Measuring posttraumatic growth and depreciation after spinal cord injury: A Rasch analysis

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Abstract

Purpose Individuals with spinal cord injury (SCI) may experience both positive (posttraumatic growth, PTG) and negative (posttraumatic depreciation, PTD) psychological changes following the injury. PTG and PTD were assessed using the 10-item short form of the posttraumatic growth inventory (PTGI-SF) and ten matched negatively worded items for PTD (selected from the PTGI-42) within Swiss Spinal Cord Injury Cohort Study (SwiSCI). This item selection is henceforth called PTG/D-SF. The objective of this study was to test the metric properties of the PTG/D-SF to determine the best strategy to derive reliable sum scores and to test the validity of several different structural conceptualizations.

Method Using cross-sectional data (N=278), a series of unidimensional and multidimensional Rasch analyses of the PTG/D-SF (N=20) were performed. Rasch analyses were conducted separately for the items or by domains to investigate dimensionality, monotonicity, item and model fit and local item dependency of the instrument.

Results The separate PTG and PTD items or their domains can be summated to form a unidimensional scale. Aggregation into domains improved the score distribution and increased the scope of the instruments. The reliability of the sum score for PTG was good (Person Separation: 0.81) the one for PTD admissible (Person Separation: 0.77).

Conclusion PTG and PTD should be understood as distinct constructs rather than two ends of a continuum. Findings support the use of a PTG total score and to some degree the PTD total score. Future work could adapt the PTD items to improve the performance of the scale.

Keywords: posttraumatic growth, spinal cord injuries, psychometrics, Rasch analysis, rehabilitation

IMPACT

- The current study is the first to examine the metric properties and dimensionality of a measure for posttraumatic growth (PTG) and depreciation (PTD) in spinal cord injury using modern test theory.
- Higher reliability is achieved with a separate scoring of the PTG and PTD dimensions which therefore must be understood as two distinct constructs.
- Clinicians and rehabilitation professionals should monitor in parallel, both, positive and negative perceived life changes after the onset of a spinal cord injury.
- Both, PTG and PTD items can be aggregated into overall sum scores and meaningfully interpreted, although the measurement precision of the PTG sum score can be expected to be higher than the one of the PTD sum score.

Introduction

Spinal cord injury (SCI) is a severe life event leading to chronic disability (World Health Organization, 2013). SCI can result in permanent paralysis and loss of sensation corresponding to the level of the spinal lesion. It affects bladder, bowel, and sexual functions and can lead to secondary health conditions, such as spasticity, chronic pain, pressure sores, cardiovascular disease, or osteoporosis (Lin, 2003). These severe physical consequences reverberate on the level of everyday activities and societal participation. Hand and arm use can be impaired, leading to limitations in eating, drinking or self-care. Work and leisure activities are often negatively influenced, work re-education, or usage of specialized transport services may be necessary (Kirshblum, Campagnolo, & DeLisa, 2002). Further, SCI may also exert a negative impact on mental health. The risk for anxiety disorders, poor quality of life, substance abuse, and suicide is elevated for people with SCI compared to the general population (Craig, Tran, & Middleton, 2009; Post & van Leeuwen, 2012).

In spite of the serious physical, social and psychological consequences, several studies showed that persons with SCI may also experience positive psychological changes following the injury, such as an increased sense of personal strength or a higher appreciation of life (e.g., Kunz, Joseph, Geyh, & Peter, 2017; McMillen & Cook, 2003). Different terms have been used to refer to this phenomenon (e.g., stress-related growth, adversarial growth), but "posttraumatic growth" (PTG) is viewed as describing best its underlying meaning (Tedeschi & Calhoun, 2004; Zoellner & Maercker, 2006). PTG has not only been observed in persons with SCI, but in many persons who have experienced a severe life event, including violent assaults or loss of a significant other (e.g., Barskova & Oesterreich, 2009; Linley & Joseph, 2004; Zoellner & Maercker, 2006).

One of the most widely used instruments to assess PTG is the posttraumatic growth inventory (PTGI; Tedeschi & Calhoun, 1996)**.** The PTGI has 21 items comprising the five domains "Relating to others", "New possibilities in life", "Personal strength", "Spiritual change", and "Appreciation of life". Besides the original PTGI, different versions of this instrument have been developed and used in research. For example, a short form consisting of 10 items (with two items each per domain) has been constructed (Cann, Calhoun, Tedeschi, Taku, et al., 2010) to reduce participant burden within large data collections. Furthermore, as a response to the critique that using the PTGI may lead to biased findings because only "positive" psychological changes are surveyed, Baker, Kelly, Calhoun, Cann, and Tedeschi (2008) constructed the PTGI-42. Next to the original 21 positively framed PTG-items, the PTGI-42 adds 21 matched but negatively worded items (example item*: I have less of an appreciation for the value of my own life*) allowing respondents to report also about negative psychological changes, termed "posttraumatic depreciation" (PTD). By assessing positive and negative changes in each domain with separate items rather than using one bipolar item, the PTGI-42 takes into account that both may co-exist (even within the very same domains).

Assessing both, PTG and PTD, can give insights not only into the resources but also into the problems and challenges that a person experiences post-trauma. Both may be relevant to plan and perform targeted psychological interventions and to support the person in the rehabilitation process. To investigate this potential clinical relevance of both, PTG and PTD, in individuals with SCI and aiming to reduce participant burden, an abbreviated version of the PTGI-42, henceforth labeled PTG/D-SF, has been used in the Swiss Spinal Cord Injury Cohort (SwiSCI) Study. This 20-item measure consists of the 10-item PTGI-SF for PTG and the 10 matched negatively worded items for PTD taken from the PTGI-42.

The scale properties of the PTGI and of its short form (both assessing PTG only) have received considerable attention in the past, without yielding clear evidence concerning dimensionality. Results of studies examining the factorial structure in various populations typically suggest that both the 5-factor model (corresponding to the five domains) as well as a 5-factor model with a second order factor offer acceptable fit regarding the PTGI (e.g., Linley, Andrews, & Joseph, 2007; Maercker & Langner, 2001; Purc-Stephenson, 2014; Saltzman, Easton, & Salas-Wright, 2015; Taku, Cann, Calhoun, & Tedeschi, 2008) and its short form (e.g., Cann, Calhoun, Tedeschi, Taku, et al., 2010; Kaler, Erbes, Tedeschi, Arbisi, & Polusny, 2011; Prati & Pietrantoni, 2014). In sum, the results of these studies leave it open whether the domain scores need to be examined separately (as suggested by the 5-factor solution without a second-order factor) or whether they can also be aggregated into a total score (as suggested by the second-order factor solution).

Considering positive *and* negative changes, as it is done with the PTGI-42, adds a further question regarding dimensionality, that is, whether PTG and PTD represent opposite poles of a single construct (i.e., posttraumatic life changes with a continuum from high positive to high negative change) or two separate constructs (i.e., two separate dimensions each with a continuum of no change to high positive or negative change, respectively) (Joseph

& Linley, 2008b). Clear-cut evidence regarding this question is lacking so far since the dimensionality of the PTGI-42 has not been tested yet. Correlational research revealed that PTG and PTD can be experienced in parallel (Linley & Joseph, 2004; Wortman, 2004), in the same domains (e.g., Baker et al., 2008; Cann, Calhoun, Tedeschi, & Solomon, 2010) and independently of each other (Frazier, Conlon, & Glaser, 2001; Solomon et al., 1999; Tedeschi & Calhoun, 2004; Updegraff, Taylor, Kemeny, & Wyatt, 2002). This suggests that PTG and PTD, even in the same domains, seem to be independent dimensions and not two ends of the same continuum. Supporting this assumption further, a hierarchical model with two higher order factors (PTG and PTD dimensions) and each with five lower order factors representing the respective domains reached an acceptable fit for the PTG/D-SF used in the SwiSCI study (Kunz et al., 2017).

The metric evaluations described above have commonly used classical test theory (CTT) to investigate the characteristics of the measure. However, in order to construct a measurement, scale calibration methodologies from the field of probabilistic measurement are more appropriate means to determine if an instrument possesses the metric properties required for valid and reliable measurement (Petrillo, Cano, McLeod, & Coon, 2015; Tennant & Conaghan, 2007).

The Rasch analysis is a probabilistic approach from the field of modern test theory that was first introduced by George Rasch in 1966 in the field of educational sciences (Rasch, 1960). In Rasch's theory, responses to a measurement scale are expected to follow a certain pattern, the Guttmann pattern, where the probability of a response is a function of the item's difficulty and the person's ability.

Rasch-based analysis has several advantages over CTT (Andrich, 1988; Tesio, 2003; Wright & Linacre, 1989). First, contrary to CTT, ordinal data that fits the Rasch model can be reliably aggregated into interval scale scores, which is required for further statistical, parametric testing or the measurement of change. Second, many methodologies are data dependent and aim to fit models to the data, the mathematical formulation of the Rasch model fits the data to the model to obtain information regarding metric properties. Third, Rasch analysis is a probabilistic methodology which places sample and test-independent estimates for the person and the items on one continuum providing hereby sample independent reliability estimates. In contrast, CTT-based reliability estimates are not robust to factors such as the test length and the distribution of the sample. Nowadays, methods from the field of modern test theory are considered to be the gold standard to determine metric properties in assessment tools as they build on more theoretically sound fundamental measurement principles and have "greater potential to solve practical measurement problems" than CTT (Embretson & Reise, 2000, p.3).

