Detecting Sinusoidal Patterns from Circumplex

Models of Psychological Constructs

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Abstract

An interesting feature of circumplex models of psychological constructs is that they may yield a sinusoidal (i.e., sine wave) pattern of relations between the elements in the model and variables that are external to the model. Thus far, however, the fit to a sinusoidal pattern has been evaluated with visual inspection or arbitrary means of parsing patterns of association. In this research, we developed and validated a sinusoidal fit index (SFI). We then applied the SFI to Schwartz’s original (1992) and revised (Schwartz et al., 2012) models of human values and the circumplex model of interpersonal problems (Alden et al., 1990). Examination of data from the European Social Survey revealed adequate to very good sinusoidal fit of Schwartz’s model to two-thirds of the variables in the survey. Data from published papers revealed very good fit to all variables in the model of interpersonal problems. The results also suggested potential adjustments to the scoring of human values and to the ordering of the values. Discussion focuses on implications for research on values, applications to other circumplex models of individual difference, and broad implications for detecting sinusoidal patterns in data.

 *Keywords*: Sinusoidal relations, circumplex models, human values, interpersonal problems, curvilinear test

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Models of Psychological Constructs

 Many models of individual differences have predicted a circumplex (circular) pattern of associations between psychological constructs. Prominent among these are circumplex models of *human values* (Schwartz, 1992; Schwartz et al., 2012) and *interpersonal problems and orientations* (Alden, Wiggins, & Pincus, 1990). By virtue of the circular shape in these models, they support predictions of a specific curvilinear pattern of associations with other variables (e.g., attitudes, beliefs): a sinusoidal waveform. Yet, the methods for testing whether data fit this waveform have differed greatly between researchers, with heavy reliance on case-by-case visual inspection or arbitrary means of parsing patterns of association. In this article, we describe and apply a new procedure that directly evaluates the extent to which circumplex models yield a sinusoidal pattern of association with other variables. Because large amounts of archival data facilitate a test of this pattern of association with a circumplex model of human values, we focus on evaluating this model in our Introduction and the first three studies. We then turn to the circumplex model of interpersonal problems and describe how the findings can be used to further refine circumplex models of individual differences.

## Schwartz’s Circumplex Model of Human Values

Human values are frequently defined as abstract ideals that are held as important guiding principles in one’s life (Maio, 2010; Schwartz, 1992). Research on values has examined associations between ratings of human values (e.g., equality, freedom) and numerous kinds of judgments, affective states, and behavior. For example, individuals’ ratings of value importance are associated with religiosity (Saroglou, Delpierre, & Dernelle, 2004), the Big Five traits (Fischer & Boer, 2014; Parks-Leduc, Feldman, & Bardi, 2014), social attitudes (Boer & Fischer, 2013), well-being (Sagiv & Schwartz, 2000), clinical constructs (Hanel & Wolfradt, 2016), organizational citizenship (Arthaud-Day, Rode, & Turnley, 2012), environmental behavior (Hurst, Dittmar, Bond, & Kasser, 2013; Schultz & Zelezny, 1998), protest action (Mayton & Furnham, 1994), and diverse other behaviors (Bardi & Schwartz, 2003; Schwartz & Butenko, 2014). Many of these associations have been revealed using Shalom Schwartz’s (1992; Schwartz & Bilsky, 1987) model of human values as the theoretical framework. Schwartz predicted and found that (a) 10 value types can be distinguished, and (b) they are ordered in the same structure across more than 80 countries (Fig. 1; Schwartz, 1992). As shown in Table 1, each of the value types contains two to nine values (Schwartz, 1992, 1994; Schwartz et al., 2001).

A recent revision of this model has subdivided the 10 value types into 19 types (Schwartz et al., 2012), but the core structure and predictions remain the same. That is, because of the motivational synergies and conflicts in the circular model, Schwartz’s revised model predicts that importance ratings of adjacent values are positively correlated with each other, orthogonal values are non-related, and opposing values are negatively correlated. In an additional model, Schwartz (2006) has divided his values into seven types in order to model *cultural-level* differences in value orientations (i.e., based on aggregated data in nations), but the core structure and predictions again remain the same.

