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# Development and psychometric analysis of the 10-item resilience scale specific to cancer: A multidimensional item response theory analysis

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ABSTRACT

*Purpose:* Resilience is an important concept in the cancer literature and is a salient indicator of cancer survivorship. Classic theory test (CTT) and item response theory (IRT) were performed to develop and validate the 25-item Resilience Scale Specific to Cancer (RS-SC). This study was designed to develop and validate a short form of RS-SC (RS–SC–10) with a multidimensional IRT (MIRT) analysis.

*Methods:* MIRT analysis was performed to test two models (three- and five-factor) derived from previous studies and assess the item parameters of RS-SC and RS–SC–10.

*Results:* A total of 451 Chinese patients with different cancer diagnoses were analyzed. The three-factor structure showed better goodness of fit compared with the five-factor structure in RS-SC. RS–SC–10 retained 10 items with high discriminative parameters from RS-SC and consisted of two factors, *Generic* and *Shift-Persist*. Item information function indicated that RS–SC–10 had the highest discrimination ability among patients with low to moderate levels of resilience.

*Conclusions:* MIRT provided useful information on RS-SC and RS–SC–10 by combining the approaches of CTT and IRT. RS–SC–10 showed great potential in clinical settings owing to the low scale of burden on patients. More studies on the Minimum Clinically Important Difference of RS–SC–10 are warranted.

## 1. Introduction

With the advances in medical technology (e.g., PD-1 immunotherapy), cancer is increasingly treated as a chronic disease (McCorkle et al., 2011). Thus, rehabilitating cancer survivors from the traumatic event of living with cancer has become a topic of great interest in cancer research (Deshields et al., 2016; Ye et al., 2017a). Resilience is defined as one's ability to “bounce back” in adversity and is a salient indicator of patients' quality of life and even survival (Rutter, 1985; Ye et al., 2017b). However, there are no resilience scales specific to patients with cancer, and the application of generic resilience instruments among the cancer-specific population is debated (Deshields et al., 2016; Ye et al., 2017a). A resilience instrument, called Resilience Scale Specific to Cancer (RS-SC), has been developed based on “Shift-Persist” theory and Resilience Model to Breast Cancer (Chen and Miller, 2012; Ye et al., 2016a, 2017b, 2018a). RS-SC is a 25-item, self-report scale designed to assess five resilience-related domains/factors (i.e., *Generic Elements*, *Benefit Finding*, Support *and Coping*, *Hope for the Future*, and *Meaning for Existence*) with higher scores indicating higher levels of resilience (Ye et al., 2018b). Recent psychometric evidence has provided some support for the use of RS-SC in patients with cancer. However, owing to different statistical models derived from Classic Theory Test (CTT) and Item Response Theory (IRT), the psychometric performance of RS-SC has shown some variability: the three-factor

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structure (*Generic*, *Shifting*, *Persisting*) supported by IRT is inconsistent with the original five-factor structure proposed by CTT (Ye et al., 2018b, 2018c). In addition, some items of RS-SC have low discriminative parameter or problematic threshold according to previous studies (Ye et al., 2018c), raising concerns that these items cannot discriminate among patients with different resilience levels and should be deleted or redefined. As such, further psychometric testing of RS-SC is needed to improve its performance for this population. A shorter form of RS-SC with better discriminative power and higher item information function may have feasibility in complex clinical settings. Furthermore, the shorter form of RS-SC could also be used as a potential quick tool to evaluate patients' psychosocial functions and assess the efficacy of resilience-related intervention in future studies. Thus, a Multidimensional Item Response Theory (MIRT) analysis, also called the full information analysis (Reckase, 2009), which combines the factor analyses derived from CTT and IRT, was performed to re-test the problematic structure and item parameters of RS-SC in the current study. The present study was designed to (1) retest the problematic structure of RS-SC (three-factor vs. five-factor structure) and provide more item information on this instrument using MIRT analysis; (2) develop a short-form of RS-SC with high-quality items; and (3) provide the psychometrics of the short-form scale when administered in patients diagnosed with cancer in Mainland China.

## 2. Methods

### 2.1. Data source

Patients from six hospitals in Guangdong and Heilongjiang Provinces were evaluated by the RS-SC between October 2015 and July 2017. The inclusion criteria were as follows: (1) confirmed cancer diagnosis based on biopsy and medical imaging; (2) aged 18–65 years; (3) ability to communicate in Mandarin or Cantonese fluently; and (4) receiving active treatment. The exclusion criteria were as follows: (1) misdiagnosed with cancer; (2) cannot communicate in Mandarin or Cantonese fluently; and (3) unwilling to participate in the study. Informed consent was obtained. A project nurse was made available for any questions raised during the completion of the scales. The Human Research Ethics Committee approved the study (registration number: 2016KYTD08).

## 3. Measures

### 3.1. Demographic scale

This scale included demographic (e.g., age and sex) and clinical variables (e.g., stage of cancer and combordities), which were detailed in our previous studies (Ye et al., 2017a, 2018b; 2019a).

### 3.2. RS-SC

This scale was originally developed based on CTT and further validated by IRT. RS-SC has a second-order structure and consists of five factors: *Generic Element* (items 1–6), *Benefit Finding* (items 7–11), Support *and Coping* (items 12–16), *Hope for the Future* (items 17–21), and *Meaning for Existence* (items 22–25) (See the Appendix). There are five categories within each item (1 = never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always); higher scores indicated higher levels of resilience (scores range from 25 to 125). Previous studies have demonstrated the scale's high internal consistency (α = 0.825) and test-retest reliability (r = 0.874) (Ye et al., 2018b, 2018c).

