Supplementary Material (A) - Procedure for testing and adjusting translations of the Soundscape (quasi-)Circumplex Model

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Abstract

In depth description for the procedure developed for the paper: "Soundscape descriptors in eighteen languages: translation and validation through listening experiments

1. Introduction

In this analysis, we aim to test the circumplex structure of various soundscape survey translations. The circumplex model is a powerful tool in psychology, often used to visualize and interpret complex multivariate data. In order to enable its use across many contexts, cultures, and languages, its necessary to validate the structure of the circumplex items. The goal of validated translations is to ensure that the circumplex structure is maintained across translations, allowing for cross-cultural comparisons.

1.1. Defining the circumplex model

The concept of the psychometric circumplex model, first introduced by Guttman (1954), revolves around the idea of a circular relationship among variables. This circular relationship can be seen by identifying certain correlation patterns within the correlation matrix among variables, when appropriately ordered (Browne, 1992). In the case of the circular structure, the strength of the correlation coefficients in the matrix decreases as you move away from the diagonal, and then increases again as you move towards the opposite diagonal. This pattern of correlations can be seen in Table 1.

Table 1: Theoretical pattern of the correlation matrix corresponding to a circular structure. $\rho_1 > \rho_2 > \rho_3 > \rho_4$ (Gurtman and Pincus, 2000).

	V1	V2	V3	V4	V5	V6	V7	V8
V1	1							
V2	ρ_1	1						
V3	ρ_2	ρ_1	1					
V4	ρ_3	ρ_2	ρ_1	1				
V5	ρ_4	ρ_3	ρ_2	ρ_1	1			
V6	ρ_3	ρ_4	ρ_3	ρ_2	ρ_1	1		
V7	ρ_2	ρ_3	ρ_4	ρ_3	ρ_2	ρ_1	1	
V8	ρ_1	ρ_2	ρ_3	ρ_4	ρ_3	ρ_2	ρ_1	1

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This pattern of the corrrelation matrix indicates that the variables are ordered in a circular fashion, with the strongest correlations between adjacent variables, and the weakest correlations between variables that are furthest apart. It also means that the correlations between these variables follow a pattern that increases and decreases in a way that resembles a cosine wave, as explained by Yik and Russell (2004) and Grassi et al. (2010). This circular arrangement of the variables can be tested using a method proposed by Rounds et al. (2000).

Browne further expanded on the circumplex model in 1992 and 1995 by differentiating between equal spacing and equal communality (or radii) constraints. Browne described four variations of circumplex models, which include three types of quasi-circumplex models and one circulant model. These variations include the unconstrained or loosely ordered quasi-circumplex, the equal spacing quasi-circumplex, the equal communality quasi-circumplex, and the circulant model that maintains both equal spacing and equal communality.

In certain instances, the rigidity of a circumplex may be relaxed, leading to the concept of a quasi-circumplex. The term "quasi" implies a departure from strict adherence to even spacing and equal communality, allowing for some flexibility in the arrangement of variables. This flexibility is often necessary in order to accommodate the complexity of psychological constructs, which may not always fit neatly into a rigid circular structure. It refers to any graphical or conceptual representation where variables or dimensions are organized in a circular or circular-like manner. This umbrella term recognizes the spectrum of circular models, acknowledging variations in the spacing, organization, and relationships among variables.

As researchers delve into the intricacies of psychological spaces, the choice between a strict circumplex, a quasi-circumplex, or a more general circular structure becomes crucial. These models play a pivotal role in visualizing and understanding the complex interplay of variables, offering researchers nuanced frameworks to explore and interpret their data.

As described by Rogoza et al. (2021):

> The circumplex model can be defined through the terms of: 1) the possibility to locate variables differentiated in the model in the two-dimensional space with 2) equal spacing (i.e. same distance between variables within the model around circumplex) and 3) equal communality (i.e. same distance between variables from the middle of the circle) (Gurtman, 1994, ?). On the basis of these criteria, one could differentiate four models, depicted on Fig. 1: a circular one (less restrictive Model 1), quasi-circumplex (Model 2 and 3), and circumplex (most restrictive Model 4).