Schwartz’s (1992) original model was the first to propose an integrative perspective that facilitates inferences about the relations between values and external variables (but see Münsterberg, 1908, for a provocative model that was not empirically tested). External variables are defined here as any variables that are outside of the given model. If one external variable exhibits a strong positive correlation with one of the value types, then the circumplex model predicts that correlations should become progressively less positive (and then perhaps more negative) as we move around the circular model from the adjacent value types through the orthogonal value types to the opposing value types. This pattern follows a sine wave if the 10 value types are plotted on the x-axis of a Cartesian coordinate system, with the strength of the correlation on the y-axis (Fig. 2).

The use of the circumplex model of values to predict the sinusoidal pattern is an important reason why the model has had a large impact (Boer & Fischer, 2013; Maio, 2010; Parks-Leduc et al., 2014). Whereas prior research relied on post hoc inferences to explain patterns of association with values, the circumplex model enables researchers to *predict* patterns in relations between values and other variables. Diverse studies have sought evidence for sinusoidal patterns within research on values (Kasser, Koestner, & Lekes, 2002; Schwartz, 1992; Sortheix & Lönnqvist, 2014). For example, in a recent meta-analysis, it was postulated and found that the personality trait of openness to new experiences correlates positively with stimulation, self-direction, and universalism values, while correlating negatively with conformity, tradition, and security values (Parks-Leduc et al., 2014). The correlation coefficients between openness and all ten values are displayed in Figure 2 (line A). This line was qualitatively judged by Parks-Leduc et al. to resemble a sine function.

Of course, it is not the case that all external variables should follow the sinusoidal pattern. In order for sinusoidal fit to arise, the external variable must be relevant to the psychological functioning of values and, if this relevance exists, the external variable must not be particularly relevant to *orthogonal* values in the model. For example, in the aforementioned meta-analysis (Parks-Leduc et al., 2014), the researchers expected that the positive peak correlations between conscientiousness and values would arise for *orthogonal* values in the model (conformity and achievement); indeed, correlations between values and conscientiousness were judged not follow the sinusoidal pattern.

However, reliably distinguishing between sinusoidal fit and a non-sinusoidal pattern is difficult without a systematic method for detecting a sinusoidal waveform. Past investigations have relied on visual inspection or devised different approaches to parsing the correlations to determine if the pattern is sinusoidal. This subjectivity and variability in approach is important because there can be differences in whether people construe a pattern as being sinusoidal or not: one researcher’s sine wave may be another researcher’s linear relationship or just a random pattern of points. The importance of this subjectivity is exacerbated by the fact that circumplex models offer a very specific two-dimensional pattern; other viable two-dimensional models could array the constructs in different shapes, such as ellipses or rhomboids, following different assumptions about the psychological dynamics between the constructs. These alternate models would not necessarily predict the same waveform of associations with external variables. Hence, one aim of this research was to develop a straightforward and rigorous quantitative test of sinusoidal fit. We then applied it to both the circumplex model of human values (original and refined, Schwartz, 1992; Schwartz et al., 2012) and the circumplex model of interpersonal problems (Alden et al., 1990). This enabled us to test the validity of both models, while evaluating potential changes to their scoring and structure.

## Derivation of the Sinusoidal Fit Index (SFI)

An important issue is whether or not obtained patterns of correlation can be better described by a sinusoidal waveform than by other mathematical functions. For instance, a polynomial function of the ninth degree, f(x) = ax9 + bx8 + … + j, would always fit perfectly for 10 points on the x-axis. The perfect fit would arise because a polynomial function of degree N can have a maximum of N-1 turning points (minima and maxima are turning points). This means that a polynomial function of ninth degree can have 8 turning points and is assured to fit the maximum of 8 changes in direction for 10 data points. However, this function must estimate 10 parameters. As described below, a sinusoidal function needs only four parameters and is therefore more parsimonious. Hence, only cubic, quadratic, and linear functions should be considered as alternatives for the sinusoidal function, because these functions require only 4 or fewer parameters[[1]](#footnote-1).