Current Study

The overall objective of the current project is to evaluate the metric properties of the PTG/D-SF and to determine the best strategy to derive reliable summary scores for future quantitative analyses by using Rasch analysis. The specific aims are:

1. to test several different structural conceptualizations of the PTG/D-SF including a unidimensional, two unidimensional, and a two-dimensional Rasch model with either the items or domains.
2. to examine the metric properties of the different conceptual structures with Rasch and to determine its reliability at scale and item level for measurement.

In doing so, the current study aims to contribute in particular to a clarification of the questions whether PTG and PTD are best conceptualized as a unidimensional construct or as two distinct constructs and whether the corresponding domains can be meaningfully aggregated into one total score. Based on a previous analysis of PTG/D-SF data in a subsample of the SwiSCI study sample, we expect PTG and PTD to be two distinct but not totally unrelated dimensions with moderate to strong correlation and good to excellent reliability of the respective total scores.

Methods

Participants and Procedure

We used data collected within the on-going inception cohort of the SwiSCI study (Post et al., 2011). The SwiSCI study collects clinical and questionnaire data (in German, French, and Italian) on individuals newly diagnosed with a traumatic or non-traumatic SCI. Eligible individuals must be admitted for clinical rehabilitation to one of the four national SCI rehabilitation centers (Spinal Cord Injury Center of the Balgrist University Hospital, Zürich; Centre for Spinal Cord Injury and Severe Head Injury, REHAB Basel; Clinique Romande de Réadaptation, Sion; and the Swiss Paraplegic Centre, Nottwil), aged 16 years or above, and permanently residing in Switzerland. Excluded are individuals with congenital conditions leading to SCI, new diagnoses of SCI in the context of palliative care, and neurodegenerative disorders such as multiple sclerosis. The SwiSCI study was formally approved by the principal ethics committee on research involving humans from from northwest and central Switzerland (covering the collaboration centers in Nottwil and Basel), the Ethics Committee Vaud (covering the center in Sion), and the Ethics Committee Zürich (covering the center in Zürich). All participants gave written informed consent.

In the inception cohort of the SwiSCI study, data is collected at four measurement time points during clinical rehabilitation: one, three, and six months after injury diagnosis and at rehabilitation discharge. For our secondary data analysis, we only used cross-sectional data from the discharge assessment. All SwiSCI participants who completed their clinical rehabilitation until May 29, 2017 were considered for the analysis. However, not all eligible individuals participated in the SwiSCI study and some dropped out before the discharge assessment. The corresponding participant flow is depicted in Appendix 1. The study's reporting is based on the STROBE statement (von Elm et al., 2007).

Measures

PTG. As part of the PTG/D-SF, PTG was measured with the short form of the Posttraumatic Growth Inventory (PTGI-SF, Cann, Calhoun, Tedeschi, Taku, et al., 2010) in the SwiSCI study. The PTGI-SF consists of 10 items that ask respondents to report the degree to which they perceive positive changes resulting from SCI. Two items each refer to one of five domains: 'Relating to others' (items: 'distance' & 'people'), 'New possibilities in life' (items: 'way' & 'life'), 'Personal strength' (items: 'difficulty' & 'strong'), 'Spiritual change' (items: 'religion' & 'belief'), and 'Appreciation of life' (items: 'priority' & 'esteem'). The questions of the PTGI-SF that correspond to the labels used in the brackets can be found in Appendix 2. The response options for these items range from 0 (*I did not experience this change*) to 5 (*I experienced this change to a very great degree*).

In previous research, sum scores for each of the five PTGI-SF domains (each having a possible range of 0 to 10) and an overall sum score (possible range from 0 to 50) have been used. Relying on CTT, admissible reliability (i.e., Cronbach $\alpha > .70$) of the domain scores (despite consisting of only two items each) and good reliability of the overall score (i.e., $\alpha > .80$) was reported (Cann, Calhoun, Tedeschi, Taku, et al., 2010).

PTD. PTD was assessed with 10 negatively worded items corresponding to the 10 positively worded items of the PTGI-SF (see Appendix 2 for specific wording). Accordingly, we used the same labels as for the PTG items to refer to these items which were selected from the broader PTGI-42 (Baker et al., 2008). Relying on CTT, admissible reliability (i.e., $\alpha > .70$) of all the PTD domain sum scores (consisting of two items each), except for the reliability of the relating to others score ($\alpha = .61$), and good reliability (i.e., $\alpha > .80$) of the PTD overall sum score (consisting of 10 items) was reported (Kunz et al., 2017).

Language versions in the SwiSCI study. The PTGI (Tedeschi & Calhoun, 1996) and its variants were originally developed in English. In the SwiSCI study, existing validated German, French, and Italian versions of the PTG measurement instruments were used (Lelorain, Bonnaud-Antignac, & Florin, 2010; Maercker & Langner, 2001; Prati & Pietrantoni, 2014). Concerning PTD, items in German, French, and Italian were not available and therefore translated from the English original scale (Baker et al., 2008) using a forward translation procedure. Next, the resulting three language versions of the PTG/D-SF were harmonized in parallel in group sessions by bilingual persons, because both validated PTG items and translated PTD items were not necessarily consistent, although based on the same English original measure (Baker et al., 2008). Minor revisions consisted of deleting or adding some single item subsets or word replacements. The English original measure served as point of reference in this harmonization process.

Data Analysis

In response to the inconsistent findings concerning dimensionality, a series of Rasch analyses were conducted (Figure 1). The items of the PTG/D-SF were analyzed with the Partial Credit Model (PCM; Masters, 1982), a special type of Rasch model which is used with polytomous rating scales. The PCM assumes that the distances between thresholds of adjacent response options can vary within and across rating scales. All analyses were conducted in R (R Core Team, 2015), using the package eRm (Mair, 2007) for the unidimensional Rasch analyses, and the package TAM (Robitzsch, Kiefer, & Wu, 2018) for the multidimensional Rasch analyses.

First (Step 1), the 20 items making up the PTG/D-SF were submitted conjointly to unidimensional Rasch analyses using two different conceptualizations, an analysis of the 20 items as such (Model 1a) and an analysis of the domain scores (Model 1b) which were built by summing up the item scores from a common domain (see *Measures* section), as pairwise associations of items from the common domains (e.g., Relating to others) within the PTG and the PTD dimension were expected due to their specific conceptual overlap. Second (Step 2), two separate unidimensional PCMs were tested, with PTG representing one and PTD the other potentially distinct dimension (Model 2a). Next, the items from common domains from each potential dimension of the PTG/D-SF (i.e., PTG and PTD, respectively; Model 2b) were aggregated and submitted to separate unidimensional Rasch analyses. Third (Step 3), two multidimensional Rasch analyses, with either items or domains were performed. The multidimensional Rasch analysis accounted for the two potential dimensions of the PTG/D-SF. Multidimensional Rasch analysis can be used, when several known, but not totally independent, dimensions are expected within a latent construct. The multidimensional Rasch analysis will then test if, to some extent, PTG and PTD could be represented by a higher-level construct, such as, for example here, posttraumatic life change. Analogous to the previous Steps 1 and 2, the first multidimensional model (Model 3a) used the items, the second model again aggregated the items by domains (Model 3b). A graphical illustration of our modeling approach is depicted in Figure 1.

When doing a unidimensional Rasch analysis, a series of metric assumptions, that would negatively impact the validity of a scale for measurement if not taken into account, have to be verified. Besides the item and the model fit, assumptions such as the dimensionality, response monotonicity, person-item targeting, local item dependency, and differential item functioning need to be tested.

Dimensionality of a scale can be assessed through different means. In the present analysis, a principal component analysis of the standardized Rasch residuals will support the analysis of the dimensionality of the items. First eigenvalues > 2 are considered as substantial and indicative of multidimensionality (Raîche, 2005), unidimensionality is supported with first eigenvalues < 1.5, which is a more critical cut-off (Linacre & Tennant, 2009). Additionally, items can be grouped according to their positive or negative loading on the first residual PCA factor. These two subgroups of items are then submitted separately to a Rasch analysis and the person estimates, and their measurement error are then compared individually using dependent t-tests. The expected percentage of significant t-tests due to chance lies at 5%. A percentage and upper confidence interval (CI) below 5% are expected to support the unidimensionality of the scale (Smith, 2002).

Monotonicity of the rating scales assumes that response options appear strictly ordered from 0 meaning that the person did not perceive a certain change to 5 meaning that the person perceived change to a very high extent after SCI. The PCM analysis computes the response thresholds, which are the equal probability points between adjacent response options. In presence of ordered thresholds, one can assume that the monotonicity of a rating scale is supported. When, for some reason, thresholds appear disordered the adjacent levels of a rating scale can be collapsed and the PCM analysis rerun until all rating scales of the instrument present a monotonic ordering.

Targeting: A well targeted metric presents a mean item difficulty and mean person ability close to zero on the continuum of the construct indicating that the measurement instrument has the right scope to assess the population in question well. Further, the proportion of persons with abilities below the smallest item difficulty or above it should not exceed 15% to meet standards and indicate a good targeting of the model (McHorney & Tarlov, 1995).