< figure src="figures/Rogoza2021three-fig1.png" caption="Fig. 1. Four models of circumplex structure. Model 1 is a circular model, Model 2 is a quasi-circumplex model with equal spacing, Model 3 is a quasi-circumplex model with equal communality, and Model 4 is a circumplex model with equal spacing and equal communality." >

1.2. Locating external variables within circumplex models

Once the general circumplex structure is tested, it is possible to investigate the likelihood to locate an external variable (e.g., psychoacoustic loudness, N) within the empirical circumplex. The circumplex model provides a precise framework for predicting the relationships between an external variable and all circumplex variables. The Structural Summary Method (SSM) yields several key estimations, including: Model fit (R2), which assesses how well the observed sinusoidal curve aligns with the cosine function, indicating the goodness of fit. Elevation, representing the average correlation between an external variable and all circumplex variables. Amplitude (vector length), measuring the distance from the mean of the external variable's correlation to its peak correlation with circumplex variables. This value signifies the uniqueness of the profile, indicating whether it is prominently associated with a specific circumplex variable or equally related to all. Angular displacement, denoting the angle at which the profile reaches its maximum point, indicating the empirical location of the variable within the circumplex as observed in the data. The Structural

Summary Method (SSM) is a technique used to summarize correlation patterns among measurement scores that are hypothesized to conform to a circumplex structure (Rogoza, Cieciuch, & Strus, 2021). SSM aims to fit a sinusoidal curve to data points (qi) based on their nominal angular positions (i). This is achieved by optimizing the parameters for elevation (e), amplitude (i), and displacement (d). Mathematically, these parameters are used to model the correlational information (qi) in equation 1: q_i=e+ cos (_i-d) . (1) It is essential to evaluate how well the sinusoidal curve aligns with the cosine function by examining its goodness of fit, as indicated by the R2 value. If R2values fall below 0.70, it is advisable not to interpret the remaining coefficients and to discontinue the process of locating external variables. Conversely, R2 values exceeding 0.80 indicate a strong fit. Additionally, it's worth mentioning that amplitude estimates, reflecting the distinctiveness of the profile, and elevation estimates, indicating the presence of a general factor, are considered notable when they surpass 0.15.

The structure of the circumplex is key to determining where external variables are located. Given differing angles and communalities, the external variable can occupy different locations within the circumplex. Revealing and validating the true structure of a particular circumplex model is therefore key to reliably identifying correct location of external variables within the circumplex space.

1.3. Translating circumplex instruments

Typically, circumplex scales are measured via a series of questions in a survey instrument. These instruments are initially developed in one language and the validity and structure of the instrument is tested in that language. Often these instruments are directly translated into other languages to enable their use in other countries. However, the validity of the instrument in the new language is not guaranteed. Changes in the correlation structure can be caused by errors in the translation process, by semantic and linguistic differences between the translated scales even given a valid translation, and by a lack of generalisability of the circumplex instrument.

It is easy to see how errors in the translation process can lead to changes in the correlation structure. For example, if a question is mistranslated, then the responses to that question will not be correlated with the responses to the other questions in the instrument. Semantic and linguistic differences between the translated scales can also lead to changes in the correlation structure. For example, if a question is translated into a language where the concept does not exist or cannot be easily expressed, then the responses to that question will not be correlated with the responses to the other questions in the instrument. Finally, it may be that even if the original instrument is valid for e.g. the English-speaking population, it may not be valid for other populations due to cultural differences.

1.3.1. Goals of translating a circumplex instrument

Two approaches could be taken when attempting to translate a survey instrument. The first approach would attempt to achieve direct concurrence with the original instrument, where each scale is directly correlated with the corresponding scale from the original instrument. If the circumplex structure is identical between the two languages, then this approach would allow for the most direct comparison between the two languages. However, if the circumplex structure is not identical between the two languages, then this approach would lead to a loss of information. The second approach would attempt to achieve the same circumplex structure in the new language as in the original language. This approach would allow for the most direct comparison between the two languages.

In this second approach, identifying the differences in structure between translations enable the process of locating an external variable to be corrected for the differences in structure. Given that at minimum a quasi-circumplex structure can be confirmed, then the deviations in either the angles or communalities from the ideal circumplex structure can be measured and accounted for. When this is done separately for the origianl and translated instruments, then an external variable which has the same theoretical location in both instruments should be located in the same location in both corrected instruments.