### 3.3. Statistical methods

The recommended sample size for MIRT analysis has been debated (Draxler, 2010; Julious, 2010). In the present study, we took Linacre's strategy (1994) and anticipated that a sample size of n = 550 will be a robust estimation of item parameters (within 0.5 logits [contraction of log-odds probability units] at α = 0.01) with a minimum dropout of 15% on the basis of data from previous research. Exploratory factor analysis (EFA) with oblique rotations (Quartimax) was adapted to determine the factor number of RS-SC, and the two models (three- and five-factor) derived from our previous studies were compared according to log-likelihood, Akaike information criterion (AIC), and Bayesian information criterion (BIC, de Ayala, 2009). When the factor structure was confirmed, local dependence hypothesis was examined by residual correlations among all 25 items, and the expected correlations should be lower than 0.2 (Chen and Thissen, 1997). Then, MIRT analysis was performed to evaluate the psychometrics of items and a compensatory logistic multidimensional grade response model (MGRM-C), proposed by Muraki and Carlson, was chosen to estimate the item parameters (de Ayala, 1994; Muraki and Carlson, 1995; Samejima, 1997). MGRM-C is detailed as the equation below:

$$P_{ijk} = \frac{\exp(a_i\theta_j + d_{ik})}{1 + \exp(a_i\theta_j + d_{ik})} \tag{1}$$

MGRM-C is a logistic probability model (also called item characteristic surface, ICS, $P_{ijk}$) that examinee (*j*) will respond with category *k* (and above) of item *i* as a function of the item-category threshold (or easiness parameter, $d_{ik}$), item discrimination parameter vector ($a_i$), and examinee ability parameter vector ($\theta_j$); $E(\theta_j)$ refers to the expected score (ES) of subject *j* with ability vector $\theta_j$, which is the linear accumulation of probability of responding to each category of an item (Muraki and Carlson, 1995). $k_i$ is defined as category *k* of item *i*, and ES is detailed in Eq. (2):

$$E(\theta_j) = \sum_{k=1}^{k_i} P_{ijk} \tag{2}$$

In addition, guessing parameter was not calculated in this study. Item information function (IIF), which reflects the precision of an item in a test, was assessed for every item and is detailed as the equation below (Du and Xiao, 2012):

$$I_{i\alpha}(\theta_j) = \sum_{k=0}^{k_i} (P_{ij,k} - P_{ij,k+1})(1 - P_{ij,k} - P_{ij,k+1})^2 \left(\sum_{v=1}^{m} a_{iv} \cos\alpha_v\right)^2 \tag{3}$$

$I_{i\alpha}$ indicates the IIF of item *i*, and $\alpha_v$ the direction vector. Other indicators (e.g., $P_{ijk,}$ $a_i$) are identical to those in Eq. (1). IIF will change with the direction of observation ($\alpha_v$). Thus, we set α to 45° for all 25 items in the current study. All item parameters were assessed by the Markov chain Monte Carlo (MCMC) method with a maximum of 4000 cycles in the estimation (Chalmers, 2012). EFA, CFA, and MIRT analysis were performed by IRTPRO and FlexMIRT software; ICS, ES, and IIF were visualized using MATLAB software. Significance level was 0.05 for all statistical tests.

## 4. Results

### 4.1. Participant characteristics

A total of 550 patients were contacted; 58 patients refused to participate in the study for reasons such as a busy schedule and early discharge. Additionally, 41 patients were excluded from the analysis owing to missing demographic or invalid scale data, resulting in a sample of 451 (82.0%). Lung, gastric, and colorectal cancer were the three most common cancer diagnoses in this study, constituting 21.51%, 27.94%, 15.08%, respectively. Other information on the participants are presented in Table 1.

**Table 1**
Characteristics of patients in the MIRT analysis of RS-SC.

| Characteristics | Lung Cancer | Gastric Cancer | Colon-Rectal Cancer | Liver Cancer | Leukemia | Other Cancer |
|---|---|---|---|---|---|---|
| **No.** | 97 | 126 | 68 | 45 | 54 | 61 |
| **Sex** | | | | | | |
| Female | 26 | 59 | 35 | 11 | 24 | 29 |
| Man | 71 | 67 | 33 | 34 | 30 | 32 |
| **Age (years)** | 45.87 ± 16.36 | 56.05 ± 17.29 | 52.15 ± 15.02 | 47.13 ± 14.51 | 38.54 ± 17.39 | 44.77 ± 21.15 |
| **Time since first confirmed diagnosis (months)** | 13.05 ± 11.13 | 18.17 ± 8.96 | 21.77 ± 12.98 | 10.03 ± 9.53 | 7.96 ± 7.05 | 15.92 ± 10.31 |
| **Duration of treatment (months)** | 6.92 ± 5.66 | 12.11 ± 7.94 | 16.05 ± 9.33 | 5.97 ± 5.66 | 6.89 ± 7.88 | 9.12 ± 8.68 |
| **Education Level** | | | | | | |
| Middle school or lower | 57 | 77 | 37 | 24 | 33 | 30 |
| High school or higher | 40 | 49 | 31 | 21 | 21 | 31 |
| **Family Income** (yuan/month) | | | | | | |
| < 5000 | 46 | 71 | 34 | 21 | 24 | 32 |
| 5000–10000 | 25 | 35 | 18 | 15 | 23 | 20 |
| > 10000 | 26 | 20 | 16 | 9 | 8 | 9 |
| **Marital Status** | | | | | | |
| Married | 82 | 100 | 52 | 33 | 48 | 50 |
| divorced or other | 15 | 26 | 16 | 12 | 6 | 11 |
| **Religious Beliefs** | | | | | | |
| Yes | 15 | 27 | 13 | 10 | 11 | 18 |
| None | 82 | 99 | 55 | 35 | 43 | 43 |
| **Employment Status (before diagnosis)** | | | | | | |
| Employment | 50 | 62 | 28 | 12 | 8 | 19 |
| Unemployment | 47 | 64 | 40 | 33 | 46 | 42 |
| **Stage of Cancer** | | | | | | |
| I | 15 | 12 | 13 | 7 | 10 | 10 |
| II | 26 | 64 | 16 | 18 | 19 | 21 |
| III | 40 | 40 | 24 | 15 | 21 | 23 |
| IV | 16 | 10 | 13 | 5 | 5 | 7 |
| **Type of Therapy** | | | | | | |
| Chemo | 47 | 84 | 40 | 39 | 43 | 38 |
| Chemo + radiation | 52 | 42 | 28 | 6 | 11 | 23 |
| **Combordities** | | | | | | |
| None | 23 | 41 | 18 | 15 | 30 | 21 |
| one | 36 | 55 | 26 | 20 | 15 | 25 |
| Two or more | 38 | 30 | 24 | 10 | 10 | 15 |

### 4.2. EFA of RS-SC

In the EFA analysis, the three-factor structure showed better fitting indicators compared with the five-factor structure (-2loglikelihood, 36487.84 vs. 37155.02; AIC, 36917.84 vs.37499.02; BIC, 37858.11 vs. 38251.23, Table 2). Thus, based on these findings, we recommended the three-factor structure for RS-SC. The inter-factor correlations ranged from 0.41 to 0.59. The structure for the *Generic* dimension was stable, but some items from the *Shifting* and *Persisting* dimensions showed cross-loadings (e.g., items 7, 8, and 9), which was inconsistent with our "*Generic*, *Shifting*, *Persisting*" hypothesis.