Local item dependency (LID) indicates response dependency between items, which may bias the item and model fit estimates (Yen, 1993) and impact on the dimensionality (Marais & Andrich, 2008). LID is often caused by response redundancies in an assessment with items addressing similar aspects of a latent trait. Correlations of standardized item residuals above .2 are indicative of a local dependency between items. In presence of locally dependent items, a testlet strategy could be adopted which creates one single item in aggregating the correlated items by summing their respective scores. Our domain-based approach also aggregates the items from a common domain. However, these are not strictly speaking testlets, as the respective items are not expected to correlate statistically above a fixed threshold but are aggregated based on a conceptual reasoning only. With testlets that aggregate dependent items, ordering of thresholds is no longer expected (Andrich, 2006).

Differential Item Functioning (DIF) implies that the item difficulties are not invariant across sample characteristics. In the present study we investigated DIF for injury characteristics (completeness and level of injury) as well as person characteristics (sex, age, and language). In presence of DIF the response probability differs systematically for a given person ability. This is often considered a measurement bias which may indicate favoritism in a sample's subgroup (Holland & Wainger, 1993). DIF adjustment often requires to split items, that is, creating items where the difficulty gets adjusted for the significant sample characteristic (Andrich & Hagquist, 2015; Hagquist, Bruce, & Gustavsson, 2009). However, considering that DIF is a conditional property where causal pathways between the group factor and an item are not always clear, scale preservation can be prioritized against group specific scale adjustments to preserve the homogeneity of the scale and its applicability across the entire population.

Item and model fit are expected to support the validity of a metric. The fit of the items is given with the infit statistic which is a less outlier sensitive fit statistic derived from the analysis residuals. More specifically the infit statistic corresponds to the mean squared standardized residuals. Good fitting items are expected to present infit values close to 1, at least between 0.8 and 1.2 (Wright, Linacre, Gustafson, & Martin-Löf, 1994).

To determine the fit of the models, the internal consistency of the unidimensional and multidimensional Rasch models will be examined based on their reliability, which is determined 1) by the person separation reliability (PSR), which gives the reliability of the overall model basing on the Rasch ability estimates and their variance, and 2) by the Warm's weighted likelihood estimator, which provides the reliability of the Rasch estimates in each dimension. Both indices range from 0 to 1 (Wright & Stone, 1979) and can be interpreted in the same way as Cronbach α. The minimum acceptable PSR-value is 0.7 for the use of a metric at group level. For measurement at individual level, a PSR of at least 0.85 is expected (Tennant & Conaghan, 2007). Further the fit of the unidimensional and multidimensional models will also be described based on deviations of the expected from the true observations using the root mean squared deviation (RMSD). The RMSD can also be used to compare the fit of a multidimensional Rasch model with the fit of a nested unidimensional model (Adams, Wilson, & Wang, 1997). RMSD values < .05 indicate a good model fit, .05 < RMSD < .08 value indicate moderate model fit and RMSD > .08 a poor model fit. RMSD change in fit can be compared across nested models with an ANOVA. The RMSD gives an estimate of the degree of fit of the data to the Rasch assumptions which can in turn be used to compare nested models in order to determine the best fitting modeling approach.

Persons with at least 20% responses to the PTG/D-SF scale or dimension (i.e., PTG and PTD) entered the analysis. However, the percentage of persons with more than 50% of missing was low (2%). Remaining missing values were not imputed. One of the most important properties of the Rasch analysis is the specific objectivity which assures that all estimated difficulty parameters are sample independent (item parameter invariance) and all latent trait related parameters are independent of the items used for estimation (person parameter invariance). In that sense it can be expected that Rasch estimation is consistent even on an incomplete dataset, whatever the type of missing data (Hardouin, Conroy, & Sebille, 2011).

Results

The sample counted 342 participants. A total of 278 participants with at least 20% responses to the PTG/D-SF were included in the analyses (Appendix 1). Of these, 81.7% filled in the German, 14.7% the French, and 3.6% the Italian version of the SwiSCI questionnaire. Socio-demographic and lesion-related characteristics of the analyzed sample can be found in Table 1. The proportion and percentage of responses, including missing responses for the items measuring PTG and PTD are shown in Appendix 2.

Table 2 shows the results at model level, including the information about the number of observations entered in the analysis, the number of dimensions, the targeting (item and person mean, threshold range, floor and ceiling effects), model reliability, dimensionality, and model fit. More detailed information about the difficulty, fit, difficulty rank, threshold ordering, results of the principal component analysis and local item dependencies are shown in Appendix 3.

Step 1

Model 1a: Item-based unidimensional Rasch analysis of the PTG/D-SF.

Dimensionality: The results of the PCM analysis of the PTG/D-SF including all the items indicated strong multidimensionality with 17.0% of significant t-tests. The PC1 loadings emphasized and confirmed the two dimensions of the PTG/D-SF, where PTG items’ PC1 loadings were positive and most PTD items presented negative PC1 loadings. The only exception was the ‘religion’ item of the PTD dimension which loaded positively on the PTG dimension. However, this item’s PC1 loading was close to zero (PC1 loading = .02).

Monotonicity: The analysis of the PTG/D-SF indicated disordered thresholds for all items. At this stage, no response option recoding strategy was undertaken, as it could be expected that the scale is multidimensional, and a unidimensional co-calibration of all items of the two dimensions would not be further supported. Further, it is known that threshold disordering is often caused by the multidimensionality and item dependencies (Sideridis, 2011; Yen, 1993).

Targeting: The mean item difficulty and person ability were about half a logit away. Five persons presented the lowest possible score when using all items for calculating the row scores. After the Rasch analysis the percentage of persons with abilities below the easiest item difficulty was 11.9%, indicating a small floor effect, and a higher proportion of participants reporting to perceive no or very small change in any direction as a result of their SCI.

Local item dependency: Several locally dependent items with residual correlations > .2 were found. However, no LID was observed across PTG/D-SF dimensions, only within. The PTG questions for ‘esteem’, ‘priority’, ‘way’, ‘life’, and ‘difficulty’ correlated and the PTD questions for ‘religion’ and ‘belief’ correlated. The correlational structure and the strength of the associations are shown in Figure 2.

Item Fit: The PCM analysis of the items resulted in poor fit, that is infit > 1.2, for the ‘esteem’ (PTG) item.

Reliability: The person separation reliability was good in the analysis with all the items (α = .89, PSR = .88).

DIF. Uniform-DIF for person or injury characteristics was not found.

Model 1b: Domain-based unidimensional Rasch analysis of the PTG/D-SF.

Dimensionality: The multidimensionality issue, as indicated by 24.3% of significant t-tests, remained, even increased, in the analysis of the PTG/D-SF using the domains. Here also, the loadings on the first component confirmed the dimensional structure of the instrument. One exception were the 'Spiritual change' domain items of the PTG dimension which showed loadings close to 0 on this dimension.

Targeting: The mean item difficulty and person ability were about half a logit away. After the Rasch analysis the percentage of persons with abilities below the easiest item difficulty was only 2.9%, supporting a better targeting and the absence of any floor effect when item scores were aggregated by domains.

Local item dependency: Most of the local dependencies found in the previous Model 1a got absorbed when aggregating the items into domains. Still, the 'Personal strength' and 'New possibilities in life' domains of the PTD dimension were locally dependent with $r = .27$.

Item fit: Domain-based analysis presented only good fitting domains with infit values within the expected boundaries.

Reliability: The person separation and the reliability were good in the analysis with domains (PSR = .85; α = .84). Recoding of items improved the scope and the reliability of the metric. However, interpretations at this stage are biased by the significant multidimensionality of the item and domain analyses (Baghaei, 2008).

DIF. Uniform-DIF for person or injury characteristics was not found.

Step 2

Model 2a: Item-based unidimensional Rasch of each PTG/D-SF dimension.

Dimensionality: The lower CI-bound of the t-tests addressing the dimensionality question were all < 5% and the first eigenvalues were below 2 which supports the unidimensionality of the PTG and the PTD dimension, respectively.

Monotonicity: Disordering of thresholds was an issue in both dimensions and concerned all the items. One recoding strategy leaving three response thresholds instead of six was applicable to both PTG/D-SF dimensions (0->0, 1->0, 2->1, 3->1, 4->1, 5 ->2) and solved the disordering for all items across both dimensions (Figure 3).

Targeting: Both, the PTG and the PTD dimension presented a floor effect before and after the recoding of the items. The difference between mean item difficulty and mean person ability was below 0.5 logit in the non-recoded analyses of the PTG dimension and above one with recoded items (logit difference = 1.18). With regards to the PTD dimension, the recoding of items also increased the difference between the mean item difficulty and the mean person ability, the difference being above 1.5 logit (logit difference = 1.73). Recoding of the items affected the targeting and increased the number of persons with a lowest possible score, and thereby the number of observed floor effects after the PCM analysis, especially in the PTD dimension. In both dimensions, these effects were always in the direction of no perceived changes after the SCI. Recoding of items improved the scope of the metric.

Local item dependency: Some residual correlation was found between the 'belief' and 'religion' items of the PTG dimension (r = .44) as well as in the PTD dimension (r = .26). For both dimensions, the recoding strategy, which aimed to solve the disordering with one single strategy, had no effect on the LID, the 'belief' and 'religion' items remained locally dependent, in both, the PTG and the PTD dimension.

Item Fit: The item fit in the PTG dimension was good for all items and only one item of the PTD dimension, 'people' (infit = 1.33), presented an underfit beyond the boundaries for acceptable fit. The misfit observed in the PTD dimension for 'people' remained in the analysis with recoded items (infit = 1.31).