This has an important impact on comparing results under the two translations. If an external variable is theoretically located in a single, fixed position in the circumplex space, locating it without accounting for the differences in structure between the two translations will lead to different locations in the two translations. The interpretation of this result would then be that the external variable is located in different positions in the two languages. However, if the differences in structure are accounted for, then the external variable should be located in the same position in both translations. By applying the correction we can attempt to discover differences in the effect of external variables, independent of the differences in structure between the two translations.

1.4. A test case: The Soundscape Circumplex Model (SCM)

In 2010, Axelsson et al. (2010) proposed a *principle components* model of soundscape perception. Due to its similarity to the widely-studied Russell's circumplex model of affect (Russell, 1980), Axelsson's principal component model is often referred to as the Soundscape Circumplex Model (SCM) in soundscape literature. The SCM and the Swedish Soundscape Quality Protocol (SSQP) (Axelsson et al., 2012) utilizing it quickly became the predominant method of soundscape assessment in both scientific literature and professional practice (Aletta and Torresin, 2023), due to its ease of use, interpretability, and, crucially, its ability to summarise the complex interrelationships between soundscape descriptors within a straightforward and familiar two-dimensional space. Togeter with a similar principal component model in Cain et al. (2013), the framework of the circumplex model of soundscape perception was subsequently adapted into an integral part of the standardised protocols for soundscape data collection, specifically in Method A of ISO/TS 12913-2:2018 (2018).

Currently, the soundscape community relies very heavily on the framework proposed in ISO/TS 12913-2:2018 (2018), both for theory development and for procuring empirical evidence of the benefits of the soundscape approach, in real life scenarios. In a recent systematic literature review, Aletta and Torresin (2023) idenitified 254 scientific publications which have referred to ISO 12913 since its publication in 2018, with 50 of them appropriately making use of the data collection methods. Of those, several papers included multiple studies, with 51 studies making use of the SCM as recommended in the ISO standard. In addition, the SCM has been used in many more studies without reference to the ISO standard (Engel et al., 2018), and has been haphazardly translated into many languages (Tarlao et al., 2016; Nagahata, 2019; Tarlao et al., 2020; Aletta et al., 2019).

The Soundscape Circumplex Model (SCM) was developed in 2010 by Axelsson et al. (2010) to describe the perception of ambient sound environments. It has since been used in a number of studies to describe the perception of soundscapes in different contexts and cultures (ISO/TS 12913-2:2018, 2018). The SCM is composed of eight scales, which closely resemble the eight scales of the Circumplex Model of Affect (Russell, 1980). The 7 scales are arranged in two bipolar dimensions, with pleasant-annoying along the x-axis (valence) and eventful-uneventful along the y-axis (arousal). Arranged in a circular pattern around the circumplex, beginning at 0 degrees and moving counter-clockwise, the eight scales are: pleasant (0)

2. A four step procedure for the analysis of circumplex models

In Rogoza et al. (2021), the authors propose a three-step procedure for assessing circumplex models. The steps in this procedure are: 1) "verify whether the analzed model is circumplex or not" using Structural Equation Modelling based on Browne (1992)'s model; 2) "test the possibility to locate an external variable within empirical circumplex" using the Structural Summary Method (Gurtman, 1994); and 3) "assess the extent of which empirical locations are in congruence to the theoretical predictions within the circumplex structure" (Rogoza et al., 2021).

We expand upon the three-step procedure proposed by Rogoza et al. (2021) and adapt it to the specific case of testing multiple variations (i.e. translations) of the same circumplex instrument. The goals of this procedure are, for each translation, to verify the quasi-circumplex structure of the instrument, to derive angle corrections, and to test the congruence between the corrected circumplex and the theoretical circumplex structure. We do this by first adding an initial step to incorporate Rounds et al. (2000)'s test of the circular ordering of the scales to confirm that the order of the scales is maintained across translations. We then follow the same three steps as Rogoza et al. (2021), but we adapt the third step to test the congruence between the circumplex structure of the original instrument and the circumplex structure of the translated instruments and to allow for adjustments to be made by extracting adjusted angles from the SEM step.