### 4.3. Local independence

Based on the three-factor structure, item-pair local dependence was visualized (Fig. 1 heat map). Most item-pair relations were lower than 0.20, indicating a low risk of systematic model fit issues. The local independence hypothesis was satisfied.

### 4.4. Psychometric evaluation of RS–SC–10

The phenomenon of item cross-loadings between the *Shifting* and *Persisting* dimensions indicated the probability of unidimensional latent trait of "*Shift-Persist*" and a short form of RS-SC with two latent traits (*Generic* and *Shift-Persist*) might have its potential in clinical application. Thus, the sample was randomly divided into two parts with a ratio of 2:1: Sample 1 (N = 301) for item selection and calibration, and Sample 2 (N = 150) for scale validation.

### 4.5. Development of RS–SC–10

In Sample 1, CFA combined with MIRT analysis (between-item MIRT model) was performed to select items with high quality ($a > 1.5$), presented in Table 3. Items 2 ($a_1 = 2.48$), 3 ($a_1 = 1.88$), 4 ($a_1 = 3.85$), and 5 ($a_1 = 4.05$) were chosen as *Generic* items; Items 7 ($a_2 = 1.64$), 9 ($a_2 = 1.80$), 10 ($a_2 = 1.59$), 17 ($a_3 = 1.61$), 19 ($a_3 = 1.69$), and 22 ($a_3 = 1.79$) were chosen as *Shift-Persist* items. These items comprised the resulting RS–SC–10. The correlation between *Generic* and *Shift-Persist* was 0.54.

### 4.6. Validation of RS–SC–10

In Sample 2, EFA combined with MIRT analysis (within-item MIRT model) was performed to test the structure of RS–SC–10 derived from Sample 1. All items' loadings were more than 0.60, with no item showing disordered thresholds (Table 4). Items 1 to 4 (renamed) had higher loadings on Factor 1, whereas items 5 to 10 (renamed) had higher loadings on Factor 2, confirming the stability of the two-factor structure of RS–SC–10. The correlation between *Generic* and *Shift-Persist* was 0.59.

As shown in Fig. 2, the accumulated probability of endorsing different categories of an item ($E(\theta_j)$) increased as the latent traits ($\theta_j$) of participants increased among the 10 items of RS–SC–10. The compensatory effects of the two latent traits were identified, and the parameters of items based on MCMC method are presented in Table 4. *Generic* had greater impacts on the ES of items 1–4, whereas *Shift-Persist* had greater impacts on responses to items 5–10. The IIFs of 10 items are presented in Fig. 3. In general, maximum IIFs were achieved as latent trait ($\theta_j$) leveled between $-2$ and 1, whereas minimum IIFs (near zero)

