Operationalising resilience in longitudinal studies: a systematic review of methodological approaches

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ABSTRACT
Over the life course, we are invariably faced with some form of adversity. The process of positively adapting to adverse events is known as ‘resilience’. Despite the acknowledgement of 2 common components of resilience, that is, adversity and positive adaptation, no consensus operational definition has been agreed. Resilience operationalisations have been reviewed in a cross-sectional context; however, a review of longitudinal methods of operationalising resilience has not been conducted. The present study conducts a systematic review across Scopus and Web of Science capturing studies of ageing that posited operational definitions of resilience in longitudinal studies of ageing. Thirty-six studies met inclusion criteria. Non-acute events, for example, cancer, were the most common form of adversity identified and psychological components, for example, the absence of depression, the most common forms of positive adaptation. Of the included studies, 4 used psychometrically driven methods, that is, repeated administration of established resilience metrics, 9 used definition-driven methods, that is, a priori establishment of resilience components and criteria, and 23 used data-driven methods, that is, techniques that identify resilient individuals using latent variable models. Acknowledging the strengths and limitations of each operationalisation is integral to the appropriate application of these methods to life course and longitudinal resilience research.

INTRODUCTION
Over the life course, we are invariably faced with some form of adversity. Responses to adversity are diverse, ranging from very negative, for example, psychiatric disorder and premature mortality, to very positive, for example, thriving, and may be physiological, psychological or social in nature. The process of positively adapting to adverse events is known as ‘resilience’. Despite the acknowledgement of two common components of resilience, that is, adversity and positive adaptation, no consensus operational definition has been agreed.

Owing to the unobservable nature of the construct, resilience cannot physically be measured, only inferred via measurement of its two constituent components. Consequently, there are several ways in which these components can be operationalised to identify resilient individuals. Three popular means of operationally defining resilience in longitudinal studies are psychometrically driven, definition-driven and data-driven methods.

The majority of studies to date have examined resilience in cross-sectional studies. Longitudinal studies capture at least three waves of data and are able to provide data that illuminate trends that occur over time. Many variables are not static, interacting dynamically and changing over time; therefore, longitudinal methods must be employed to disentangle these relationships. Consequently, these studies provide greater insights into the nature of a phenomenon than is possible with cross-sectional methods or two-wave pre–post follow-up designs.

Longitudinal studies that employ psychometrically driven methods repeatedly administer previously validated resilience scales such as the widely used Connor-Davidson Resilience Scale. These methods have been developed under the assumption that resilience is a universal concept that can be operationalised uniformly across populations and age groups using a single scale. Thresholds may be applied to identify resilient individuals, but generally resilience is captured on a continuum. Whereas the definition-driven and data-driven approaches to longitudinal data are used to identify resilient individuals based on dynamic measures of adaptation, repeat observations of resilience captured by psychometric scales are used to describe continuity or change in resilience over time.

Definition-driven methods use an a priori set of criteria and components to establish which individuals are resilient. The adversity and adaptation components included in these definitions, and the thresholds used to establish which individuals are resilient, are usually determined by the researchers; generally there is no established benchmark. Within a longitudinal context, resilience may involve the continued avoidance or absence of a negative state, for example, symptoms of depression. In contrast to psychometrically driven methods, definition-driven methods are situation-specific, that is, thresholds are applied within the specific adversity–adaptation dyad examined in a given study.

Data-driven methods are used to identify resilient groups of people or levels of resilience on a continuum using statistical procedures. These methods generally employ latent variable models, such as growth mixture modelling (GMM). GMM is a person-centred latent variable modelling procedure that allows the identification of subgroups with similar outcome trajectories in samples with at least three repeated-measure data collection waves. Within the framework of resilience, individuals who function physically, mentally or socially particularly well over time, despite experiencing some sort of adversity, for example, cancer, can be identified as ‘resilient’. As with definition-driven methods, data-driven methods are specific to the adversity–adaptation dyad.