2.1. Step 1: Confirm the circular ordering of the circumplex scales

In line with the procedure taken in Gurtman and Pincus (2000) and previously employed for the SCM by **?**, we begin by confirming the circular ordering of the circumplex scales. This test, developed by Rounds et al. (2000), the test of the circular order model involves comparing the obtained order relations for a set of scales against their hypothesized order given a certain circular model. This test is applied in order to ensure that the process of translation has not altered the order of the scales and so the test is applied against the order of the scales in the original instrument. The test is applied to each translation separately, and the results are compiled into a single table.

The index used for this test is Hubert and Arabie (1987)'s correspondence index (CI). This offers a descriptive measure reflecting the degree to which the model's ordered predictions align with a specific sample matrix. The metric is calculated as the proportion of predictions met minus the proportion violated, yielding a range from 1.0 (indicating complete prediction fulfillment) to -1.0 (indicating all predictions contradicted). In alignment with the methodology outlined by Tracey et al. (Tracey, 1997), we applied a randomization test to the hypothesized order relations (Hubert and Arabie, 1987), producing an exact probability, determining the likelihood of achieving the observed model fit in relation to all potential permutations of the matrix. The index thresholds for this test are: a p-value < 0.05 and a CI > 0.70.

2.2. Step 2: Confirm the quasi-circumplex structure of the circumplex scales

We confirm the structure of the circumplex instrument by applying Browne (1992)'s circular stochastic process model with a Fourier series correlation function. This model represents a non-standard Structural Equation Model (SEM) specifically tailored to testing circumplex structures which allows a researcher to examine the extent to which the underlying structure of a sample correlation matrix conforms to a circumplex pattern. The four model variations (unconstrained circular, equal spacing quasi-circumplex, equal-communality quasi-circumplex, and strict circumplex with equal spacing and communality) can each be investigated using this model. For the unconstrained and quasi-circumplex models, Brownen's model allows for the estimation of the angles and communalities of the circumplex scales. From these results for the quasi-circumplex models, we can derive the corrected angles (or communalities) for each translation, which can be used in the next step of the analysis.

This model is implemented in the CircE package (Grassi et al., 2010) for R (R Core Team, 2018). The model is applied to each translation separately, testing each of the four model variations, and the results are compiled into a single table. CircE provides a suite suite of SEM fit indices, which are statistical measures used to evaluate the goodness of fit of the models. For this study, we use the following fit indices: Comparative Fit Index (CFI), Goodness of Fit Index (GFI), and Standardized Root Mean Square Residual (SRMR), summarised with their respective thresholds in Table 2.

Readers might note that these indices differ slightly from those used by Rogoza et al., most notably the exclusion of the Root Mean Square Error of Approximation (RMSEA), a commonly used metric. RMSEA was excluded from the analysis on the basis of both Rogoza's own critiques[1] and recent warnings from West et al. (2023).

[1]"it is worth noting that the RMSEA may not be best suited to evaluate circumplex models. It becomes biased in the case of high correlations between proximal variables, as found in circumplex models, and should be interpreted with caution." (Rogoza et al., 2021)

Table 2: Fit indices and thresholds, including the reference from which the threshold is derived.

Fit Index	**Threshold**	**Reference**
Correspondence Index (CI)	$p < 0.05$, CI > 0.70	Gurtman and Pincus (2000)
Comparative Fit Index (CFI)	*0.92*	Moshona et al. (2023)
Goodness of Fit Index (GFI)	*0.90*	Rogoza et al. (2021)
Standardized Root Mean Square Residual (SRMR)	*0.08*	Hu and Bentler (1999) Moshona et al. (2023) Tarlao et al. (2020)

Once each of the model variations are assessed against the above fit indices, we can determine whether that model variation is a good fit for the data. If the strict circumplex model meets the fit thresholds across the translations tested, then the procedure can be continued and no adjustment will be needed. If, however, the structure of some or all of the translations are found to have a quasi-circumplex structure, then adjustments will need to be derived and applied to ensure cross-comparability between the translated instruments. If the model variation for the equal-communality model (where the angles are allowed to vary) is a good fit for the data, then we can use the derived angles from CircE as adjustments to the circumplex structure.

Importantly, this table also reports the derived angles for each scale for the unconstrained and Equal comm. models. These angles will be carried over and used in the next stage of the analysis, where we will validate the survey instrument by correlating the survey responses with the acoustic indices using the Structural Summary Method (SSM).