**Table 2**
Exploratory factor analysis for 3-factor and 5-factor structure of RS-SC.

| Item | Three-Factor Structure | | | | | | Five-Factor Structure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\lambda_1$ | *s.e.* | $\lambda_2$ | *s.e.* | $\lambda_3$ | *s.e.* | $\lambda_1$ | *s.e.* | $\lambda_2$ | *s.e.* | $\lambda_3$ | *s.e.* | $\lambda_4$ | *s.e.* | $\lambda_5$ | *s.e.* |
| 1 | ***0.57*** | 0.02 | 0.18 | 0.02 | −0.09 | 0.02 | 0.03 | 0.02 | 0.16 | 0.01 | ***0.50*** | 0.01 | −0.17 | 0.01 | −0.04 | 0.02 |
| 2 | ***0.83*** | 0.05 | −0.08 | 0.05 | 0.12 | 0.06 | −0.03 | 0.04 | −0.01 | 0.03 | ***0.73*** | 0.02 | −0.18 | 0.01 | 0.13 | 0.06 |
| 3 | ***0.72*** | 0.07 | −0.05 | 0.10 | −0.01 | 0.10 | 0.13 | 0.04 | 0.07 | 0.05 | ***0.63*** | 0.05 | −0.07 | 0.05 | −0.04 | 0.08 |
| 4 | ***0.95*** | 0.05 | 0.07 | 0.09 | −0.05 | 0.10 | 0.01 | 0.06 | 0.01 | 0.04 | ***0.92*** | 0.04 | 0.08 | 0.03 | −0.04 | 0.06 |
| 5 | ***0.89*** | 0.07 | −0.03 | 0.09 | −0.03 | 0.10 | 0.01 | 0.05 | −0.05 | 0.08 | ***0.88*** | 0.05 | 0.03 | 0.07 | −0.03 | 0.08 |
| 6 | ***0.63*** | 0.11 | 0.02 | 0.11 | 0.17 | 0.07 | 0.06 | 0.06 | 0.09 | 0.09 | 0.02 | 0.05 | −0.03 | 0.07 | ***−0.90*** | 0.06 |
| 7 | −0.01 | 0.10 | 0.06 | 0.12 | ***0.70*** | 0.08 | 0.01 | 0.09 | −0.06 | 0.13 | −0.01 | 0.08 | −0.03 | 0.10 | ***−0.68*** | 0.07 |
| 8 | −0.01 | 0.09 | −0.01 | 0.09 | ***0.91*** | 0.06 | −0.01 | 0.07 | −0.06 | 0.07 | 0.01 | 0.06 | ***0.85*** | 0.07 | 0.01 | 0.04 |
| 9 | 0.01 | 0.09 | −0.03 | 0.09 | ***0.85*** | 0.06 | −0.03 | 0.06 | −0.07 | 0.10 | 0.01 | 0.06 | ***0.81*** | 0.09 | −0.01 | 0.05 |
| 10 | −0.08 | 0.10 | ***0.70*** | 0.10 | 0.13 | 0.10 | 0.05 | 0.09 | −0.04 | 0.10 | −0.03 | 0.09 | ***0.65*** | 0.08 | 0.06 | 0.09 |
| 11 | −0.03 | 0.11 | ***0.67*** | 0.10 | 0.02 | 0.10 | 0.04 | 0.10 | 0.03 | 0.10 | 0.02 | 0.09 | ***0.68*** | 0.11 | −0.07 | 0.09 |
| 12 | −0.02 | 0.10 | ***0.59*** | 0.11 | −0.01 | 0.11 | ***0.60*** | 0.10 | 0.01 | 0.10 | 0.02 | 0.08 | −0.10 | 0.11 | −0.09 | 0.09 |
| 13 | −0.01 | 0.09 | ***0.63*** | 0.11 | 0.01 | 0.10 | ***0.57*** | 0.13 | 0.01 | 0.10 | 0.01 | 0.10 | −0.08 | 0.12 | 0.14 | 0.09 |
| 14 | −0.03 | 0.10 | ***0.74*** | 0.09 | 0.05 | 0.10 | 0.02 | 0.09 | −0.03 | 0.10 | 0.01 | 0.08 | ***0.74*** | 0.09 | −0.02 | 0.09 |
| 15 | 0.04 | 0.09 | ***0.65*** | 0.10 | −0.02 | 0.10 | −0.16 | 0.08 | −0.30 | 0.13 | 0.13 | 0.08 | ***0.48*** | 0.08 | −0.05 | 0.10 |
| 16 | 0.02 | 0.09 | ***0.63*** | 0.10 | −0.09 | 0.10 | 0.02 | 0.08 | ***−0.67*** | 0.09 | 0.03 | 0.08 | −0.06 | 0.08 | −0.04 | 0.08 |
| 17 | −0.01 | 0.10 | ***0.69*** | 0.09 | 0.03 | 0.12 | 0.10 | 0.08 | ***−0.60*** | 0.10 | −0.01 | 0.09 | −0.11 | 0.10 | 0.08 | 0.08 |
| 18 | −0.01 | 0.09 | −0.06 | 0.10 | ***0.69*** | 0.10 | 0.04 | 0.07 | ***−0.77*** | 0.09 | 0.01 | 0.08 | −0.03 | 0.09 | 0.02 | 0.08 |
| 19 | −0.03 | 0.09 | −0.16 | 0.10 | ***0.66*** | 0.11 | 0.01 | 0.06 | ***−0.87*** | 0.07 | −0.02 | 0.08 | 0.07 | 0.07 | −0.08 | 0.06 |
| 20 | 0.11 | 0.09 | −0.08 | 0.12 | ***0.53*** | 0.11 | 0.06 | 0.09 | ***−0.59*** | 0.10 | 0.11 | 0.08 | 0.01 | 0.10 | −0.02 | 0.08 |
| 21 | 0.08 | 0.10 | ***0.40*** | 0.13 | −0.09 | 0.11 | −0.09 | 0.10 | −0.17 | 0.11 | 0.03 | 0.10 | −0.10 | 0.10 | ***−0.24*** | 0.10 |
| 22 | 0.17 | 0.11 | ***0.38*** | 0.14 | −0.12 | 0.10 | −0.10 | 0.06 | −0.09 | 0.11 | 0.02 | 0.08 | 0.02 | 0.09 | ***−0.66*** | 0.09 |
| 23 | 0.16 | 0.11 | 0.01 | 0.14 | ***0.40*** | 0.11 | ***0.63*** | 0.10 | −0.05 | 0.12 | 0.01 | 0.09 | −0.04 | 0.13 | 0.04 | 0.10 |
| 24 | 0.21 | 0.10 | −0.13 | 0.14 | ***0.33*** | 0.10 | ***0.75*** | 0.07 | 0.02 | 0.10 | 0.05 | 0.08 | 0.03 | 0.09 | −0.09 | 0.08 |
| 25 | 0.19 | 0.11 | 0.02 | 0.14 | ***0.48*** | 0.12 | ***0.83*** | 0.08 | −0.02 | 0.12 | 0.01 | 0.08 | −0.05 | 0.13 | 0.06 | 0.07 |
| -2loglikelihood: | | 36487.84 | | | | | 37155.02 | | | | | | | | | |
| AIC: | | 36917.84 | | | | | 37499.02 | | | | | | | | | |
| BIC: | | 37858.11 | | | | | 38251.23 | | | | | | | | | |

AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; s.e., standard error; λ indicate factor loadings.
Bolded and italicized items indicate the dominant factor loadings.

were recognized as latent trait ($\theta_j$) were close to −3 or 3, indicating that RS–SC–10 showed better discriminative ability among participants with low to moderate levels of resilience, instead of those with minimum or maximum levels of resilience. In addition, the item characteristic surfaces (ICSs, $P_{ijk}$) of RS–SC–10 were provided. Two examples of items 3 and 6 are presented in Fig. 4 (other ICSs could be obtained from the correspondence).

## 5. Discussion

MIRT analysis provides information on factor structure and the underlying pattern of item responses by combining the advantages of CTT and IRT. With the RS-SC's ability to transform into an interval-level metric by MIRT, applications of the RS-SC have the potential to quantify patient's resilience with greater precision compared with summed scores, which can only have ordinal scaling. However, the local independence assumption was partly compromised owing to several high (> 0.2) item-pair associations (i.e., association between items 5 and 7).