It is also possible to utilize cubic and quadratic functions to test for sinusoidal fit in an ad hoc manner. For example, Schwartz and Butenko (2014) have tested whether the refined value theory with 19 distinct value types (Schwartz et al., 2012) follows a quadratic pattern. The authors correlated participants’ scores on the 19 value types with their endorsements of each of 19 sets of behaviors expressing the value types (yielding a sinusoidal test for each of the behaviors as the external variable). For each external variable, the correlations were again manually ordered starting from the highest correlation and then moving along the circle. Next, the 19 empirical correlation coefficients were correlated with the polynomial coefficients 10, 9, …, 2, 1, 1, 2, …, 9 resembling a quadratic or U-shaped trend. For example, if the highest correlation was between the value type hedonism and the behavioral expression of hedonism, the polynomial coefficient 10 was assigned to this correlation. The polynomial coefficients assigned to the two adjacent value types – achievement and stimulation – were 9. This approach requires manually arranging the values by choosing the highest correlation and assigning the polynomial coefficient to it. It remains unclear how this rigid assignment of these polynomial coefficients can be implemented if an external variable such as conscientiousness is linked to two orthogonal value types (see above) and if we accept that “distances between the values around the circle may not be equal” (Schwartz et al., 2012, p. 669).

Similar approaches were suggested by Roccas, Sagiv, Schwartz, and Knafo (2002), Fischer and Hanke (2009), and Boer and Fischer (2013). Fischer and Hanke’s (2009) method is similar to Schwartz and Butenko’s (2014). Boer and Fischer’s (2013) method, which resembles the procedure used by and Roccas et al. (2002), is more distinct. Boer and Fischer implemented flexibility in the polynomial contrasts. That is, the authors assigned a hypothetical pattern (i.e., polynomial coefficients) to each of the value types and then correlated this with the obtained correlation coefficients. For example, they “arbitrarily set” (Boer & Fischer, 2013, p. 1145) .95 to security and conformity, versus -.95 for stimulation and self-direction, and .59, 0, or -.59 for the value types in between. Thus, the distances between the polynomial coefficients were not the same, and these distances were assumed to be different in different analyses (i.e., to test whether social attitudes are more in line with openness and conservation values or self-enhancement and self-conservation values, see Boer & Fischer, 2013, p. 1145). Although this approach may have suited their research aims, it cannot be easily generalized as a testing procedure applicable across different types of variables, circumplex models of individual difference, and research projects. Furthermore, none of the four above approaches to test sinusoidal relations cited the others, making it apparent there is a lack of shared understanding about the best way to test for sinusoidal waveforms in associations with individual differences variables.

 In the present research, we attempt to solve this problem by starting with the recognition that sinusoidal predictions do not require ad hoc rearrangements of the correlation coefficients: a sine wave is visible regardless of where the analysis begins. Consequently, we calculated and compared the fit of the sinusoidal function with the fit of a cubic function, which also requires no rearrangement of values on a case-by-case basis. However, a cubic test would be restricted to a maximum of 1.5 periods of a sine function, which limits its general usability for sine waves longer than 1.5 periods. In contrast, our approach can easily be extended to any sine wave. Moreover, a cubic function is not more parsimonious than a sinusoidal test, because four parameters need to be estimated in both approaches.

Both functions were tested using the program *R*. Cubic fit was evaluated using an internal optimization function in *R* (*R* command: *lm*). To devise our test of a sinusoidal function, we wrote a new function in *R* (see appendix). In its application to Schwartz’s model, *x* in equation (1) is a vector containing the numbers 1, 2, 3, …, 10 (or 19 for the 19 value type model); *ŷ* are the estimated numerical values (e.g., estimated correlation coefficients).