2.3. Step 3: Locate the full dataset circumplex scales within each language's circumplex space

Once the general circumplex structure is tested, it is possible to investigate the likelihood to locate an external variable (this could be an objective feature such as sound level dB or it could be another perceptual or psychometric variable such as tranquility) within the empirical circumplex. The circumplex model provides a precise framework for predicting the relationships between an external variable and all circumplex variables. The Structural Summary Method (SSM) is a technique used to summarize correlation patterns among measurement scores that are hypothesized to conform to a circumplex structure (Rogoza et al., 2021). SSM aims to fit a sinusoidal curve to data points (q_i) based on their nominal angular positions (θ_i). This is achieved by optimizing the parameters for elevation (e), amplitude (i), and displacement (d). Mathematically, these parameters are used to model the correlational information (q_i) in Equation 1:

$$q_i = e + \alpha cos(\theta_i - d) \tag{1}$$

SSM analysis yields several key estimations, including:

- Model fit (R2), which assesses how well the observed sinusoidal curve aligns with the cosine function, indicating the goodness of fit.
- Elevation, representing the average correlation between an external variable and all circumplex variables.
- Amplitude (vector length), measuring the distance from the mean of the external variable's correlation to its peak correlation with circumplex variables. This value signifies the uniqueness of the profile, indicating whether it is prominently associated with a specific circumplex variable or equally related to all.
- Angular displacement, denoting the angle at which the profile reaches its maximum point, indicating the empirical location of the variable within the circumplex as observed in the data.

> It is essential to evaluate how well the sinusoidal curve aligns with the cosine function by examining its goodness of fit, as indicated by the R^2 value. If R^2 values fall below 0.70, it is advisable not to interpret the remaining coefficients and to discontinue the process of locating external variables. Conversely, R^2 values exceeding 0.80 indicate a strong fit. Additionally, it's worth mentioning that amplitude estimates, reflecting the distinctiveness of the profile, and elevation estimates, indicating the presence of a general factor, are considered notable when they surpass 0.15.

As described in Rogoza et al. (2021), Step Two involves testing whether external variables can be located within the circumplex.

Because we have derived new angles in the SEM step, we use these 'adjusted' angles for calculating the SSM parameters.

In order to determine whether the language circumplexes can adequately allow an external variable to be located, we use the following criteria:

- $R^2 > 0.8$
- amplitude $> .15$

These indices are based on the criteria used by Rogoza et al. (2021), however we use an increased criterion of $R^2 > 0.9$ since we have a prior expectation that the circumplex variables should fit very well within each translation's circumplex.

2.4. Step 4: Accurately locating circumplex items within each language

The final step of Rogoza et al. (2021) 's three step procedure is to test the congruence between the empirical locations and theoretical expectations within the circumplex structure. In the case of the soundscape circumplex and our SATP data, we don't have an external variable with a defined theoretical location within the circumplex - for instance loudness does not have a defined location within the circumplex where it is expected to be located.

Taking inspiration from Yik and Russell (2004), we propose to use the circumplex structure of the soundscape survey itself as the theoretical expectation. Yik and Russell (2004) proposes that one circumplex can be located within another by calculating the SSM correlation between each of the scales of the reference circumplex and the test circumplex. In this way, each scale of the reference circumplex can be located within the test circumplex, and we can test whether these empirical locations meet our expectations.

The process to do this is as follows:

1. For both the reference and test circumplex, calculate the mean value of each scale for each recording.
2. Calculate the SSM correlation between each scale of the reference circumplex and the test circumplex, in our case using the corrected angles.
3. Test the congruence betwen the empirical locations and theoretical expectations using the Procrustes congruence test (Rogoza et al., 2021).

We will be using the full dataset as the reference set and the data from each translation as the test set. This effectively means that we are testing whether each translation is able to locate the circumplex structure of the soundscape survey, consistently across all languages.

This aligns with the overall goal of our process of allowing data (i.e. the circumplex coordinate) from different languages to be directly compared, by correcting for the differences in the circumplex structure between languages.

2.4.1. Congruence

What Rogoza et al. (2021) (and Orthosim) refer to as Tucker's Congruence Coefficient is also commonly referred to as the cosine similarity (see the Tensorly documentation). We therefore use the sklearn implementation of cosine similarity to calculate the congruence between the empirical locations and theoretical expectations. This produces a matrix of cosine similarity values, which we then use to calculate the mean congruence, to match the model congruence from Rogoza et al. (2021).