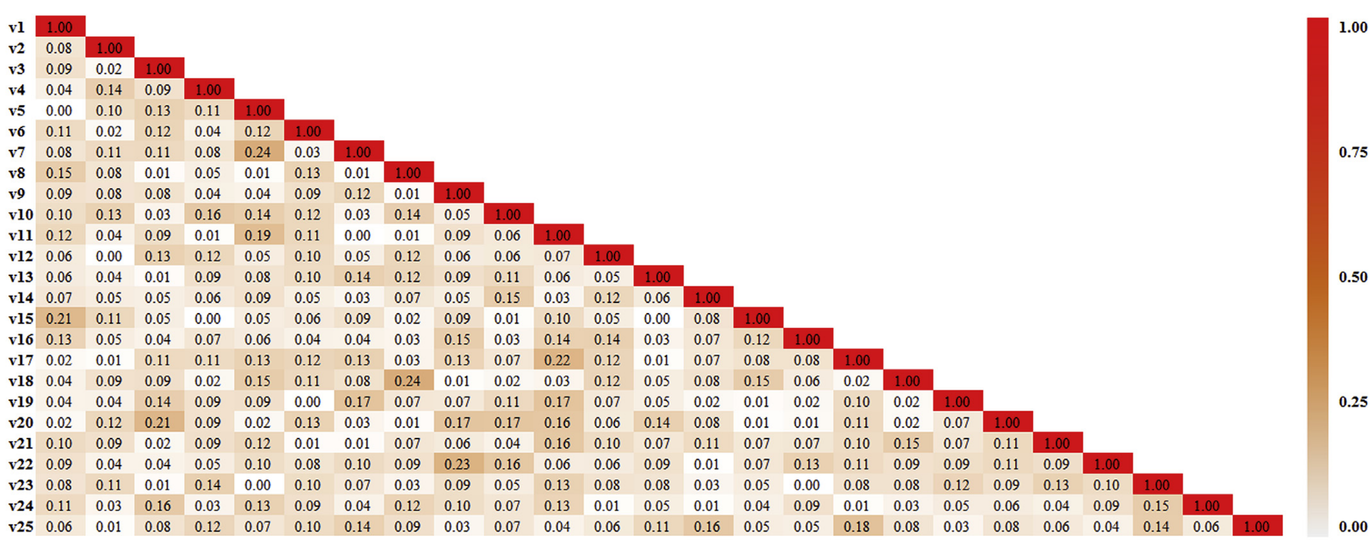


**Fig. 1.** Heat map of the local dependence between the 25 items of RS-SC. Darker colors imply greater local dependence. . (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

**Table 3**
Confirmatory factor analysis combined with MIRT for 3-factor structure of RS-SC.

| Item | $\lambda_1$ | *s.e.* | $\lambda_2$ | *s.e.* | $\lambda_3$ | *s.e.* | $a_1$ | *s.e.* | $a_2$ | *s.e.* | $a_3$ | *s.e.* | $d_1$ | *s.e.* | $d_2$ | *s.e.* | $d_3$ | *s.e.* | $d_4$ | *s.e.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.54 | 0.07 | – | – | – | – | 1.10 | 0.12 | – | – | – | – | 2.12 | 0.14 | 1.51 | 0.12 | 0.52 | 0.10 | −0.61 | 0.10 |
| **2** | **0.82** | **0.03** | - | - | - | - | **2.48** | **0.18** | - | - | - | - | **3.68** | **0.22** | **2.96** | **0.19** | **1.30** | **0.14** | **−0.22** | **0.13** |
| **3** | **0.74** | **0.05** | - | - | - | - | **1.88** | **0.15** | - | - | - | - | **2.62** | **0.17** | **1.60** | **0.14** | **0.65** | **0.12** | **−0.96** | **0.12** |
| **4** | **0.91** | **0.02** | - | - | - | - | **3.85** | **0.32** | - | - | - | - | **3.78** | **0.34** | **2.48** | **0.25** | **0.57** | **0.17** | **−1.54** | **0.18** |
| **5** | **0.92** | **0.02** | - | - | - | - | **4.05** | **0.35** | - | - | - | - | **4.13** | **0.31** | **2.82** | **0.24** | **0.88** | **0.17** | **−1.65** | **0.21** |
| 6 | 0.39 | 0.07 | – | – | – | – | 0.72 | 0.09 | – | – | – | – | 1.00 | 0.10 | 0.35 | 0.09 | −0.23 | 0.09 | −1.46 | 0.11 |
| **7** | - | - | **0.69** | **0.06** | - | - | - | - | **1.64** | **0.15** | - | - | **3.30** | **0.20** | **2.57** | **0.17** | **1.41** | **0.13** | **−0.18** | **0.11** |
| 8 | – | – | 0.63 | 0.07 | – | – | – | – | 1.38 | 0.15 | – | – | 1.00 | 0.12 | 0.26 | 0.11 | −0.45 | 0.11 | −1.76 | 0.14 |
| **9** | - | - | **0.73** | **0.06** | - | - | - | - | **1.80** | **0.18** | - | - | **3.11** | **0.22** | **2.15** | **0.18** | **1.17** | **0.14** | **−0.47** | **0.12** |
| **10** | - | - | **0.68** | **0.06** | - | - | - | - | **1.59** | **0.15** | - | - | **2.40** | **0.16** | **1.52** | **0.13** | **0.52** | **0.11** | **−1.10** | **0.13** |
| 11 | – | – | 0.53 | 0.06 | – | – | – | – | 1.07 | 0.10 | – | – | 1.70 | 0.13 | 1.04 | 0.11 | 0.26 | 0.10 | −1.18 | 0.11 |
| 12 | – | – | 0.65 | 0.06 | – | – | – | – | 1.45 | 0.14 | – | – | 2.72 | 0.18 | 1.76 | 0.14 | 0.92 | 0.12 | −0.82 | 0.11 |
| 13 | – | – | 0.64 | 0.06 | – | – | – | – | 1.43 | 0.14 | – | – | 3.19 | 0.20 | 2.16 | 0.16 | 1.22 | 0.12 | −0.45 | 0.11 |
| 14 | – | – | 0.60 | 0.07 | – | – | – | – | 1.28 | 0.13 | – | – | 1.01 | 0.11 | 0.22 | 0.10 | −0.36 | 0.10 | −1.65 | 0.13 |
| 15 | – | – | 0.60 | 0.08 | – | – | – | – | 1.27 | 0.15 | – | – | 2.61 | 0.17 | 2.05 | 0.14 | 1.20 | 0.12 | −0.93 | 0.11 |
| 16 | – | – | 0.57 | 0.07 | – | – | – | – | 1.17 | 0.12 | – | – | 1.84 | 0.14 | 1.00 | 0.12 | 0.15 | 0.11 | −1.06 | 0.11 |
| **17** | - | - | - | - | **0.69** | **0.06** | - | - | - | - | **1.61** | **0.15** | **2.57** | **0.17** | **1.78** | **0.15** | **0.86** | **0.12** | **−0.43** | **0.12** |
| 18 | – | – | – | – | 0.61 | 0.06 | – | – | – | – | 1.32 | 0.12 | 2.35 | 0.16 | 1.40 | 0.13 | 0.49 | 0.12 | −1.00 | 0.12 |
| **19** | - | - | - | - | **0.70** | **0.06** | - | - | - | - | **1.69** | **0.16** | **2.06** | **0.15** | **1.21** | **0.14** | **0.41** | **0.12** | **−0.93** | **0.14** |
| 20 | – | – | – | – | 0.65 | 0.06 | – | – | – | – | 1.44 | 0.14 | 2.23 | 0.15 | 1.38 | 0.13 | 0.57 | 0.11 | −0.89 | 0.12 |
| 21 | – | – | – | – | 0.54 | 0.07 | – | – | – | – | 1.09 | 0.11 | 3.30 | 0.21 | 2.45 | 0.16 | 1.29 | 0.11 | −0.16 | 0.11 |
| **22** | - | - | - | - | **0.72** | **0.06** | - | - | - | - | **1.79** | **0.19** | **2.92** | **0.22** | **2.35** | **0.19** | **1.76** | **0.17** | **0.45** | **0.13** |
| 23 | – | – | – | – | 0.61 | 0.06 | – | – | – | – | 1.31 | 0.13 | 3.13 | 0.21 | 2.40 | 0.16 | 1.75 | 0.13 | 0.32 | 0.11 |
| 24 | – | – | – | – | 0.55 | 0.06 | – | – | – | – | 1.11 | 0.16 | 2.58 | 0.18 | 1.84 | 0.14 | 1.13 | 0.13 | 0.01 | 0.12 |
| 25 | – | – | – | – | 0.60 | 0.06 | – | – | – | – | 1.28 | 0.19 | 2.92 | 0.22 | 2.35 | 0.19 | 1.76 | 0.17 | 0.45 | 0.13 |