Reliability: The analysis of the PTG dimension resulted in good reliability when keeping the original item encoding (PSR = .84, α = .86) and with recoding of the response options (PSR = .81, α = .84). For the PTD dimension, the reliability measured by the PSR and the Cronbach α was only good in the analysis with the unrecoded items (PSR = .83 and α = .86). The Cronbach α was also good for the recoded model (α = .82) but the PSR was only admissible (PSR = .75).

DIF: The 'difficulty' item of the PTG dimension showed uniform language DIF (French against German translation of the item). The language DIF did not occur anymore in the analysis with recoded items. All other person or injury characteristics included in the DIF analysis, that is, gender, age, injury completeness and injury level, did not affect the functioning of the PTG/D-SF items.

Model 2b: Domain-based unidimensional Rasch of each PTG/D-SF dimension.

Dimensionality: When calibrated by domains, the proportion of significant t-test was < 5% and the first eigenvalues were < 2, supporting the unidimensionality of the PTG and the PTD dimension, respectively.

Targeting: The use of the domains instead of the items clearly improved the targeting of the PTG dimension, from 11.9% detected participants with abilities below the lowest difficulty in the item analysis to 2.9% in the analysis with the domains. Such an improvement was also observed in the PTD dimension. Nonetheless, a significant floor effect remained in this latter dimension even after aggregation by domains, as indicated by 28.1% of the participants showing abilities below the lowest item difficulty. The targeting of the scales was good for the analysis of the PTG dimension with domains since differences between the mean item difficulty and mean person ability were below 0.5 logit. The targeting in the PTD dimension was a little less favorable with differences of 0.65 logit, indicating again a higher percentage of participants experiencing no changes after their SCI. The biggest change among PTG and PTD domains was reported for the 'Appreciation of life' and the least for 'Spiritual changes'. The analysis with domains instead of items improved the scope of the metric.

Local item dependency: No remaining LID was found between domains of the PTG or PTD analyses.

Item Fit: Also, the analyses by domains resulted in good fit for all the domains and in both dimensions.

Reliability: The analysis of the PTG dimension resulted in good reliability in the domain-based model (PSR = .81, α = .82). For the PTD dimension, the reliability measured by the PSR and the Cronbach α was good (α = .80) but the PSR was only admissible (PSR = .77). Here again, it can be expected that the low PSR was due to the skewed distribution of the scores, with floor effects when aggregating the items from a domain.

DIF: No DIF was observed in the analysis with domains.

Step 3

Model 3a: Item-based multidimensional Rasch of the PTG/D-SF.

Monotonicity: The multidimensional Rasch analysis of the PTG/D-SF scale with two separate dimensions resulted in threshold disordering for all items. No single recoding strategy allowed to solve the disordering of all the items. The best strategy, different from the strategy applied in Step 2, was 0->0, 1->0, 2->1, 3->2, 4->2, 5->2. However, seven items, with one exception, all from the PTD dimension, still presented disordered thresholds: 'religion' (PTD), 'distance' (PTD), 'difficulty' (PTD), 'life' (PTD), 'belief' (PTD and PTG), 'strong' (PTD).

Targeting: The differences between the mean item difficulties and the mean person abilities was below 0.5 logit in the model without recoding, indicating good targeting.

However, the floor effects did not disappear in the multidimensional context and the proportion of persons in the extremes of the PTD dimension remained high (15.1%) and increased for both dimensions with the recoding of the items (PTG: 23.4%; PTD: 66.6%).

Item Fit: The two-dimensional analysis with items resulted in underfit only in one of the 20 items. The PTD 'people' item, with original coding and when applying the recoding strategy showed an infit > 1.2, that is, 1.32 and 1.22, respectively.

Reliability: The reliability of multidimensional models is depicted by dimension in Table 3. The PTG dimension presented a better person separation reliability. While the reliability of the PTG dimension was admissible to good without and with recoding of the item thresholds (PSR = .80; PSR recoded = .75), the PTD dimension presented inadmissible to poor person separation reliability (PSR = .6; PSR recoded = .52).

Model fit: The model fit was moderate for the multidimensional conceptualization with the 20 items (RMSD = .07) and their recoded version (RMSD = .06). The correlation between the item-based PTG and PTD dimensions was $r = .64$ before and $r = .67$ after recoding.

Comparing the unidimensional model with all items in Step 1 to the corresponding multidimensional model with two dimensions in Step 3 revealed a significant difference in model fit, as the ANOVA test comparing the two models based on a likelihood ratio test was significant ($\chi^2(2) = 287.69$, $p < .001$). The change in the RMSD, however, indicated a deterioration of the quality of the model fit when applying the multidimensional model instead of the unidimensional model.

Model 3b: Domain-based multidimensional Rasch of the PTG/D-SF.

Targeting: The targeting was good and the aggregation by domains did not lead to high proportions of person ability estimates below the lowest threshold after the two-dimensional Rasch analysis.

Item Fit: The two-dimensional analysis with domains resulted in low fit for the 'Spiritual change' domain, in both the PTG and the PTD dimension, that is, infit values of 1.36 and 1.31.

Reliability: With the domain aggregation, the reliability of the PTG dimension was admissible (PSR = .77), but the person separation reliability of the PTD dimension further dropped to an inadmissible level (PSR = .45).

Model fit: The model fit was good for the multidimensional conceptualization with domains (RMSD = .05). The domain-based PTG and PTD dimensions correlated with $r = .61$.

Comparing the unidimensional model with domains in Step 1 to the corresponding multidimensional model with two dimensions in Step 3 resulted also in a significant change in the model fit, as the ANOVA test comparing the two models based on a likelihood ratio test was significant ($\chi^2(2) = 224.94$, $p < .001$). However, the direction of the change was in favor of the item-based analysis, not towards the multidimensional conceptualization.

Discussion

The present study examined the psychometric properties of the PTG/D-SF (i.e., an item set corresponding to the PTGI-SF and 10 matched negatively phrased items selected from the broader PTGI-42) in a sample of individuals with SCI by testing and comparing a series of Rasch models. The results of these Rasch analyses supported our hypothesis that treating PTG and PTD as two different concepts (Step 2) reflects the structure of the PTG/D-SF better than assuming a common latent trait for PTG and PTD. A unidimensional analysis of both, the PTG and the PTD items together (Step 1), results in multidimensionality with the items loading distinctly on either the PTG or the PTD dimension. However, although the PTG and PTD dimension correlated at least moderately ($r > 0.6$), accounting for the correlation in a multidimensional Rasch approach (Step 3) resulted in poor reliability and a lower model fit as compared to the separate calibration of the two dimensions. This finding supports and expands previous research indicating that PTG and PTD should be understood as distinct constructs rather than two ends of a continuum. Together, these findings also support Baker et al. (2008) who created the PTGI-42 in such a way that individuals are enabled to independently report PTG and PTD in the same domains.

The finding that PTG and PTD are best conceptualized as separate dimensions is also consistent with the organismic valuing theory of PTG (Joseph & Linley, 2005, 2008a). This theory proposes that an individual can process trauma-related information in different ways with regards to the various facets of his or her self-structure and worldviews. Accordingly, it is well possible that some of these facets are positively altered, whereas other facets are negatively altered or remain unchanged as a result of the coping process. Therefore, the presence of PTG in one of the domains should not necessarily be taken as an indication for the absence of PTD, or vice versa, because both can co-exist at the same time in the same individual. Consequently, a comprehensive assessment of an individual's reactions to potential trauma in clinical research and practice requires that both, PTG and PTD, are considered separately (Linley & Joseph, 2004).

Overall, the results of the present study lend some support for the use of the PTG/D-SF to accomplish such a comprehensive assessment of reactions to potential trauma like SCI onset. The results of the separate PCMs for the PTG and the PTD dimension suggested that for both, PTG and PTD, the items or the domains can be summated to form a unidimensional scale. Aggregation into domains improved the score distribution and increased the scope of the instruments with a bigger range of threshold difficulties (Model 2b). The analysis of the PTG dimension by domains also improved the unidimensionality and solved the local dependency between the 'belief' and 'religion' items. Dimensionality of the PTD dimension was good in all analyses. The domain-based analysis of the PTD dimension presented good fit statistics unlike the item-based analysis where the 'people' item was not fitting. The reliability of the item analysis may seem better but could be expected to be artificially inflated due to the local item dependencies (Baghaei, 2008). As such, our findings support previous work (e.g., Cann, Calhoun, Tedeschi, Taku, et al., 2010; Linley et al., 2007) suggesting that the individual domains of PTG (and PTD) can be meaningfully aggregated into an overall total score for each.

The results of the DIF analyses revealed that the PTG/D-SF items or domains generally discriminated equally across different sample characteristics (i.e., across categories of injury completeness and level, sex, age, and language of the questionnaire). This suggests that the measure does not systematically favor specific subgroups. The only exception was that the PTG 'difficulty' item showed uniform language DIF (French against German) in one of the tested models. It is possible, that this result could be caused by a little variation in the formulation of the item.