1. *ŷ = f(x) = a + b\*sin(c\*x + d)*

Parameter *a* is the y-offset that moves the function up and down along the ordinate (y-axis). Parameter *b* determines the differences between the maximum and minimum points of the sinusoidal function (amplitude). Parameter *c* stretches and compresses the function (i.e., changes the distance between the turning points). Parameter *d* isthe x-offset that moves the sinusoidal function along the abscissa (x-axis). The restrictions placed on these parameters are explained in the supplementary materials.

To estimate how well the data follow a sine or cubic function, the R function calculates the sum of the squared residuals between the predicted and the empirical data for each external variable. To make the fit index comparable across circumplex models with different numbers of measurement points (e.g., 8 interpersonal problems, Alden et al., 1990; 19 value types, Schwartz et al., 2012), we divide the sum of the squared residuals by the number of correlations minus 1. For each external variable, the obtained fit is divided by the variance between the correlation coefficients in order to standardize the fit indices. Otherwise the fit indices would be influenced by the average magnitude of the correlations: Correlations between -.2 and .2 would result on average in smaller fit indices than correlations between -.8 and .8, making comparisons impossible. The obtained index was named Sinusoidal Fit Index (SFI).

(2) $SFI=\frac{\frac{1}{K-1} \sum\_{k=1}^{K}(y\_{k}- \hat{y}\_{k})^{2}}{\frac{1}{K-1}\sum\_{k=1}^{K}(y\_{k}- \overbar{y}\_{k})^{2}}$

K: the number of numerical data values (e.g., number of correlation coefficients)

yk: the numerical data values (e.g., the correlation coefficients)

ŷk: estimated numerical values through the optimization function

$\overbar{y}\_{k}$: mean of the numerical data values (e.g., mean of the correlation coefficients)

The fit index for the cubic function is calculated in the same way as for the SFI, except for using the cubic function instead of the sine function to calculate the residuals. In both cases, the worst possible fit is 1, and the best is 0. Of course, there is also a need to determine thresholds for evaluating goodness of fit. Below, we describe how we obtained such thresholds for the SFI using past data. We then describe three studies that applied the SFI to circumplex models of values and interpersonal problems.

## Thresholds for the Sinusoidal Fit Index (SFI)

As for many statistical tests, thresholds for evaluating the numerical value returned by the SFI can be obtained in at least two ways. First, the thresholds can be obtained based on “effect sizes”, using more or less arbitrary conventions to determine when an effect is small, medium, or large (e.g., Cohen, 1988). In application to the SFI, “effect size” refers to the goodness of fit of the data to a sine wave. Second, we can aim to reduce the number of false positives using the conventional .05 criterion. In practice, both approaches are often used. We follow this combined approach by determining thresholds based on thorough visual inspections and then computing the percentage of false positive results through Monte-Carlo simulations (Study 1).

Although visual inspections lead to subjectivity problems when applied on a post-hoc, case-by-case basis, they are useful for determining thresholds at an initial stage of test development. In this case, they can tell us the extent to which values of SFI that are closer to 0 actually reflect sinusoidal curves. Based on visual inspections of 40 graphs calculated with the data from the European Social Survey (ESS, see below)*,* we propose that a very good fit arises when the SFI is smaller than .10. That is, the deviance of the predicted values to empirical values is fairly small. We propose further thresholds at .20 (good fit), and .30 (acceptable fit). To illustrate these criteria, Figure 3 gives examples of external variables from the European Social Survey (ESS) data that exhibited very good to unacceptable fit.