λ indicate factor loadings, a indicate item discrimination, d indicate item easiness (transitions between the different answer categories).
Bolded items indicate the items chose for short form of RS-SC.

In the current study, the three-factor structure was supported by MIRT analysis, but several items had cross-loadings between the *Shifting* and *Persisting* domains. Therefore, we proposed a two-factor structure (*Generic* and *Shift-Persist*) for RS-SC and developed a 10-item scale, named RS–SC–10. Overall, the short-form scale has good psychometrics with good discriminative power and high item information function. RS–SC–10 could provide the most information among patients with low to moderate levels of resilience, indicating that it could be used to distinguish effectively patients with low resilience from the entire cancer population. In the interest of providing the best available resilience measurement instrument for cancer research or resilience-related intervention trials, some considerations for applying the presently derived RS–SC–10 should be warranted. For example, a cut-off of RS–SC–10 should be provided and validated in future research if this instrument is to be used as a psychosocial screening tool in clinical settings. The Minimum Clinically Important Difference (MCID) of RS–SC–10 should also be supplemented if it is to be used as an evaluation tool in different resilience-based interventions in future research (research on the MCID of RS-SC and RS–SC–10 is ongoing in our Be Resilient to Breast Cancer program, Ye et al., 2016a, 2017b). Nonetheless, RS–SC–10 causes less scale burden on patients and takes 63% less time compared with RS-SC, indicating that RS–SC–10 may have great potential for application in outpatients and communities (Ye et al., 2017c, 2017d, 2017e). However, the shortened RS–SC–10 may have potential drawback owing to the loss of comparability based on the original 25-item RS-SC. Future researchers who are interested in applying this instrument and its associated interval-level scaling in their research may consider whether the trade-off is worthwhile. In addition, some problematic threshold steps are recognized in RS–SC–10. For instance, in item 1, threshold 1($d_1$) between responses of *never* and *seldom* was 3.62 logits, whereas threshold 2 ($d_2$) between responses of *seldom* and *sometimes* was 2.90 logits, resulting in a threshold step of 0.72 logits, indicating that patients with different resilience levels chose the same option (*seldom*) in item 1: the *seldom* option could not distinguish patients with low resilience from those with moderate or high ones. Similar conditions were also identified for items 5 ($d_1$ and $d_2$, 0.62 logits), 6 ($d_2$ and $d_3$, 0.79 logits), and 10 ($d_2$ and $d_3$, 0.78 logits). According to Wolfe (2007), the threshold step of a five-point Likert graded response model should be no less than 0.81 logits, and these problematic items' options should be redefined. For instance, we may adapt a