2.4.2. Procrustes

However, it appears that, despite Rogoza et al. (2021) 's description, this method is not actually based on a Procrustes analysis. The equivalent distance metric from a Procrustes method would be the rotational-based Procrustes distance, i.e. the squared Froebenius norm of the difference between the two orthogonal matrices. See Andreella et al. (2023):

> Instead, the second distance exploits the orthogonal matrix parameters solution of the Procrustes problem. The rotational-based distance computes the squared Frobenius distance between these estimated orthogonal matrices. As we will see, this metric measures the level of dissimilarity/similarity in orientation between matrices/subjects before functional alignment.

Based on the proof given in **?**, given that the input matrices are scaled (i.e. `rotational(scale=True)`), then the Procrustes distance is a true distance measure which obeys $0 < p(X, Y) < 1$ (Bakhtiar and Siswadi, 2015, 322). Therefore we can convert the Procrustes distance to a similarity measure by subtracting it from 1.

3. Results

3.1. Step 1: Confirm the circular ordering of the circumplex scales

The results of the circular ordering test are shown in Table 3. The following translations were not confirmed to have a circular ordering of their scales which matches the theoretical order: 'zsm' and 'vie'. They are therefore excluded from the following steps of the analysis.

Table 3: Results of the Circular Order analysis of the SATP dataset.

mat	pred	met	tie	CI	p	description
1	288	283	0	0.965	0.000	SATP
2	288	272	0	0.889	0.000	arb
3	288	262	0	0.819	0.000	cmn
4	288	284	0	0.972	0.000	deu
5	288	276	0	0.917	0.000	ell
6	288	286	0	0.986	0.000	eng
7	288	278	0	0.931	0.000	fra
8	288	268	0	0.861	0.000	hrv
9	288	255	0	0.771	0.000	ind
10	288	275	0	0.910	0.000	ita
11	288	264	0	0.833	0.000	jpn
12	288	262	0	0.819	0.000	kor
13	288	261	0	0.812	0.000	nld
14	288	254	0	0.764	0.000	por
15	288	283	0	0.965	0.000	spa
16	288	284	0	0.972	0.000	swe
17	288	261	0	0.812	0.000	tur
18	288	244	0	0.694	0.002	vie
19	288	241	0	0.674	0.002	zsm

Table 3: Results of the Circular Order analysis of the SATP dataset.

mat	pred	met	tie	CI	p	description

3.2. Step 2: Confirm the quasi-circumplex structure of the circumplex scales

The results of the SEM model fit for the equal-communality quasi-circumplex structures are shown in Table 4.

Table 4: SEM fit results

	Language	Model Type	n	m	CFI	GFI	SRMR	Score	passing
5	arb	Equal comm.	809	3	0.971	0.969	0.044	3	Pass
9	cmn	Equal comm.	1832	3	0.960	0.954	0.044	3	Pass
13	deu	Equal comm.	810	3	0.943	0.915	0.059	3	Pass
17	ell	Equal comm.	810	3	0.928	0.934	0.079	3	Pass
1	eng	Equal comm.	864	3	0.934	0.907	0.052	3	Pass
21	fra	Equal comm.	891	3	0.919	0.913	0.098	1	Fail
25	hrv	Equal comm.	864	3	0.949	0.926	0.065	3	Pass
29	ind	Equal comm.	891	3	0.933	0.923	0.078	3	Pass
33	ita	Equal comm.	810	3	0.944	0.932	0.069	3	Pass
37	jpn	Equal comm.	917	3	0.892	0.896	0.087	0	Fail
41	kor	Equal comm.	810	3	0.952	0.941	0.084	2	Fail
45	nld	Equal comm.	864	3	0.967	0.943	0.056	3	Pass
49	por	Equal comm.	1890	3	0.925	0.917	0.092	2	Fail
53	spa	Equal comm.	1647	3	0.920	0.910	0.063	3	Pass
57	swe	Equal comm.	945	3	0.944	0.924	0.053	3	Pass
61	tur	Equal comm.	918	3	0.927	0.915	0.079	3	Pass

Of the remaining 16 languages considered, all but 3 pass the fit indices thresholds. The three which do not achieve the required performance are ‘fra’, ‘por’, and ‘jpn’. These are excluded from the following steps of the analysis.