Of importance, thesechosen thresholds for the SFI (e.g., SFI < .20 as a “good” fit) match judgments of sinusoidal fit independently derived in past research. In Parks-Leduc et al. ‘s (2014) meta-analysis of the relations of Schwartz’s (1992) ten value types with the Big-Five personality dimensions, the fit of the correlation patterns to a sinusoidal relationship was evaluated by the authors. They judged that openness to new experience followed most clearly the predicted sinusoidal pattern (cf. Fig. 2, line A, in this paper), agreeableness had the second best fit, and extraversion the third best. As noted earlier, these researchers postulated and found that conscientiousness did not follow the sinusoidal pattern because of two positive correlations with orthogonal value types. Emotional stability (neuroticism) was found to be uncorrelated with the ten value types and also did not follow the sinusoidal pattern because the correlations were random. We have calculated the five SFIs based on the correlations reported by Parks-Leduc et al. (2014) and found that our labeling of the SFIs corresponds with the judgments of the researchers. The SFI is .11 for openness, .17 for agreeableness, .16 for extraversion, .37 for conscientiousness, and .44 for emotional stability. That is, all of the SFIs that we would judge as good (i.e., SFIs < .20) were judged by Parks-Leduc et al. as fitting the sine wave.

## The Present Research

We conducted four studies to evaluate the SFI and then apply it to testing circumplex models of individual difference. To further evaluate the SFI, Study 1 used Monte-Carlo simulations to discern the adequacy of the optimization function for the SFI, related to the number of false-positive results generated. The next three studies used the SFI to examine circumplex models of individual difference. Study 2 used the SFI to test the application of Schwartz’s (1992) 10-value-type circumplex model of values to over 150 external variables, using a large international data set. In Study 3, we used the SFI to examine the fit of Schwartz et al.’s (2012) 19-value-type model and compare it with the prior model. Finally, Study 4 used the SFI to examine the circumplex of interpersonal problems.

# Study 1

Our first study sought to validate our optimization function for the SFI. To validate the developed optimization function (see Appendix B for the *R* commands) and the chosen thresholds for the SFI, we used a multi-method approach. First, we conducted Monte-Carlo simulations in order to estimate the number of false-positive results. That is, we estimated the SFI for which the number of false-positives will be below the conventional probability thresholds of .05, .01, and .001 and how often the SFI will be ≤ .30 (our threshold for acceptable fit) simply by chance. Second, we tested whether the residuals were normally distributed. Third, we determined whether our optimization function is at least as good as an already established fit function for a cubic relationship.

## Monte Carlo simulations

*Method*. To obtain the number of false-positives (Type I error rate) for the SFI, numerous simulations of *m* = 100,000 samples each were conducted. We examined different distributions of the correlation coefficients. (1) Assuming a *uniform* distribution, we sampled *k* numbers between -.5 and .5, with *k* being the number of correlation coefficients. The numbers -.5 to .5 represent the interval in which most correlation coefficients of values with external variables usually fall (e.g., data in Study 2 or Parks-Leduc et al., 2014), but changing this interval to -.7 to .7 or -.3 to .3 did not affect the results. (2) We sampled *k* numbers from a *normal* distribution with ~*N*(0, .1), and ~*N*(0, .3). The simulated numbers >|1| were restricted to -1 or 1, respectively. We varied *k* between 4 and 19, thereby encompassing the circular models of individual difference considered in this article: Starting from 4 (higher-order values in Schwartz, 1992), 7 (the cultural value orientations in Schwartz, 2006), 8 (interpersonal problems in Alden et al., 1990), and 10 (lower-order value types in Schwartz, 1992), to 17 and 19 (value types in Schwartz et al., 2012; cf. Study 3).

*Results and discussion.* Using these simulated data, we tabulated the number of occasions when the returned SFIs were lower than each of our SFI thresholds, falsely suggesting a sine wave even though the pattern of correlations was in fact drawn at random. As can be seen in Table 2, the percentage of false positives varies as a function of the points sampled. If only 4 points are sampled (representing the correlation coefficients of Schwartz’s four higher-order value types), it is much more likely that the four points resemble a sine wave solely by chance compared to when more points are sampled. Nineteen correlation coefficients almost never follow the proposed sinusoidal pattern solely by chance. This indicates that at least 8 correlations are needed to decrease the estimated probability of false positives to the common level of < .05 for SFI < .30.