**Table 4**
Exploratory factor analysis combined with MIRT for two-factor structure of RS–SC–10.

| Item | Description | Two-factor Structure of RS–SC–10 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $a_1$ | *s.e.* | $a_2$ | *s.e.* | $d_1$ | *s.e.* | $d_2$ | *s.e.* | $d_3$ | *s.e.* | $d_4$ | *s.e.* |
| 1 | Proud of my achievements | ***2.35*** | 0.20 | 0.95 | 0.14 | 3.62 | 0.23 | 2.90 | 0.21 | 1.26 | 0.16 | −0.28 | 0.14 |
| 2 | Tend to bounce back after illness or injuries | ***1.98*** | 0.16 | 1.26 | 0.15 | 2.58 | 0.19 | 1.55 | 0.15 | 0.59 | 0.12 | −1.02 | 0.13 |
| 3 | Can handle emotional distress | ***3.75*** | 0.33 | 1.68 | 0.26 | 3.85 | 0.31 | 2.48 | 0.25 | 0.49 | 0.21 | −1.74 | 0.26 |
| 4 | Can adapt to changes in surroundings | ***3.62*** | 0.32 | 1.35 | 0.23 | 3.84 | 0.35 | 2.58 | 0.27 | 0.74 | 0.20 | −1.67 | 0.22 |
| 5 | Try to see the good side | 1.07 | 0.11 | ***2.85*** | 0.12 | 2.82 | 0.18 | 2.20 | 0.15 | 1.21 | 0.11 | −0.14 | 0.10 |
| 6 | Pay more attention to the family | 1.49 | 0.12 | ***2.47*** | 0.13 | 2.59 | 0.16 | 1.78 | 0.12 | 0.99 | 0.11 | −0.37 | 0.10 |
| 7 | Accept things more easily | 1.26 | 0.13 | ***3.02*** | 0.14 | 2.27 | 0.16 | 1.44 | 0.13 | 0.49 | 0.11 | −1.05 | 0.12 |
| 8 | Cancer can be cured | 1.42 | 0.21 | ***1.81*** | 0.24 | 3.19 | 0.30 | 2.19 | 0.23 | 1.06 | 0.17 | −0.50 | 0.15 |
| 9 | Good fortune will come after surviving from a disaster | 1.50 | 0.20 | ***1.90*** | 0.24 | 2.59 | 0.25 | 1.54 | 0.20 | 0.53 | 0.15 | −1.14 | 0.15 |
| 10 | Feel the happiness in my life | 1.65 | 0.11 | ***2.36*** | 0.12 | 2.72 | 0.14 | 1.87 | 0.13 | 1.09 | 0.11 | −0.34 | 0.09 |

a indicate item discrimination, d indicate item easiness.
Bolded and italicized items indicate the dominant factor loadings or item discrimination.

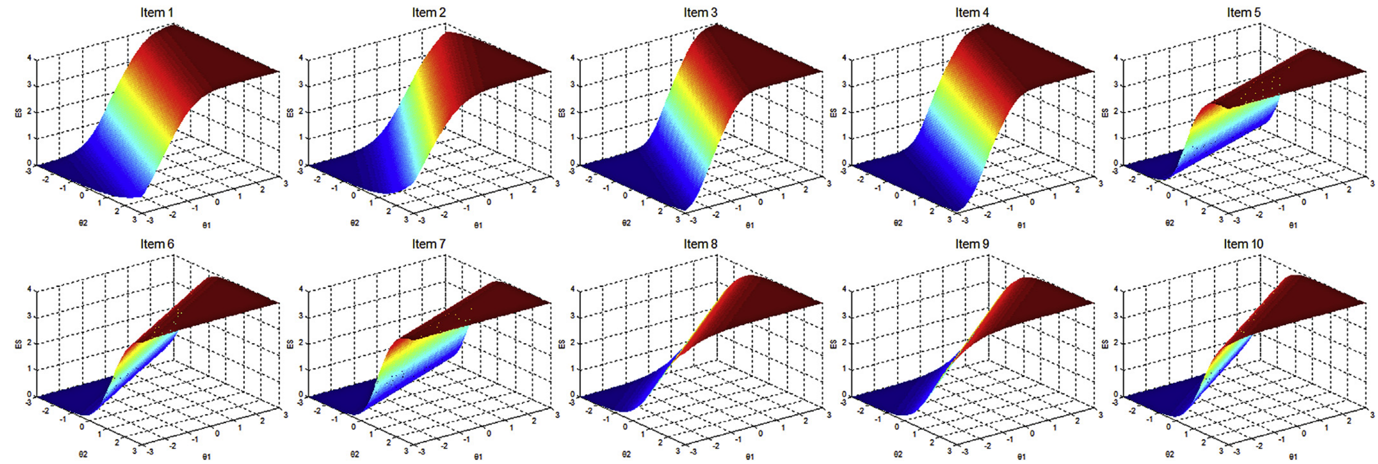


**Fig. 2.** Expected score surfaces. The X and Y axes are the levels of the two latent traits ($\theta_j$), respectively. The Z axis is the expected score ($E(\theta_j)$).

four-point Likert response model for item 5 by combining responses of *never* and *seldom* into one or combining responses of *seldom* and *sometimes* into one, to narrow down the threshold step. However, deleting a response option will lose much item information and cause inconsistency within the domain, which should be weighed against the benefits of these revisions (Baker, 2001). In addition, MIRT indicated that some items (i.e., items 2, 8, and 9) were associated with both the *Generic* ($a_1$) and *Shift-Persist* ($a_2$) domains. On the one hand, this phenomenon indicates that an MGRM-C may not be suitable for RS–SC–10, although we hold that the two latent traits of *Generic* and *Shift-Persist* are mutually correlated (a higher ability can compensate a lower ability), and a non-compensatory MGRM (in which $P_{ijk}$ is the product of all probabilities instead of linear accumulation) might provide more useful information in future studies (Bolt and Lall, 2003). On the other hand, this phenomenon indicates that the characteristics of *Generic* and *Shift-Persist* could be explained by the same item (i.e., item 9, Good fortune will come after surviving a disaster). If so, the current strategy of a between-item multidimensional structure (BIMS) for RS-SC (one item could only identify one latent trait in the test; Reise and Waller, 2009) may be not the best choice; a within-item multidimensional structure (WIMS, in which one item can discriminate between distinct levels of different latent traits) might be another choice to test the psychometrics of RS-SC and provide a more precise evaluation of item calibration parameters (Thomas, 2011). Thus, the goodness of fit of these four models should be compared in future research: MGRM-C + BIMS vs. MGRM-C + WIMS vs. MGRM-NC + BIMS vs. MGRM-NC + WIMS. Lastly, demographics (e.g., education level and income) should also be considered as a potential influencing factor for resilience structure (Ye et al., 2015, 2016b; 2019b; Qiu et al., 2017), which should also be tested in subgroup analysis in future research.

### 5.1. Limitations

Several limitations should be considered. First, the recommended sample size for MIRT analysis has been debated. Jiang et al. (2016) suggested that a sample size ≥ 500 is recommended in the process of item calibration to ensure accurate MIRT parameter estimates. In this view, the 451 patients in the current analysis may compromise the statistical power of MIRT. Therefore, future research with more robust sample sizes is warranted to confirm these findings. Second, the maximum information of items varies based on the observation direction set by the researcher; moreover, the way to maximize the IIFs remains unsolved in the current research. Third, the current sample is only composed of patients receiving active cancer treatment; more patients in remission or in the phase of palliative care could be included to increase the variation and generalization of RS-SC and RS–SC–10.