Although there have been two reviews of cross-sectional resilience metrics and measurement, a review of longitudinal methods of operationalising...
resilience has not been conducted. The aim of the current study is to systematically review studies of ageing to examine the ways in which resilience has been operationalised in longitudinal studies to deepen our understanding of how to maximise resilience in the challenges faced by an ageing population. Through an investigation of the ways in which adverse events and positive adaptations are used in resilience operationalisations, we aim to identify practical methods for characterising resilient individuals. It is hoped that by providing a comprehensive snapshot of the ways in which resilience has been operationalised, clinicians, policymakers and researchers will be better informed as to how to apply and critically evaluate these models in their own work.

METHODS

Search strategy
A systematic review was conducted across Scopus (which provides 100% MEDLINE, Embase and Compendex coverage) and Web of Science databases. Between 5 February 2015 and 11 February 2015, the search terms ‘resilience AND (ageing OR aging)’ were employed. In Scopus, article title, abstract and keywords were searched across all years. In Web of Science, ‘topics’ were searched across all years excluding books, letters, corrections, meetings or editorial, that is, non-peer reviewed articles. Additionally, reference lists and relevant articles were hand searched.

Inclusion criteria
Studies were included if they met the following criteria: (1) original peer-reviewed research, (2) operationally defined resilience, for example, quantified resilience using individual data and (3) the study was longitudinal, that is, collected at least three waves of quantitative data.7

Exclusion criteria
Studies were excluded if they met the following criteria: (1) ineligible article type, that is, conference proceeding, editorial, commentary, perspective, book chapter, book review and dissertation; (2) non-English article; (3) resilience beyond or below the level of the individual, for example, family or cellular resilience and (4) resilience as a personality trait, for example, overcontroller, undercontroller and resilient personality types.10

Screening
TDC, MS and AK conducted independent title/abstract and full-text screening. Disagreements concerning the decision to include studies in the data extraction phase were resolved via discussion.

Data extraction
Demographics, that is, age, gender distribution, sample population and study characteristics, were extracted from the included studies. Information regarding the components of resilience, that is, positive adaption, adverse event, as well as the analytical methods for quantifying resilience, for example, data-driven approach using GMM, were also collected.

RESULTS

Search
We were interested only in studies of individual-level resilience but did not identify suitable search terms to exclude studies of resilience at higher and lower level units at the title/abstract screening stage. Furthermore, we did not limit the search to studies with resilience in the results sections of articles since this also had the potential to miss relevant studies. Thus, a large number of articles (5909) were yielded at this stage. Of these, 36 met inclusion criteria (figure 1). Although there are related and potentially overlapping terms, such as resistance and adaptation, we limited our search to the specific term of resilience used by the original authors.

Included studies
Included studies (n=36) most commonly examined protective/risk factors for resilience and were conducted in the USA (n=16) with young-aged to middle-aged adults, that is, 20–40 years (table 1). Sample size ranged from 30 to 10 835 with an average of 758.69 (SD=1877.6) and median of 233.5. Studies conducted a minimum of three waves of data collection and a maximum of seven (mean=3.9; SD=3.9), with an average follow-up period of 265.4 weeks (SD=461.4 weeks). The source of adversity varied greatly; more studies included non-acute adversity, for example, cancer, than acute adversity, for example, disaster. The positive adaptations to these adverse events were less varied, generally demonstrated by low levels of psychological distress, for example, low levels of anxiety or post-traumatic stress symptoms (figure 2).

Methods of operationalisation
The majority (n=23) of studies conducted data-driven operationalisation procedures, followed by definition-driven (n=9) and psychometrically driven (n=4) methods. One study used psychologically driven and definition-driven methods, that is, using a definition to capture a group of resilient individuals and then examining the level of resilience later in these groups using the resilience scale.48

Psychometrically driven methods repeatedly employed an established resilience scale: Donohoe et al11 repeatedly administered the Prince-Embury Resiliency Scale for Children and Adolescents,49 and Fortney et al,12 Songprakun and McCann18 and Mlinac et al15 repeatedly administered the resilience scale.48