The thresholds that are in line with the common inferential statistical approach can be found in Table 3. For 10 correlations, the estimated probability of false-positives $\hat{p}$ is below .05 for SFIs < .40. For 19 value types, even SFIs < .68 occurred very rarely by chance ($\hat{p}$ < .05). Nevertheless, it may be hard to recognize a sinusoidal pattern if the SFI is .67 (see Study 3 for an example). This difficulty is analogous to the way in which it is hard to spot a correlation of .1 by looking at a scatterplot, even if the sample size is large enough for *p* < .05. Therefore, we mainly focus on the interpretation of the goodness of fit thresholds outlined above (i.e., SFI < .30 as acceptable etc.).

 In addition, assumptions about the distribution of the correlation coefficient have little impact on the percentage of false positives. Assuming a uniform distribution results in a slightly higher number of false positives compared to a normal distribution (Tables 2 and 3). Nonetheless, our simulations are highly conservative because they do not consider the sample size. With sample sizes as large as in our subsequent studies (> 50,000) and several correlation coefficients of > |.20| (or *R*2 > .05 for instance), which are highly unlikely to be obtained solely by chance with these sample sizes, the probability of a false-positive results (i.e., SFI < .30) decreases to almost zero.

## Distribution of residuals

To test whether our optimization function is appropriate, we tested if the residuals are normally distributed, using the Monte Carlo stimulation described above for *k* = 10. A non-normal distribution of the residuals would indicate that the optimization function is not optimal. The Shapiro-Wilk test was used for this purpose, because it has the best power out of several different tests for normality (Razali & Wah, 2011). We conducted 20 Shapiro-Wilk tests, each with *n* = 5000 residuals, assuming normally distributed correlation coefficients. Eighteen of the tests were non-significant, indicating a normal-distribution of the residuals.

## Comparison to cubic fit

Another approach for testing whether the optimization function for the sinusoidal fit is appropriate is to compare it with the cubic function. As outlined above, a sinusoidal function should fit at least as well as the cubic function in describing the data. In 2 out of 10 simulations, our unrestricted sinusoidal optimization function (i.e., all four parameters were unrestricted) fit better than the cubic fit index (*p*s < .05). In the remaining eight simulations, there was no significant difference (two-sample *t*-test). This implies that the average distance between our (unrestricted) sinusoidal optimization function and the data points is only slightly smaller compared to the cubic function implemented in R. The unrestricted sinusoidal function reveals a better fit than the cubic function if the data follow a pattern like that shown in Figure 2, line C (i.e., a sine wave of more than 1.5 periods).

# Study 2

After concluding that the SFI and its indicative thresholds for judging sinusoidal fit are appropriate, we used the SFI to examine the pattern of associations between values and external variables in the European Social Survey (ESS). The ESS has been conducted every other year since 2002 in at least 20 European countries. Each survey aims to include representative samples of the member nations. This survey was useful because it includes measures of human values from Schwartz’s (1992) circumplex model, and it has been used in many studies testing the model.

 We used the data from the most recent round at the time of the data analysis (edition 6.3), which included 29 countries and 54,673 participants. The data are available at www.europeansocialsurvey.org. Another useful feature of this survey is that it contains a variety of variables that were included for diverse aims. That is, these variables were *not* included because of conceptual links to values, as would be the case for an empirical study focused on values. Consequently, the ESS enabled us to look for sinusoidal patterns that emerge without an *a priori* design, but are reflective of processes that are relevant to many issues of importance to the social survey. This is useful because variables differ in their relevance to values. For example, attitudes and behaviors that entail deliberative reflection about values or strong spontaneous links to values are strong contenders for associations with values (Maio, 2010; Maio & Olson, 2000; Verplanken & Holland, 2002). In contrast, other variables may relate to values weakly or only indirectly through other social and environmental factors. Although the ESS was not designed in a way that enables an *a priori* separation of value-relevant and non-value-relevant variables, it does enable an empirical assessment of relevance through the strength of the obtained relations with values. It was therefore of interest whether the SFI results were stronger for those variables bearing stronger empirical associations with values than for those variables bearing weak associations with values.