3.3. Step 3: Locate the full dataset circumplex scales within each language’s circumplex space

Figure 1 demonstrates the SSM process for locating each of the circumplex scales within the circumplex space of the ‘cmn’ translation. These profile plots show the correlation between the circumplex scales and the external variable (in this case, each of the general attributes) as a function of the angle of the circumplex scale. The SSM model fits a sinusoidal curve to the data points, and the parameters of this curve are used to determine the location of the circumplex scale within the circumplex space. These plots show clearly how adjusting the angles of the circumplex scales can improve the fit of the sinusoidal curve to the data points.

The model fit results for each translation are shown in Table 5. Since every translation is able to adequately locate the circumplex scales, we can proceed to the final step of the analysis.

Table 5: Fit results for locating the general circumplex within each language

	PAQ1	PAQ2	PAQ3	PAQ4	PAQ5	PAQ6	PAQ7	PAQ8
arb	0.998	0.999	0.995	0.995	0.998	0.999	0.997	0.995
cmn	0.997	0.996	0.989	0.993	0.999	0.999	0.990	0.993
deu	0.998	0.999	0.999	0.998	0.998	0.998	0.999	0.998

Table 5: Fit results for locating the general circumplex within each language

	PAQ1	PAQ2	PAQ3	PAQ4	PAQ5	PAQ6	PAQ7	PAQ8
ell	0.998	0.996	0.998	0.998	0.997	0.998	0.996	0.997
eng	0.997	0.998	0.999	0.996	0.997	0.999	0.998	0.994
hrv	0.997	0.997	0.994	0.995	0.997	0.998	0.995	0.991
ind	0.996	0.998	0.998	0.998	0.996	0.992	0.999	0.996
ita	0.895	0.996	0.998	0.986	0.980	0.990	0.996	0.978
nld	0.993	0.998	0.999	0.998	0.998	0.996	0.999	0.999
spa	0.998	0.996	0.998	0.998	0.998	0.996	0.998	0.999
swe	0.995	0.998	0.997	0.997	0.996	0.997	0.997	0.996
tur	0.997	0.997	0.998	0.999	0.996	0.992	0.999	0.996

3.4. Step 4: Accurately locating circumplex items within each language

Table 6 shows the results of the congruence test between the circumplex structure of the original instrument and the circumplex structure of the translated instruments. In addition to calculating these results with the adjusted angles to apply the Step 4 test, we also calculate the results using the unadjusted angles to demonstrate the impact of the adjustment.

Table 6: Correspondence between the general circumplex and the language-specific circumplex

	Language	Eq Ang Model	Corr Ang Model	Eq Ang Procrustes	Corr Ang Procrustes
0	arb	0.990	0.941	0.980	0.984
1	cmn	0.931	0.992	0.879	0.990
2	deu	0.986	0.960	0.976	0.984
3	ell	0.986	0.990	0.973	0.980
4	eng	0.989	0.979	0.984	0.984
5	hrv	0.990	0.971	0.983	0.986
6	ind	0.964	0.949	0.938	0.983
7	ita	0.986	0.953	0.976	0.975
8	nld	0.980	0.974	0.942	0.979
9	spa	0.987	0.983	0.969	0.980
10	swe	0.988	0.975	0.974	0.978
11	tur	0.958	0.985	0.925	0.981

When the adjusted angles for each translation are applied, the resulting circumplex scale location achieve good congruence with their theoretical locations. It should be noted that this is not the case without using the adjusted angles: locating the scales with the cmn translation using the unadjusted angles results in a score of 0.885, below the fit threshold of 0.9, but this increases to 0.991 when using the adjusted angles (see Figure 6). All translations see some degree of improvement by using the adjusted angles.

Figure 2 gives an example of the impact of using the corrected angles for locating the circumplex scales.