### 5.2. Relevance for clinical practice

MIRT analysis confirms that the two-factor structure is suitable for RS–SC–10, although some items with problematic threshold steps should be revised in future studies. Compared with RS-SC, the items of

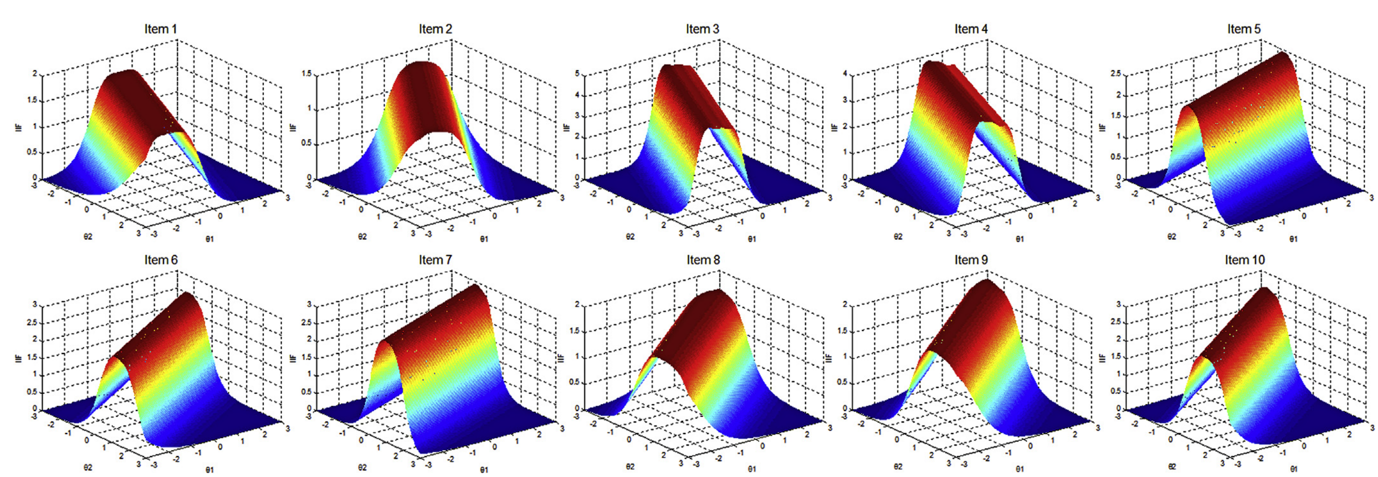


**Fig. 3.** Item information function surfaces. The X and Y axes are the levels of the two latent traits ($\theta_j$), respectively. The Z axis is the item information function (IIF, observation direction = 45°).

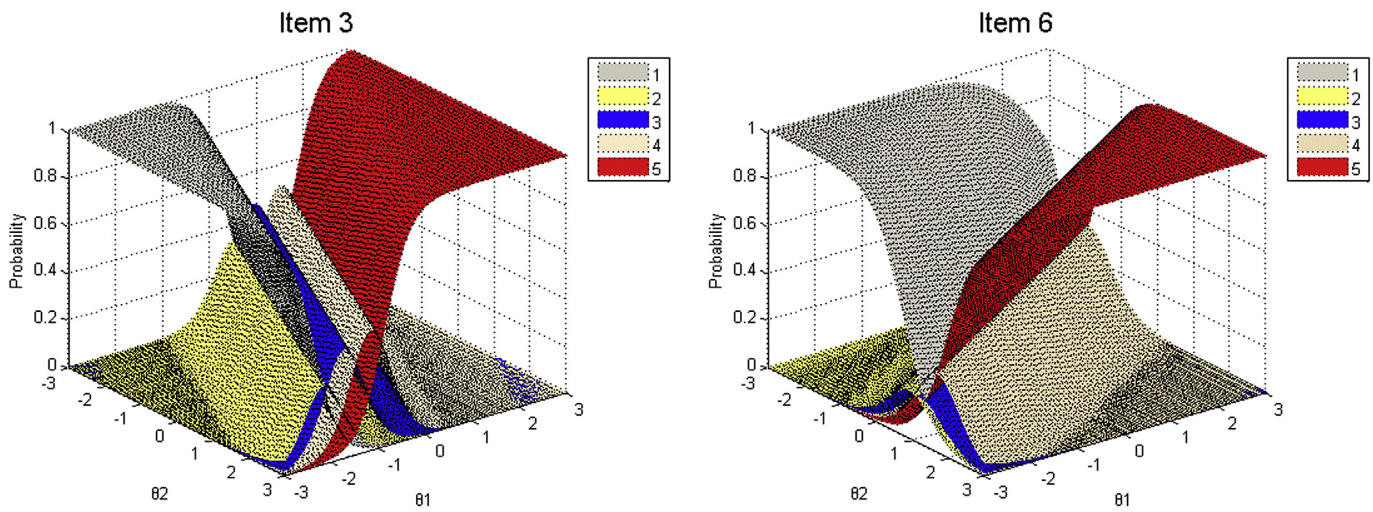


**Fig. 4.** Item characteristic surfaces.

RS–SC–10 have better discriminative power and higher information item function, as well as cause less scale burden, indicating its great potential of application in outpatients and communities. This scale could also be used as a potential tool to evaluate the efficacy of resilience intervention, but more studies on the MCID of RS–SC–10 are warranted.

Two examples of item 3 derived from *Generic* and item 6 from *Shift-Persist* are listed. The X and Y axes are the levels of the two latent traits ($\theta_j$), respectively. The Z axis is the probability of subject *j* responding to category *k* (and above) of item *i*.

## 6. Conclusions

A 10-item short form scale derived from RS-SC was validated in the MIRT analysis with a sample of Chinese patients with cancer. RS–SC–10 was characterized by a two-factor structure and showed good discrimination ability among patients with low to moderate levels of resilience. RS–SC–10 provided a useful alternative to RS-SC and could be used as a potential tool to assess the efficacy of resilience-related intervention in future studies.

## Conflicts of interest

The authors have no conflicts of interest to disclose.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejon.2019.06.005.

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