The data also enabled us to examine a set of other questions. For instance, some variables should be unrelated to values because of low reliability in their assessment and, therefore, we expected that greater reliability of the external variable measures would enhance the chances of better fit from the SFI. Another interesting question pertained to the scoring of values. Schwartz (1992, 2003) recommends controlling for individual scale use tendencies by focusing on the relative importance of each value (type) compared to all others. He achieves this by centering; that is subtracting the mean of each participant’s responses to all the value items from each of the value items. Therefore, we tested whether the correlations between the external variables and the centered value scores followed the proposed sinusoidal pattern better than the raw data.

A third research question was specifically relevant to Schwartz’s (1992) model. The model proposes that tradition and conformity values differ in distance from the center of the circumplex in the same tangent (Figure 1). To arrange tradition and conformity on the motivational *continuum*, they must be placed side-by-side (at adjacent tangents) or averaged together. Different researchers have chosen different solutions to this problem. Schwartz (1992) placed tradition next to benevolence, and conformity adjacent to security. In contrast, Parks-Leduc et al. (2014) chose to place conformity next to benevolence, and tradition adjacent to security. We decided to test both orderings: A better fit for one versus the other order may indicate that tradition is better placed next to security and conformity next to benevolence or vice versa. However, another appropriate solution is to average tradition and conformity into a single score. We examined this solution as well.

Finally, the numerous variables included in the ESS allowed us to use the SFI to test comprehensiveness of Schwartz’s model in a new way. Across many participant samples, Bilsky et al. (2011) have shown through Multidimensional Scaling (MDS) that Schwartz’s value types form a coherent motivational continuum. Whereas MDS has been a useful tool for looking at intra-value relations, there has been no comparable tool for looking at relations with external variables (see supplemental materials for a discussion about the differences between MDS and SFI). The examination of SFIs enables us to isolate a large number of variables that reliably reveal the sinusoidal pattern and then test whether there are gaps in this pattern. That is, among those variables fitting the sine wave, the absolute magnitude of difference between the adjacent correlation coefficients across the 10 value types should be broadly the same, if the values are equidistant in their coverage of relevant motivations. If the correlation coefficients disproportionately increase or decrease in magnitude between particular sets of values, this would indicate a potential gap in the motivational continuum assessed by the values.

## Method

*Participants*. The mean age of the ESS sample was 48.23 years (*SD* = 18.56, *range* = 15-103), including 29,395 women (54.35%). Five hundred ninety-one participants did not respond to more than three items on the measure of values, leaving 54,082 participants.

*Material*. The 21-item version of the Portrait Value Questionnaire (PVQ; Schwartz et al., 2001) was used to measure values in the ESS. Participants were asked to rate the extent to which the description (portrait) of another person was similar to themselves. Example descriptions include “Thinking up new ideas and being creative is important to her/him. She/he likes to do things in her/his own original way” (self-direction) and “It is important to her/him to be rich. She/he wants to have a lot of money and expensive things” (power). Responses were given on a 6-point Likert scale ranging from 1 (very much like me) to 6 (not like me at all).

One hundred and fifty-one additional items were included within the data set, including dichotomous variables (e.g., “Trust in politicians”, “How satisfied with life as a whole”, “The courts treat everyone the same”). We examined responses to all of these items as external variables in order to get a comprehensive overview of relations with values, even though relations were not expected for all of the items (e.g., “Different political parties offer clear alternatives to one another”, “Opposition parties are free to criticize the government”).