Definition-driven methods generally included the maintenance of an adaptive state throughout the duration of the study, demonstrated by lower levels of mental health problems, notably depression, than might be expected in the face of adversity. For example, in a study of bereaved spouses, resilient individuals were those who demonstrated low or no depression throughout 18 months of follow-up16 (table 2). Within the data-driven methods, several person-centred latent variable techniques, that is, statistical procedures used to group similar individuals based on a common unobserved variable, were employed: latent class analysis (n=1), longitudinal hierarchical clustering (n=2), semiparametric group-based clustering (n=3) and GMM.
Table 1 Included study demographic characteristics

| Study                              | n  | Minimum | Maximum | Mean  | SD   | Data collection waves | Length (weeks) | Country        | Female (%) | Population                     |
|------------------------------------|----|---------|---------|-------|------|-----------------------|----------------|----------------|------------|---------------------------------|
| Psychometrically driven            |    |         |         |       |      |                       |                |                |            |                                 |
| Donohoe et al                      | 11 | 33      | 14      | 12    | 12   | 3                     | 12             | Scotland       | 24.2       | Secondary school children       |
| Fortney et al                      | 12 | 30      | 40.5    | 10.1  | 4    | 12                    | 36             | USA            | 60.0       | Primary care clinicians         |
| Ritchie et al                      | 13 | 73      | 12      | 52    | 3    | 12                    | 12             | Canada         | 73.2       | First Nation youth              |
| Songprakun and McCann              | 14 | 56      | 18      | 58    | 42.1 | 9.7                   | 12             | Thailand       | 73.2       | Psychiatric outpatients         |
| Definition-driven                  |    |         |         |       |      |                       |                |                |            |                                 |
| Boe et al                          | 15 | 70      | 34.7    | 9.3   | 4    | 1274                  | 12             | Norway         | 0.0        | Disaster survivors              |
| Bonanno et al                      | 16 | 185     | 65      | 72    | 6.5  | 3                     | 72             | USA            | 79.4       | Bereaved spouses                |
| Bonanno et al                      | 17 | 185     | 65      | 72    | 6.5  | 3                     | 72             | USA            | 79.4       | Bereaved spouses                |
| Ho et al                           | 18 | 76      | 21      | 66    | 38.9 | 9.2                   | 52             | China          | 79.4       | Hereditary gastrointestinal cancer registry |
| Jaffe et al                        | 19 | 2065    | 8       | 16    | 10.96| 4.54                  | 144            | USA            | 54.0       | Maltreated children             |
| Milinac et al                      | 20 | 470     | 79.9    | 5.8   | 4    | 192                   | 12             | USA            | 74.9       | Community-dwelling older adults |
| Solomon et al                      | 21 | 94      | 16      | 3     | 21   | 1820                  | 1820           | Israel         | 94.0       | Veterans; ex-POWs               |
| Werner et al                       | 22 | 49      | 3       | 936   | 4    | 192                   | 12             | USA            | 74.9       | Offspring of alcoholics         |
| Data-driven                        |    |         |         |       |      |                       |                |                |            |                                 |
| Bonanno and Mancini et al          | 23 | 997     | 42      | 14    | 3    | 52                    | 12             | China          | 61.0       | SARS epidemic survivors         |
| Bonanno et al                      | 24 | 233     | 4       | 104   | 4    | 104                   | 12             | Austria, Germany, Ireland, Sweden, Switzerland, UK |
| deRoon-Cassini et al               | 25 | 330     | 40.4    | 15.8  | 4    | 24                    | 24             | USA            | 100.0      | Traumatic injury patients       |
| Dunn et al                         | 26 | 398     | 6       | 24    | 4    | 24                    | 24             | USA            | 100.0      | Breast cancer surgery patients  |
| Dunn et al                         | 27 | 252     | 7       | 26    | 4    | 24                    | 24             | USA            | 53.6       | Oncology patients; family caregivers |
| Galatz-Lewy et al                  | 28 | 234     | 43      | 27.42 | 4.78 | 4                     | 208            | USA            | 15.4       | Police officers                 |
| Galatz-Lewy et al                  | 29 | 234     | 43      | 27.42 | 4.78 | 4                     | 208            | USA            | 15.4       | Police officers                 |
| Holgersen et al                    | 30 | 70      | 4       | 1404  | 4    | 12                     | 12             | Norway         | 0.0        | Disaster survivors              |
| Hou et al                          | 31 | 234     | 82      | 64.44 | 10.55 | 4                     | 52             | China          | 38.0       | Colorectal cancer               |
| Lam et al                          | 32 | 285     | 50.6    | 10.1  | 4    | 32                    | 32             | China          | 100.0      | Breast cancer patients          |
| Lam et al                          | 33 | 186     | 56.2    | 9.1   | 4    | 32                    | 32             | China          | 100.0      | Breast cancer survivors         |
| Larm et al                         | 34 | 1432    | 16.5    | 1.47  | 4    | 1300                  | 12             | Sweden         | 33.8       | Clinical substance abuse; general population |
| Le Brocque et al                   | 35 | 190     | 6       | 16    | 10.7 | 2.31                  | 3              | Australia      | 37.0       | Accident victims                |
| Murphy and Marelli et al           | 36 | 111     | 6       | 11    | 8.5  | 1.8                   | 4              | USA            | 45.9       | Children of HIV/AIDS diagnosed mothers |
| Norris et al                       | 37 | 561     | 4       | 72    | 4    | 72                    | 4              | USA            | 13.4       | Flood victims                   |
| Nugent et al                       | 38 | 1267    | 4       | 120   | 4    | 120                   | 4              | USA            | 13.4       | Children referred to Family Advocacy Program |
| Pietrzak et al                     | 39 | 10837   | 45.3    | 9.6   | 3    | 416                   | 416            | USA            | 134.0      | 9/11 responders                 |
| Saad et al                         | 40 | 398     | 6       | 24    | 4    | 24                    | 24             | USA            | 100.0      | Breast cancer surgery patients  |
| Self-Brown et al                   | 41 | 426     | 16      | 11.63 | 2.26 | 5                     | 100            | USA            | 51         | Hurricane Katrina survivors     |
| Sterling et al                     | 42 | 155     | 69      | 36.9  | 12.8 | 4                     | 52             | Australia      | 63         | Whiplash patients               |
| Sween et al                        | 43 | 95      | 89      | 44.7  | 15.5 | 3                     | 52             | Sweden         | 24.2       | Burn victims                    |
| Tang et al                         | 44 | 447     | 48.9    | 12.6  | 4    | 25                    | 25             | Taiwan         | 67.8       | Caregivers of terminal patients |
| Zhu et al                          | 45 | 2172    | 45      | 65    | 4    | 312                   | 4              | USA            | 67.0       | Chronic pain                    |