Nonetheless, several issues need to be mentioned. First, while the reliability (as indicated by the PSR) of the sum score for PTG was good, the one for PTD was only admissible. The skewness of the person ability distributions with a high frequency of participants reporting that they did not perceive any change in most of the PTD items can be one reason for the low reliability. The presence of such skewed distributions may result in inflated error variance due to the high number of extreme scores which then affects the computation of the PSR more than the Cronbach α, which remains more constant (Andrich, Salatino, Converti, & Saruggia, 2015). In addition, it has been argued that the PTD scale may perform worse than the PTG scale because the items were created in the original PTGI-42 by simply mirroring the PTG-items linguistically but not based on individual narratives, literature reviews, or clinical expertise (Oshiro et al., 2019). These potential shortcomings in the creation of the PTD items may also serve as an explanation for why high PTD scores were seldom observed in the current study and also in previous work with other populations (e.g., Baker et al., 2008; Barrington & Shakespeare-Finch, 2013; Kroemeke, Bargiel-Matusiewicz, & Kalamarz, 2017; Michelsen, Therup-Svedenlof, Backheden, & Schulman, 2017).

A second notable issue was that, with regards to both, the PTG and the PTD scale, some local item dependencies were detected. In particular, the items referring to religious and spiritual changes were locally dependent in both scales. This suggests that these items measure something specific that cannot be explained by the common latent PTG or PTD trait. These results lend empirical support to a theoretical critique that positive changes in religion and spirituality should not be conceptualized as part of the PTG construct (Joseph, 2011). More specifically, Joseph (2011) recommended to exclude changes in spirituality and religion from the PTG concept because their inclusion leads to a confusion over the direction of change that is experienced as growthful: for some individuals increases in religion and spirituality may be considered as PTG, whereas others consider decreases in religion as PTG. Supporting this notion and corroborating our results, a recent study examining Japanese students demonstrated that in contrast to all other PTG items, which were judged as positive by the vast majority, a substantial proportion (31%) of the individuals judged the item “I have a stronger religious belief” as representing a negative change. Similarly, 35% judged the item “I have a weaker religious faith” as a positive change. In sum, it may indeed be advisable to exclude religious and spiritual changes from the PTG and PTD constructs. In doing so, it may be particularly interesting to consider a recent updated version of the PTGI (Tedeschi, Cann, Taku, Senol-Durak, & Calhoun, 2017) in which the original ‘Spiritual change’ domain was enriched by adding four items that refer to existential changes (e.g., I have greater clarity about life’s meaning) rather than tapping spiritual change in a more traditional, religious sense such as the original two PTGI items do. Accordingly, these four new items may perform better in secular cultures like the one in Switzerland. However, further research in different cultures is needed to strengthen such a claim.

Limitations

This study is subject to several limitations. It bases on PTG/D-SF ratings from 278 persons with SCI. Though good enough to conduct Rasch analysis, it may have led to very unequal group distributions when examining DIF (e.g., lesion type, language groups), with findings that are potentially not robust at some group levels. Second, our focus was on an SCI sample, and the generalizability to other populations experiencing different critical life events will require further investigation. However, this study was the first adopting a modern test theory approach with Rasch analysis when examining the metric criteria of a PTGI-related measure. Therefore, a more in depth understanding of the "behavior" of the PTG/D-SF items can be expected as well as strengths and weaknesses in the use of the PTG/D-SF can be anticipated. Third, convergent and divergent validity (e.g., associations with indicators of mental health or well-being) were not investigated, since this was part of a previous study at our institution (Kunz et al., 2017).

Conclusion

This is the first study examining the metric quality of the PTG/D-SF measure using a modern test theory approach. The study complements investigations that have so far relied upon a CTT approach when investigating the properties of the different versions of the PTGI. Overall, findings support the use of a PTG total score and to some degree the PTD total score. Hence, more research may be needed to improve the PTD scale. To do so, future work could adapt the PTD items by considering individual narratives and reviewing the literature. Also, the inclusion of the 'belief' and 'religion' items into both, the PTG and the PTD scales, may need to be reconsider

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Tables

Table 1

Descriptive statistics of the analyzed sample (N = 278)

	Socio-Demographic Information
	***M* (SD)**
Age (yrs)	54.11 (16.56)
Months since SCI at discharge	5.26 (2.86)
Gender	***n* (%)**
Male	187 (67.3)
Injury level and type	***n* (%)**
Complete paraplegia	27 (10.9)
Complete tetraplegia	11 (4.5)
Incomplete paraplegia	124 (50.2)
Incomplete tetraplegia	74 (30.0)
Intact	9 (3.6)
Unknown	2 (0.8)
SCI Cause	***n* (%)**
Non-traumatic	118 (42.4)
Traumatic	157 (56.5)
Unknown	3 (1.1)

Table 2

Model fit statistics including the information about the data entered in the analysis and estimation algorithm, item location, person location, threshold range, floor and ceiling, reliability, dimensionality test and model fit

							Item Location		Person Location		Threshold Range		Targetting		Reliability		Unidimensionality Paired *t*-tests	Model Fit
Analysis Step	Model	Conceptualization	*n*	Number of Dimen-sions	Number of Items	Coding Strategy	*M*	*SD*	*M*	*SD*	Min	Max	Floor	Ceiling	PSR	Alpha	% Sig t-test	RMSD
Step 1	1a	PTG/D-SF item analysis	278	1	20	0 1 2 3 4 5	0.00	0.70	-0.60	0.60	-1.4	2.07	11.87%	0.00%	0.88	0.89	17.01% [15.11% : 17.98%]	0.04
	1b	PTG/D-SF domain analysis	278	1	10	0 1 2 3 4 5	0.05	0.62	-0.41	0.44	-1.7	2.14	2.88%	0.00%	0.85	0.84	24.26% [22.53% : 25.14%]	0.03
Step 2	2a	PTG	278	1	10	0 1 2 3 4 5	0.06	0.75	-0.32	0.69	-1.2	2.33	11.87%	0.00%	0.84	0.86	6.62% [4.47% : 7.72%]	0.03
	2a	PTG recoded	278	1	10	0 0 1 1 1 2	0.46	1.63	-0.72	1.47	-2.5	2.66	20.86%	1.80%	0.81	0.84	0% [0%[a] : 1.54%]	0.05
	2b	PTG domain analysis	278	1	5	0 1 2 3 4 5	0.12	0.67	-0.21	0.53	-1.5	2.31	2.88%	0.00%	0.81	0.82	1.35% [0% [a] : 2.25%]	0.02
	2a	PTD	277	1	10	0 1 2 3 4 5	0.03	0.57	-0.79	0.70	-1	1.27	44.77%	0.36%	0.83	0.86	1.68% [0% [a] : 2.92%]	0.04
	2a	PTD recoded	277	1	10	0 0 1 1 1 2	0.34	1.19	-1.39	1.20	-1.4	1.96	60.65%	0.36%	0.75	0.82	2.35% [0% [a] : 3.82%]	0.02
	2b	PTD domain analysis	278	1	5	0 1 2 3 4 5	0.08	0.56	-0.57	0.50	-1	1.76	28.06%	0.00%	0.77	0.80	2.07% [0% [a] : 3.19%]	0.04
Step 3	3a	PTG	278	2	20	0 1 2 3 4 5	-0.08	0.10	-0.03	0.68	-1.6	1.65	1.80%	1.08%	0.80	*n.a.*	*n.a.*	0.07
		PTD					0.12	0.13	-0.03	0.84	-1	1.23	15.11%	4.32%	0.60	*n.a.*	*n.a.*	
	3a	PTG Recoded	278	2	20	0 0 1 2 2 2	0.53	0.38	0.01	1.12	-0.9	1.28	23.38%	12.59%	0.75	*n.a.*	*n.a.*	0.06
		PTD Recoded					1.16	0.26	0.24	1.00	0.64	1.81	66.55%	6.12%	0.52	*n.a.*	*n.a.*	
	3b	PTG domain analysis	278	2	10	0 1 2 3 4 5	-0.02	0.03	0.03	0.54	-1.4	1.67	1.80%	0.36%	0.77	*n.a.*	*n.a.*	0.05
		PTD domain analysis					0.06	0.07	0.09	0.56	-1.1	1.53	0.00%	0.36%	0.50	*n.a.*	*n.a.*	

Note. n.a. = not applicable.

[a] negative lower confidence interval bounds were set to zero.