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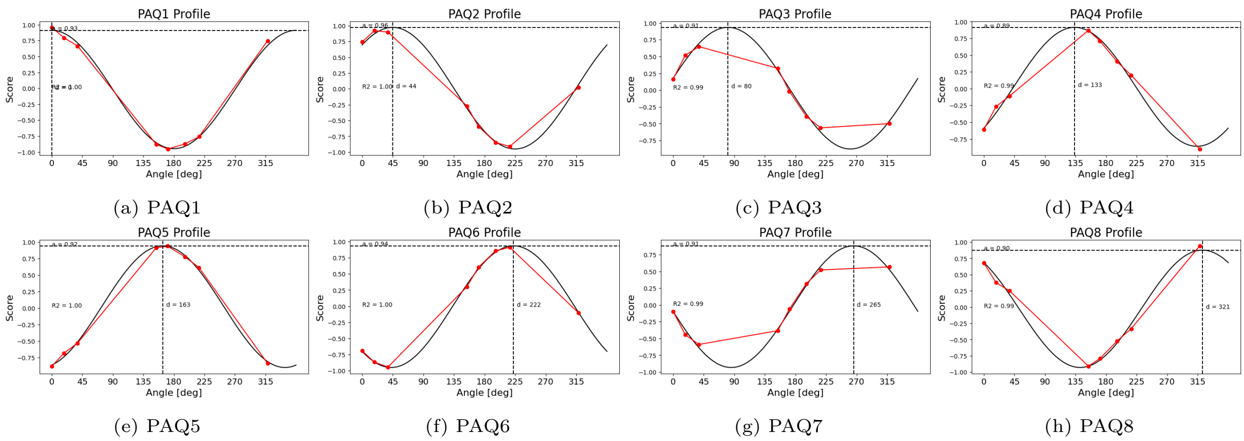
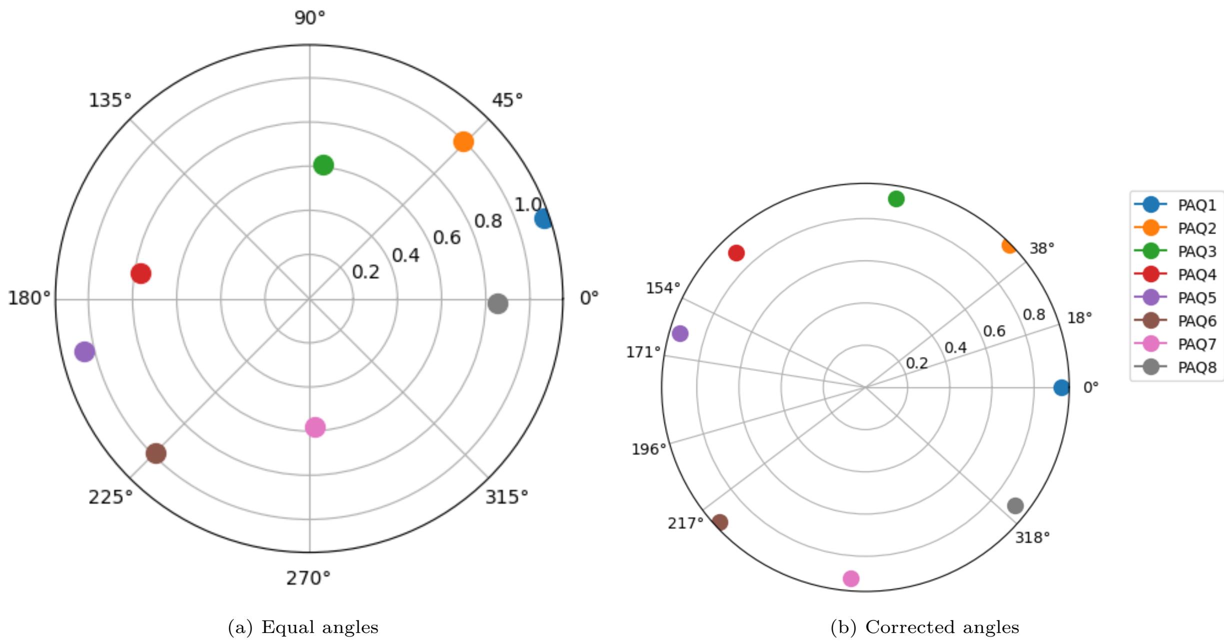


(a) PAQ1 (b) PAQ2 (c) PAQ3 (d) PAQ4

(e) PAQ5 (f) PAQ6 (g) PAQ7 (h) PAQ8

Figure 1: Profile plots for the Mandarin (cmn) translation



(a) Equal angles (b) Corrected angles

Figure 2: Locating the language-specific circumplex for Mandarin, using equal angles and corrected angles

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