POW, prisoner of war; SARS, severe acute respiratory syndrome.
identify a group of individuals who demonstrated low levels of depression over the duration of the study. Latent class analysis, longitudinal hierarchical clustering and semiparametric group-based clustering use similar approaches to GMM, that is, using latent variable models to identify groups of individuals based on similar longitudinal patterns.

**DISCUSSION**

Data-driven methods, notably latent variable models, were the most commonly used methods for operationalising resilience in longitudinal studies of ageing. Non-acute events were the most common source of adversity and the absence of psychological distress over time the most prominent source of positive adaptation. However, positive adaptation has primarily been measured by the absence of psychopathology and there have been no studies specifically measuring positive mental adaptation and well-being.

Several limitations must be acknowledged in the interpretation of these results. The present study intends to provide a comprehensive overview of methods used to capture resilience in studies that have specifically used the term ‘resilience’. Similar phrases or terms used by authors that may have intended to capture resilience, for example, hardiness or resistance, would not have been included in the present study. This may apply more to biomedically oriented disciplines where the term resilience is not as embedded in the description of responses to adversity as it is in psychologically oriented disciplines. In addition to the general resilience term, there are a number of...
modifiers that may be added to specify a particular form of resilience, for example, family resilience and biological resilience. In the interest of making direct comparisons of resilience operationalisations, only studies that specifically used the term ‘resilience’ as a standalone construct were included. Consequently, this may have prevented the inclusion of other forms of resilience and predisposed the positive adaption variables towards psychological outcomes. Although the majority of studies captured in this review examined protective factors for resilience in different stages of life and for existing studies that include resilience scales and for prospective studies, this is an effective means of operationalising resilience; however, these operationalisations are not possible for researchers using secondary data sets that have not previously administered these scales.

Psychometrically driven models of resilience used previously established, continuous measures of resilience. These models have primarily been used in cross-sectional studies and the resilience scales used have demonstrated adequate psychometric properties; however, four studies in the present review used these metrics longitudinally. Of note, these studies did not have resilience as their primary focus, but rather used resilience as one of many outcome variables. These methods are effective in that they capture a continuous measure of resilience using previously validated psychometrics and permit a high level of granularity (ie, ability to provide detailed information). For existing studies that include resilience scales and for prospective studies, this is an effective means of operationalising resilience; however, these operationalisations are not possible for researchers using secondary data sets that have not previously administered these scales.

