically within occasion) which involves item or scale nonresponse. More typical in

longitudinal studies is differential attrition; i. e., subjects do not return for further testing. If information is available on the characteristics of these dropouts it may be possible to model nonrandom attrition patterns [11]. Missing data may also be a function of unequal intervals. In this case subjects may miss some test occasion but return for later assessment. Finally, the investigator may plan selecting only partial data and then proceed to estimate population parameters [12].

*c. Causes of attrition.* Sparse missingness (within occasion) may occur because some subjects lack the ability need to perform the test, have low motivation, fear negative consequences, or accidentally fail to return to skipped questions. Subjects may fail to return in longitudinal studies because of death, illness or disability is random with respect to the dependant variables it can be ignored. Otherwise, probability of dropout depends upon covariates and/or previously observed response, or on current unobserved responses [13, 14].

*d. Algorithms for estimating missing data.* In one step approaches, structural equation approaches specify each pattern of missingness as a separate group, or estimates the case-wise likelihood of the observed data (suitable programs would be LISREL, EQS, Mx or AMOS). Alternative approaches involving sensitivity analyses can be run within a Bayesian framework. Two-step approaches begin by including all available data that might explain missingness. Here maximum-likelihood covariances and means are obtained and bootstrap methods are used to obtain standard

errors (programs for the latter approaches are EMCOV and NORM. Copies of relevant computer algorithms can be obtained from the following web sites:

|       |   |            |
|-------|---|------------|
| AMOS  | <a href="http://www.smallwaters.com/amos">http://www.smallwaters.com/amos</a>     |            |
| BUGS  | <a href="http://www.mrc-bsu.cam.ac.uk/bugs">http://www.mrc-bsu.cam.ac.uk/bugs</a> |            |
| EMCOV | <a href="http://methcenter.psu.edu">http://methcenter.psu.edu</a>                 | (freeware) |
| MX    | <a href="http://views.vcu.edu/mx">http://views.vcu.edu/mx</a>                     | (freeware) |
| NORM  | <a href="http://methcenter.psu.edu">http://methcenter.psu.edu</a>                 | (freeware) |

*e. Examples.* Studies referred to by Hofer that provide examples for this method are from the Newcastle Longitudinal Study of Cognitive Aging [15], the biomarker of aging study [16], and from prevention research [12].

## **VI. Designs for Studying Inter- and Intra-individual Variability**

*a. Problems in applying optimal designs.* Christoph Rott addresses the issue that ideal designs for longitudinal studies are time and resource consuming and that compromises must often be made in the real world. He calls attention to the fact that many longitudinal studies with less than ideal designs are often insufficiently exploited. Often only cross-sectional analyses are conducted on the different data points, and threats to the internal validity of the studies are not examined even when data are available.

*b. Examples of useful model misspecifications.* Rott points out some ways in which existing data sets can be more utilized by making limiting assumptions or testing strategically misspecified models. He uses the



example of the Bonn Longitudinal Study of Aging (BOLSA)[17], which remains the only large sample longitudinal study of aging in Germany, which was designed as a two-cohort cohort-sequential study. After comparing intra-individual change in the two cohorts, he concludes that time-of-measurement effects are likely to be trivial, or at least not related to systematic historical effects. He then proceeds to substitute age as the independent variable for cohort, and by treating the successive observations on individual subjects as independent sample. This approach makes it possible to use all observations and to model age gradients over a longer portion of adulthood (see also [18]). This approach works well, except for the limitation that while there is overlap across cohorts in the middle, different cohorts contribute to the age change information at the younger and older ends of his age distribution.

*c. Incorporating attrition adjustments into basic study design.*

Attention is made to the problem of attrition, by segregating data into subsamples that were retained in the study for various periods of time. This analysis shows results in agreement with previous findings [10] that subject attrition leads to overestimation of performance levels, but does not seem to effect estimates of rate of change.

*d. Introducing non-calendar related events.* Another novel empirical contribution of this paper is to implement use of event occurrence as an alternative for calendar time. Rott uses information on the onset of sensory deficit in BOLSA as an independent variable predicting decline on the

German version of the Wechsler Adult Intelligence Scale. He shows that the occurrence of severe decline in hearing leads to decline in cognitive functioning which is reversed after some time. On the other hand, severe decline in visual functioning is related to irreversible decline in cognition.

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