Figures

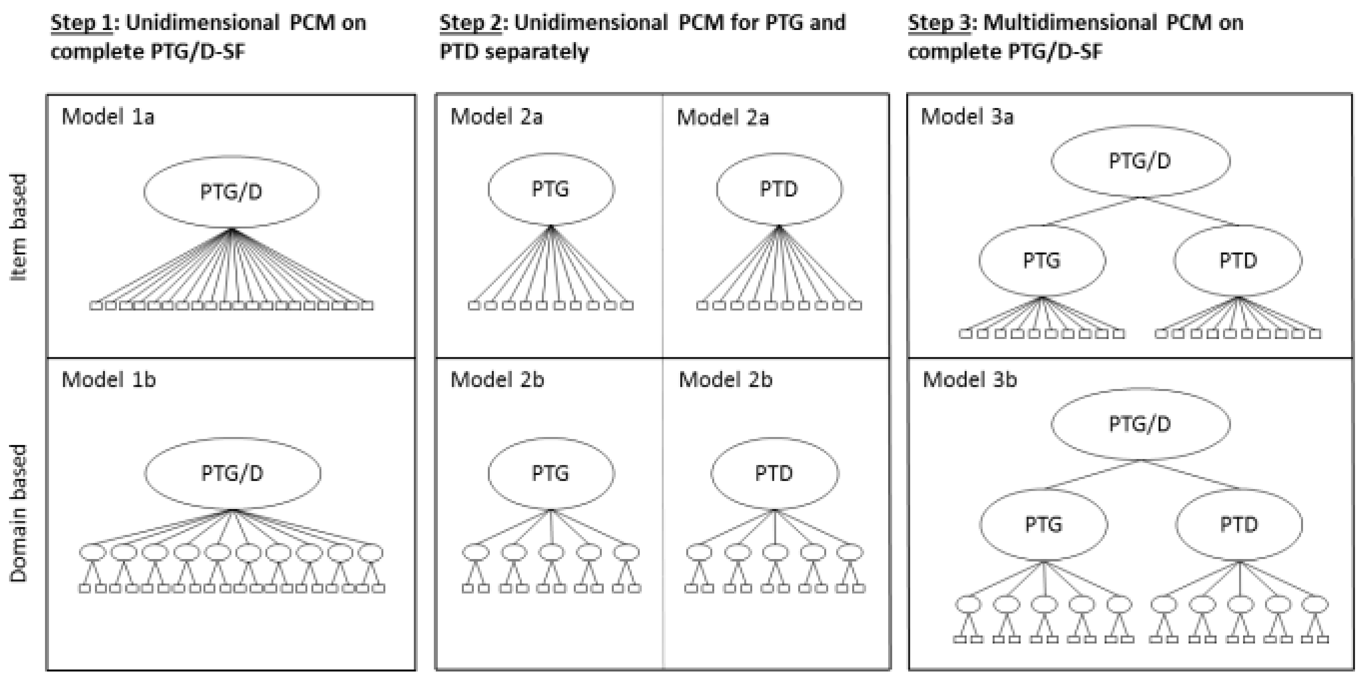


*Figure 1***.** Conceptual steps of the PTG/D-SF Rasch model based analyses. Step 1 = unidimensional analyses of the PTG/D-SF items or by domains. Step 2 = separate unidimensional analyses of the items or domains from each PTG/D-SF dimensions (PTG and PTD). Step 3 = multidimensional Rasch analyses of the items or domains of the PTG/D-SF with PTG and PTD as dimensions.

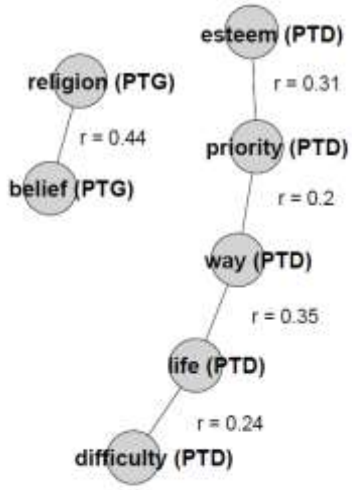


Figure 2. Local item dependencies in Model 1a (unidimensional analyses of the PTG/D-SF items).

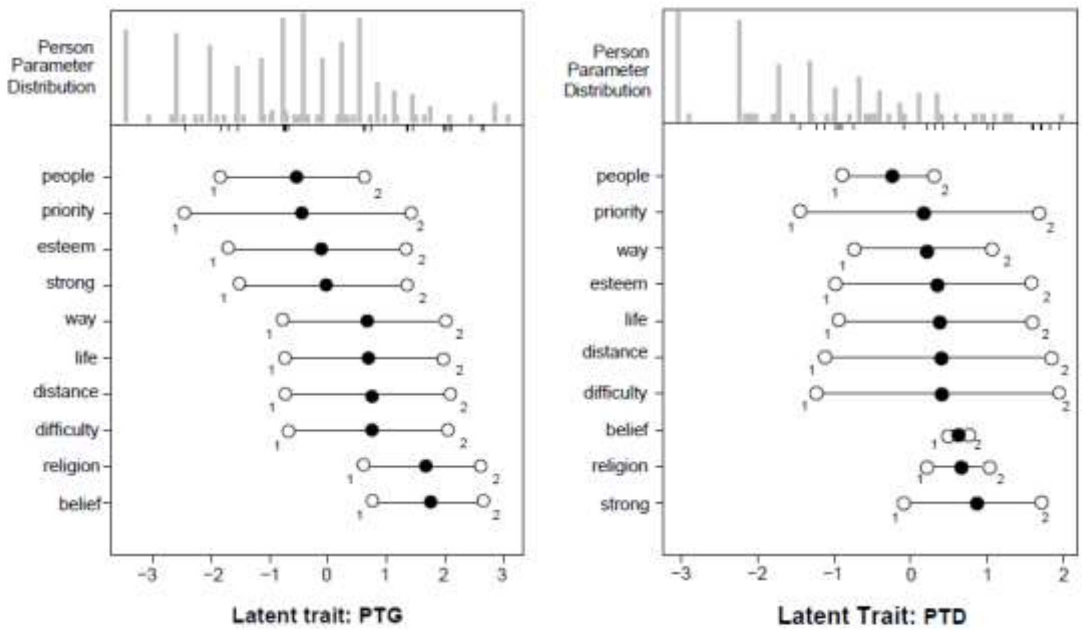
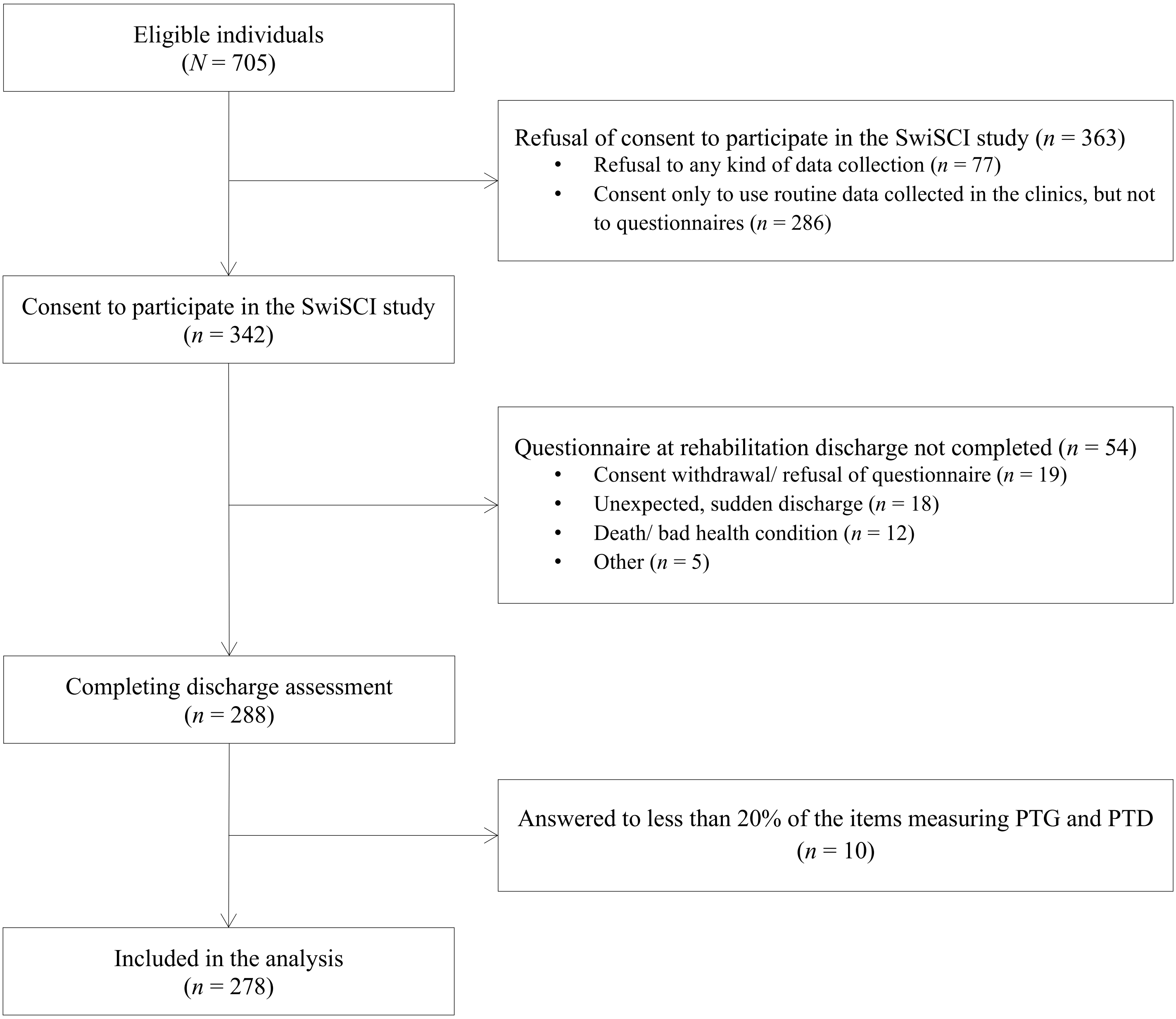


Figure 3. Person Item Map for the individual Rasch analysis of PTG and PTD with recoded items.