To date, there has not been a longitudinal analysis of resilience using an established metric where resilience is the primary outcome of interest; studies have not yet examined the ways in which resilience changes and interacts with events or behaviours. Factors that shape resilience in different stages of life and the relationship of future resilience with past resilience have not been explored in the literature, which is dominated by cross-

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**Table 3 Data-driven study characteristics**

| Study                  | Adversity (population*) | Positive adaptation | Trajectory model† | Prevalence of resilience (%) |
|------------------------|-------------------------|---------------------|-------------------|-----------------------------|
| Bonanno et al23 24     | SARS epidemic survivors | High psychological and physical functioning | Anxiety (unconditional model) | 35.0                        |
| Bonanno et al25        | Spinal cord injury      | Low anxiety         | Anxiety (conditional model) | 57.5                        |
| deRoon-Cassini et al36 | Traumatic injury patients | Low depression     | Depression (unconditional model) | 58.1                        |
| Dunn et al37           | Breast cancer surgery patients | Low depression/anxiety | Depression (conditional model) | 56.3                        |
| Dunn et al38           | Oncology patients; family caregivers | Low depression | Positive mental health | 61.4                        |
| Galatzer-Levy et al34  | Police officers         | Low psychological distress | No depression/anxiety | 65–77                        |
| Galatzer-Levy et al34  | Police officers         | Low psychological distress | Low psychological distress | 67.6                        |
| Holgersen et al35      | Disaster survivors      | Positive mental health | Low psychological distress | 61.4                        |
| Hou et al32            | Colorectal cancer       | No depression/anxiety | Low psychological distress | 60.0                        |
| Lam et al34 44         | Breast cancer patients  | Low psychological distress | Low psychological distress | 66.0                        |
| Lam et al34 44         | Breast cancer survivors | Low psychological distress | Low psychological distress | 66.0                        |
| Larm et al35           | Clinical substance abuse; general population | Low psychological distress | Low psychological distress | 61.4                        |
| Le Brocque et al36     | Accident victims        | Few PTSD symptoms   | High resilience in GP | 35.0                        |
| Murphy and Marelich37  | Children of HIV/AIDS diagnosed mothers | Cognitive function, externalising behaviours, social skills | Good resilience in GP | 52.6                        |
| Norris et al38 39      | Mexican flood victims   | Few PTSD symptoms   | High resilience in CS | 47.6                        |
| Nugent et al40         | 9/11 New York residents | Few PTSD symptoms   | High to moderate resilience in CS | 24.4                        |
| Pietrzak et al41       | Children referred to Family Advocacy Program | Few PTSD symptoms | Moderate to high resilience in CS | 33.0                        |
| Saad et al42           | Breast cancer surgery patients | Few PTSD symptoms | Low psychological distress | 38.9                        |
| Self-Brown et al43     | Hurricane Katrina survivors | Few PTSD symptoms | Low neck disability | 71.0                        |
| Sterling et al44       | Whiplash patients       | Low neck disability | Low neck disability | 40.0                        |
| Sween et al45          | Burn victims            | No PTSD             | Low neck disability | 40.0                        |
| Tang et al46           | Caregivers of terminal patients | Low depression | Low resilience in CS | 11.4                        |
| Zhu et al47            | Chronic pain            | Low depression      | Low resilience in CS | 72.5                        |

*Samples were taken from populations exposed to adversity.
†Trajectory models where one or more resilience trajectories are identified.
‡Same data set used.

CS, clinical population sample; GP, general population sample; PTSD, post-traumatic stress disorder; SARS, severe acute respiratory syndrome.
sectonal research. Prospective longitudinal studies that have the capacity to disentangle these relationships will provide invaluable information on the ways in which resilience exists across the life course.