Appendices

Appendix 1: Participation in the study



Appendix 2: Frequencies and percentages of responses regarding all PTG/D-SF items

	Overall n (%)	Overall n (%)
	PTG 342	PTD 342
Priority:	**I changed my priorities about what is important in life**	**I find it difficult to clarify priorities about what is important in life**
0=I did not perceive this change as a result of my SCI	37 (10.8)	117 (34.2)
1=I perceived this change to a very small extent as a result of my SCI	25 (7.3)	52 (15.2)
2=I perceived this change to a small extent as a result of my SCI	36 (10.5)	27 (7.9)
3=I perceived this change to a certain extent as a result of my SCI	61 (17.8)	40 (11.7)
4=I perceived this change to a high extent as a result of my SCI	78 (22.8)	25 (7.3)
5=I perceived this change to a very high extent as a result of my SCI	39 (11.4)	9 (2.6)
Missing values	66 (19.3)	72 (21.1)
Esteem:	**I have a greater appreciation for the value of my own life**	**I have less of an appreciation for the value of my own life**
0=I did not perceive this change as a result of my SCI	68 (19.9)	154 (45.0)
1=I perceived this change to a very small extent as a result of my SCI	20 (5.8)	32 (9.4)
2=I perceived this change to a small extent as a result of my SCI	31 (9.1)	21 (6.1)
3=I perceived this change to a certain extent as a result of my SCI	55 (16.1)	33 (9.6)
4=I perceived this change to a high extent as a result of my SCI	56 (16.4)	19 (5.6)
5=I perceived this change to a very high extent as a result of my SCI	38 (11.1)	9 (2.6)
Missing values	74 (21.6)	74 (21.6)
Religion:	**I have a better understanding of spiritual matters**	**I have a poorer understanding of spiritual matters**
0=I did not perceive this change as a result of my SCI	174 (50.9)	201 (58.8)
1=I perceived this change to a very small extent as a result of my SCI	25 (7.3)	24 (7.0)
2=I perceived this change to a small extent as a result of my SCI	20 (5.8)	12 (3.5)
3=I perceived this change to a certain extent as a result of my SCI	27 (7.9)	13 (3.8)
4=I perceived this change to a high extent as a result of my SCI	19 (5.6)	10 (2.9)
5=I perceived this change to a very high extent as a result of my SCI	9 (2.6)	9 (2.6)
Missing values	68 (19.9)	73 (21.3)
Way:	**I established a new path for my life**	**I have a less clear path for my life**
0=I did not perceive this change as a result of my SCI	90 (26.3)	148 (43.3)
1=I perceived this change to a very small extent as a result of my SCI	39 (11.4)	42 (12.3)
2=I perceived this change to a small extent as a result of my SCI	29 (8.5)	18 (5.3)
3=I perceived this change to a certain extent as a result of my SCI	47 (13.7)	22 (6.4)
4=I perceived this change to a high extent as a result of my SCI	39 (11.4)	20 (5.8)
5=I perceived this change to a very high extent as a result of my SCI	21 (6.1)	12 (3.5)
Missing values	77 (22.5)	80 (23.4)
Distance:	**I have a greater sense of closeness with others**	**I have a greater sense of distance from others**
0=I did not perceive this change as a result of my SCI	105 (30.7)	148 (43.3)
1=I perceived this change to a very small extent as a result of my SCI	26 (7.6)	32 (9.4)
2=I perceived this change to a small extent as a result of my SCI	31 (9.1)	26 (7.6)
3=I perceived this change to a certain extent as a result of my SCI	40 (11.7)	31 (9.1)
4=I perceived this change to a high extent as a result of my SCI	44 (12.9)	20 (5.8)
5=I perceived this change to a very high extent as a result of my SCI	19 (5.6)	7 (2.0)
Missing values	77 (22.5)	78 (22.8)

Appendix 2 (continued): Frequencies and percentages of responses regarding all PTG/D-SF items

	Overall n (%)		Overall n (%)	
	PTG	342	PTD	342
Difficulty:	**I know better that I can handle difficulties**		**I am less certain that I can handle difficulties**	
0=I did not perceive this change as a result of my SCI	99 (28.9)		139 (40.6)	
1=I perceived this change to a very small extent as a result of my SCI	36 (10.5)		35 (10.2)	
2=I perceived this change to a small extent as a result of my SCI	28 (8.2)		33 (9.6)	
3=I perceived this change to a certain extent as a result of my SCI	37 (10.8)		29 (8.5)	
4=I perceived this change to a high extent as a result of my SCI	48 (14.0)		17 (5.0)	
5=I perceived this change to a very high extent as a result of my SCI	19 (5.6)		6 (1.8)	
Missing values	75 (21.9)		83 (24.3)	
Life:	**I am able to do better things with my life**		**I am less capable of doing better things with my life**	
0=I did not perceive this change as a result of my SCI	93 (27.2)		154 (45.0)	
1=I perceived this change to a very small extent as a result of my SCI	35 (10.2)		32 (9.4)	
2=I perceived this change to a small extent as a result of my SCI	33 (9.6)		24 (7.0)	
3=I perceived this change to a certain extent as a result of my SCI	34 (9.9)		28 (8.2)	
4=I perceived this change to a high extent as a result of my SCI	44 (12.9)		17 (5.0)	
5=I perceived this change to a very high extent as a result of my SCI	20 (5.8)		8 (2.3)	
Missing values	83 (24.3)		79 (23.1)	
Belief:	**I have a stronger religious faith**		**I have a weaker religious faith**	
0=I did not perceive this change as a result of my SCI	184 (53.8)		203 (59.4)	
1=I perceived this change to a very small extent as a result of my SCI	12 (3.5)		21 (6.1)	
2=I perceived this change to a small extent as a result of my SCI	25 (7.3)		13 (3.8)	
3=I perceived this change to a certain extent as a result of my SCI	15 (4.4)		9 (2.6)	
4=I perceived this change to a high extent as a result of my SCI	18 (5.3)		6 (1.8)	
5=I perceived this change to a very high extent as a result of my SCI	8 (2.3)		9 (2.6)	
Missing values	80 (23.4)		81 (23.7)	
Strong:	**I discovered that I'm stronger than I thought I was**		**I discovered that I'm weaker than I thought I was**	
0=I did not perceive this change as a result of my SCI	75 (21.9)		175 (51.2)	
1=I perceived this change to a very small extent as a result of my SCI	18 (5.3)		34 (9.9)	
2=I perceived this change to a small extent as a result of my SCI	31 (9.1)		16 (4.7)	
3=I perceived this change to a certain extent as a result of my SCI	53 (15.5)		20 (5.8)	
4=I perceived this change to a high extent as a result of my SCI	50 (14.6)		5 (1.5)	
5=I perceived this change to a very high extent as a result of my SCI	37 (10.8)		5 (1.5)	
Missing values	78 (22.8)		87 (25.4)	
People:	**I learned a great deal about how wonderful people are**		**I learned a great deal about how disappointing people are**	
0=I did not perceive this change as a result of my SCI	55 (16.1)		143 (41.8)	
1=I perceived this change to a very small extent as a result of my SCI	24 (7.0)		37 (10.8)	
2=I perceived this change to a small extent as a result of my SCI	22 (6.4)		17 (5.0)	
3=I perceived this change to a certain extent as a result of my SCI	49 (14.3)		27 (7.9)	
4=I perceived this change to a high extent as a result of my SCI	55 (16.1)		15 (4.4)	
5=I perceived this change to a very high extent as a result of my SCI	61 (17.8)		23 (6.7)	
Missing values	76 (22.2)		80 (23.4)	

Appendix 3: Item fit statistics for Step 1 Rasch analysis, including item infit, mean location, difficulty rank, threshold ordering, principal component analysis outcome and local item dependencies (LID)

		Dimen-sion	Item	Infit	Loca-tion	Difficulty Rank	Threshold Ordering	Disor-dered	Eigen-value	Cumu-lative Eigen-value in %	PC1 Loading	LID
Step 1: Model 1a	**All Items**	**PTG**	priority	1.07	-0.69	1	3->1->2->4->5	X	3.26	16.32	0.10	
			esteem	***1.24***	-0.48	3	5->1->2->3->4	X	1.40	38.98	0.31	
			religion	0.80	0.27	9	5->2->1->3->4	X	1.21	45.05	0.04	belief (PTG)
			way	***0.89***	-0.20	5	4->2->1->3->5	X	1.07	56.12	0.22	
			distance	1.02	-0.13	8	4->1->2->3->5	X	0.91	70.36	0.17	
			difficulty	0.95	-0.15	7	4->3->1->2->5	X	0.78	78.59	0.23	
			life	0.88	-0.19	6	4->2->3->1->5	X	0.75	82.35	0.27	
			belief	0.82	0.30	10	5->1->3->2->4	X	0.59	91.90	0.02	religion (PTG)
			strong	0.98	-0.43	4	5->1->2->3->4	X	0.57	94.75	0.30	
			people	1.19	-0.68	2	5->2->1->3->4	X	0.03	100.00	0.19	
		PTD	priority	0.98	0.11	2	2->3->1->4->5	X	1.70	24.81	-0.30	esteem (PTD); way (PTD)
			esteem	0.97	0.22	4	5->2->1->3->4	X	1.44	31.99	-0.30	priority (PTD)
			religion	0.79	0.32	8	5->4->1->2->3	X	1.14	50.77	0.02	
			way	0.95	0.15	3	5->3->1->2->4	X	1.00	61.12	-0.30	priority (PTD); life (PTD)
			distance	0.91	0.26	6	4->2->1->3->5	X	0.94	65.82	-0.19	
			difficulty	0.91	0.28	7	4->1->2->3->5	X	0.87	74.71	-0.30	life (PTD)
			life	1.05	0.25	5	5->2->1->3->4	X	0.68	85.75	-0.34	way (PTD);difficulty (PTD)
			belief	0.70	0.33	9	5->2->3->4->1	X	0.64	88.96	-0.02	
			strong	0.91	0.44	10	4->3->1->5->2	X	0.52	97.37	-0.25	
			people	1.04	-0.01	1	5->3->1->4->2	X	0.49	99.84	-0.05	
Step 1: Model 1b	**All Domains**	**PTG**	Relating to others	0.94	-0.20	2	*not applicable*		2.53	25.31	-0.27	
			New possibilities in life	0.84	-0.10	4			1.24	37.70	-0.36	
			Personal strength	0.91	-0.16	3			1.15	49.25	-0.40	
			Spiritual change	0.84	0.28	5			1.09	60.14	0.01	
			Appreciation of life	1.07	-0.41	1			0.92	69.36	-0.33	
		PTD	Relating to others	0.89	0.22	3	*not applicable*		0.91	78.43	0.22	
			New possibilities in life	1.00	0.20	2			0.84	86.87	0.40	strength (PTD)
			Personal strength	0.82	0.26	4			0.64	93.29	0.41	possibilities (PTD)
			Spiritual change	0.74	0.30	5			0.62	99.50	0.02	
			Appreciation of life	1.02	0.12	1			0.05	100.00	0.39	

Appendix 3 (continued): Item fit statistics for Step 2 Rasch analysis, including item infit, mean location, difficulty rank, threshold ordering, principal component analysis outcome and local item dependencies (LID)

		Item	Infit	Loca-tion	Diffi-culty Rank	Threshold Ordering	Disord ered	Eigen-value	Cumu-lative Eigenv alue in %	PC1 Loa-ding	LID
Step 2:	**PTG**	priority	1.07	-0.43	1	3->1->2->4->5	X	1.84	18.43	-0.21	
Model		esteem	1.03	-0.21	3	4->1->2->3->5	X	1.32	31.64	-0.21	
2a		religion	0.98	0.61	9	5->2->1->3->4	X	1.26	44.26	0.61	belief
		way	0.79	0.09	5	3->2->1->4->5	X	1.23	56.51	-0.17	
		distance	0.97	0.17	8	4->1->2->3->5	X	1.10	67.48	0.05	
		difficulty	0.89	0.14	7	4->3->1->2->5	X	0.96	77.08	-0.19	
		life	0.76	0.11	6	4->1->3->2->5	X	0.88	85.92	-0.21	
		belief	1.00	0.67	10	5->1->3->2->4	X	0.83	94.23	0.61	religion
		strong	0.80	-0.16	4	5->1->2->3->4	X	0.55	99.73	-0.22	
		people	1.13	-0.42	2	5->2->1->3->4	X	0.03	100.00	-0.08	
Step 2:	**PTG**	priority	1.05	-0.51	2	1->2		1.67	16.75	-0.07	
Model	**recoded**	esteem	0.99	-0.18	3	1->2		1.34	30.11	-0.16	
2a	**items**	religion	1.04	1.62	9	1->2		1.28	42.87	0.64	belief
		way	0.82	0.61	5	1->2		1.22	55.06	-0.09	
		distance	0.87	0.69	7	1->2		1.13	66.38	-0.02	
		difficulty	0.89	0.70	8	1->2		1.03	76.71	-0.20	
		life	0.80	0.63	6	1->2		0.89	85.58	-0.10	
		belief	1.06	1.70	10	1->2		0.83	93.91	0.61	religion
		strong	0.74	-0.09	4	1->2		0.61	100.05	-0.30	
		people	1.10	-0.60	1	1->2		-0.01	100.00	-0.21	
Step 2:	**PTG**	Relating to others	0.85	0.02	2			1.39	27.87	-0.49	
Model	**domain**	New possibilities in life	0.65	0.14	4			1.32	54.26	0.45	
2b	**analysis**	Personal strength	0.72	0.06	3	*not applicable*		1.19	78.04	0.15	
		Spiritual change	1.13	0.57	5			1.03	98.74	-0.53	
		Appreciation of life	0.91	-0.21	1			0.06	100.00	0.50	
Step 2:	**PTD**	priority	0.90	-0.14	2	2->3->1->4->5	X	1.77	17.66	-0.29	
Model		esteem	0.80	0.00	4	4->2->1->3->5	X	1.38	31.50	-0.15	
2a		religion	1.07	0.17	8	5->4->1->3->2	X	1.35	44.98	0.39	belief
		way	0.84	-0.07	3	3->4->1->2->5	X	1.12	56.17	-0.32	
		distance	0.94	0.04	6	4->2->1->3->5	X	1.01	66.32	0.31	
		difficulty	0.84	0.04	7	3->1->2->4->5	X	0.96	75.93	-0.31	
		life	0.88	0.03	5	4->2->1->3->5	X	0.92	85.09	-0.41	
		belief	0.94	0.17	9	5->2->3->4->1	X	0.82	93.32	0.36	religion
		strong	0.87	0.26	10	4->3->1->5->2	X	0.68	100.11	-0.03	
		people	***1.33***	-0.25	1	4->3->1->5->2	X	-0.01	100.00	0.38	
Step 2:	**PTD**	priority	0.88	0.13	2	1->2		1.69	16.88	-0.26	
Model	**recoded**	esteem	0.77	0.30	4	1->2		1.47	31.59	-0.08	
2a	**items**	religion	1.00	0.62	9	1->2		1.38	45.41	0.35	belief
		way	0.85	0.17	3	1->2		1.16	57.02	-0.36	
		distance	0.97	0.36	6	1->2		1.01	67.09	0.33	
		difficulty	0.88	0.36	7	1->2		0.99	76.97	-0.32	
		life	0.95	0.33	5	1->2		0.89	85.84	-0.44	
		belief	0.85	0.58	8	1->2		0.73	93.19	0.32	religion
		strong	0.92	0.82	10	1->2		0.70	100.17	-0.07	
		people	***1.31***	-0.29	1	1->2		-0.02	100.00	0.41	
Step 2:	**PTD**	Relating to others	0.98	0.06	3			1.54	30.88	-0.61	
Model	**domain**	New possibilities in life	0.75	0.05	2			1.29	56.65	0.48	
2b	**analysis**	Personal strength	0.69	0.12	4	*not applicable*		1.20	80.73	0.38	
		Spiritual change	1.09	0.20	5			0.95	99.72	-0.40	
		Appreciation of life	0.77	-0.05	1			0.01	100.00	0.29	

Appendix 3 (continued): Item fit statistics for step 3 multidimensional Rasch analysis, including item infit, mean location, difficulty rank and threshold ordering

		Dimension	Item	Infit	Location	Difficulty Rank	Threshold Ordering	Disordered
Step 3: Model 3a	**2-Dimensional**	**PTG**	priority	1.13	-0.26	1	3->4->1->2->5	X
			esteem	1.13	-0.12	2	3->5->1->2->4	X
			religion	1.04	0.07	9	5->4->2->1->3	X
			way	0.92	-0.07	8	5->3->2->1->4	X
			distance	1.06	-0.09	7	4->5->1->2->3	X
			difficulty	1.00	-0.11	3	5->4->3->1->2	X
			life	0.86	-0.10	4	5->4->1->3->2	X
			belief	1.07	0.08	10	4->5->1->3->2	X
			strong	0.93	-0.09	6	4->5->1->2->3	X
			people	1.19	-0.09	5	2->5->3->1->4	X
		PTD	priority	0.98	-0.04	1	5->2->3->1->4	X
			esteem	0.91	0.05	4	5->4->2->1->3	X
			religion	1.16	0.23	8	5->4->2->1->3	X
			way	0.97	0.08	6	5->4->3->1->2	X
			distance	1.00	0.00	2	5->4->2->1->3	X
			difficulty	0.94	0.01	3	5->3->1->2->4	X
			life	0.99	0.06	5	5->4->2->1->3	X
			belief	1.07	0.34	10	5->4->1->2->3	X
			strong	0.99	0.28	9	5->3->2->1->4	X
			people	***1.32***	0.20	7	5->3->2->1->4	X
Step 3: Model 3a	**2-Dimensional recoded items**	**PTG**	priority	1.10	-0.09	1	1->2	
			esteem	1.13	0.24	2	1->2	
			religion	0.92	1.17	10	1->2	
			way	0.94	0.59	7	1->2	
			distance	1.01	0.58	6	1->2	
			difficulty	1.00	0.65	8	1->2	
			life	0.92	0.53	5	1->2	
			belief	0.89	1.07	9	2->1	X
			strong	0.91	0.29	3	1->2	
			people	1.12	0.32	4	1->2	
		PTD	priority	0.99	0.87	2	1->2	
			esteem	0.94	1.09	5	1->2	
			religion	1.06	1.57	10	2->1	X
			way	0.98	1.20	7	1->2	
			distance	0.99	0.96	3	2->1	X
			difficulty	0.94	0.82	1	2->1	X
			life	0.97	1.03	4	2->1	X
			belief	1.00	1.55	9	2->1	X
			strong	1.07	1.37	8	2->1	X
			people	***1.22***	1.17	6	1->2	
Step 3: Model 3b	**2-Dimensional domain analysis**	**PTG**	Relating to others	1.06	-0.06	1	*not applicable*	
			New possibilities in life	0.93	0.03	5		
			Personal strength	1.02	-0.03	2		
			Spiritual change	***1.36***	-0.02	4		
			Appreciation of life	1.13	-0.03	3		
		PTD	Relating to others	1.16	-0.04	1	*not applicable*	
			New possibilities in life	1.06	0.02	2		
			Personal strength	0.93	0.13	5		
			Spiritual change	***1.31***	0.13	4		
			Appreciation of life	1.05	0.08	3		