Definition-driven methods are the simplest and most easily employed methods of longitudinally operationalising resilience. These methods generally stipulated the continued absence of a negative outcome, for example, depression, during or after experiencing a negative event. More complex definitions were also identified, for example, different thresholds for subsequent waves of follow-up, as well as the development of a priori prototypical resilience trajectories. Prototypical resilience trajectories posited a decrease in functioning at the onset of an adverse event followed by a return to pre-event levels of functioning. This is an improvement on steady-state definition-driven models of resilience, as longitudinal aspects of resilience are acknowledged and included in a dynamic model. These methods can be applied in any circumstance in which an adversity–adaptation dyad using categorical or continuous variables exists, which is advantageous for researchers using secondary data. Where possible, clinically derived or previously validated cut-offs are recommended in the classification of adaptation–adversity dyads.

Shortcomings of definition-driven methods include impediments to granularity and generalisability. In studies using a binary threshold, a large degree of granularity is lost. This can be particularly problematic in longitudinal studies with older adults where individuals are unable to uphold optimal states of functioning in a binary model. Given the context-specific nature of definitions, these methods do not have a high degree of generalisability. In existing secondary data sets, the application of specific resilience definitions is limited to the variables captured in the study. This is problematic for longstanding longitudinal studies that have been collecting data for many years, but have not employed a resilience scale. Furthermore, in the absence of established benchmarks, researchers may use different thresholds for resilience limiting cross-study comparisons.

Data-driven methods employed statistical procedures to identify groups of individuals as resilient. Given that resilience cannot be directly measured, latent variable modelling techniques were employed, the most popular of these being GMM. Latent variable modelling is a meritorious method of identifying resilient individuals due to the removal of researcher-defined thresholds, that is, greater objectivity, and the ability to categorise individuals into different relative trajectories. In contrast to definition-driven methods that employ a series of components and thresholds, latent variable modelling allows group membership to be determined based on the characteristics of individuals in the sample relative to each other rather than relative to an external criterion. This is useful in unpicking different levels of resilience using person-centred methods, that is, study participants with similar performances, rather than variable-centred methods, that is, participants who perform above or below a priori threshold on a variable, as in definition-driven methods. Studies in the present review generally captured three waves of data over an average of 5 years; however, when more follow-up data waves are available, data-driven methods are better able to represent changing trajectories than definition-driven methods that posit binary states. Therefore, in circumstances with many repeat waves of data collection with continuous variables, data-driven methods are recommended over definition-driven methods in the articulation of resilience.

Several caveats must be acknowledged in the identification of resilience using GMM and other latent variable techniques. First, the identification of trajectories, although informed by objective fit indices, for example, Bayesian Information Criteria, are interpreted by the author. Other factors, such as fit to theoretical underpinnings, are also taken into account and balanced against fit indices; the final model selection is at the discretion of the author. Furthermore, the identification of trajectories is conducted only using individuals in a given sample with a specific set of demographic and cohort attributes, producing a set of trajectories specific to the study. As such, the cross-study generalisability of these methods is low.

In the identification of trajectories, the researcher dubs the trajectory as ‘resilient’ or not based on their subjective interpretation of the slope and intercept of the trajectory. Consequently, a researcher may choose to dub a trajectory ‘high functioning’ or ‘resistant’ rather than ‘resilient’ due to personal preference rather than conceptual differences. Although strides towards consensus resilience trajectory shapes have been made, through the use of definition-driven a priori prototypical trajectories, these trajectories are not necessarily employed nor do they necessarily marry with results from latent variable analyses.

The methods captured in the present review operationalise resilience using three different methods: psychometrically driven, definition-driven and data-driven. Psychometrically driven methods are generalisable, continuous measures of resilience that are applicable across studies. These studies, however, require that a resilience scale has been repeatedly administered in a study, which inhibits analysis in data sets that have not collected these data, for example, pre-existing longitudinal studies. Definition-driven methods employ situation-specific thresholds for continuous and categorical adaptation–adversity dyads. To date, these models have had low granularity due to the application of binary models and many have demonstrated limited generalisability due to study-specific constituent components of resilience and thresholds used. Data-driven methods employ person-centred statistical procedures to group similar individuals, using the granularity of continuous variables. These methods provide a level of objective classification; however, the subjectivity of model fit interpretation and situation-specific nature of the trajectories inhibits generalisability. Continued refinement of longitudinal resilience research concepts and methods, for example, through the inclusion of life course perspectives, will provide greater insights into the dynamic nature of positive adaptations to adverse events.
Theory and methods

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