*Procedure*. First, we sought to reduce the 151 items to a more manageable set. A Principal Component Analyses (PCA) of the items revealed 23 factors, containing 2 to 11 variables each, with heterogeneous reliabilities (αs = .35-.92, median = .78; cf. Table 5). Based on these results, 100 items were included in scales assessing these factors. To be included in a scale assessing one of these factors, each item had to load greater than .49 on only one factor, less than .40 on any other factor, and .25 less than on the higher of the two factors. For example, the factor we labelled “Enthusiastic about things you are doing” consisted of four items, including “Enthusiastic about what you are doing, how much of the time?”, and “Absorbed in what you are doing, how much of the time?” (α = .85). In addition, the factor labelled “Perception of democratic processes” consisted of 6 items, including “Different political parties offer clear alternatives to one another”, and “Opposition parties are free to criticize the government” (α = .83). We included factors that possessed low αs because this enabled us to test whether SFIs are negatively correlated with the reliability of the external variable measurement (see supplemental materials for the wording of the items included in each factor).

*Design*. In total, we computed the SFI for all combinations of a 2 (values: centered vs. non-centered) x 2 (external variables: 151 items vs. 23 factors) x 3 (order of values: security-tradition-conformity-benevolence vs. security-conformity-tradition-benevolence vs. security-conformity and tradition combined-benevolence) design, resulting in a total of 1044 SFIs and *R2*s.

## Results and Discussion

*Relations between values.* Before examining the SFI, we tested whether the correlations between values in the ESS data fit the circular model (Boer & Fischer, 2013). For this test, we conducted MDS using the same procedure and restrictions as Bilsky et al. (2011). Results indicated a similar fit to that reported by Bilsky et al. for the first three rounds of the ESS (*Stress 1* = .11, *S-Stress* = .019). Thus, the circular model provided a valid description of the values data obtained from the ESS.

*Relations between values and external variables*. Before looking at the SFIs, an important question was which external variable factors and single items were more strongly related to values? To address this question, we regressed each external variable factor and item on all of the values. The *R2* statisticscan be found in Table 4, for all 12 conditions in our design. Given the large sample size (*N* = 54,082), the *R2* for each of the 23 factors was significant at *p* < .001. Thus, it was more important to use *R2* as a *relative* indicator of explained variance.

The 10 value types predicted more than 10% of the variance in three factors: A pessimistic world-view (10%), the frequency of social interactions (13%), and religiosity (13%) (Table 5). The *R2*s in all cases were significantly higher if the non-centered value types were used as predictors (see fourth column of Table 4 for the average *R2* of the 23 factors or of the 151 single items).

The variability in *R2* was then used to test whether the variables more strongly related to values were better more likely to exhibit a sinusoidal pattern of relations with the values. As predicted, there were negative correlations between *R2* and SFI, median *r* = -.42. This pattern is shown in Table 4. Thus, the SFI supports Schwartz’s (1992) model more strongly for those variables that are more strongly related to values.

Contrary to our expectations, however, Cronbach’s α in the external variables did not correlate significantly with SFI (Table 4). Nonetheless, our prediction was based on the assumption that lower reliability would preclude strong relations between values and the external variables, but there was no relation between reliability and *R2* in our data (Table 4). The range of measurement reliability may have been too narrow in this dataset for us to detect a role of unreliability (i.e., most measures were reliable).

*Variation in SFI*. Results for the analysis of the 2 (values: centered vs. non-centered) x 2 (external variables: 151 items vs. 23 factors) x 3 (order of values: security-tradition-conformity-benevolence vs. security-conformity-tradition-benevolence vs. security-conformity and tradition combined-benevolence) design can be found in Table 4. For example, the average SFI for the 23 factors is .24, while using the security-conformity-tradition-benevolence order with the centered correlation coefficients.

Most important, the results enabled us to address our research questions about value scoring and about the treatment of tradition and conformity values in the model. With regard to this issue of value scoring, the SFI*s* from the non-centered value types were better than the SFIsfrom the centered value types in most of the six cells of the design that enabled this comparison (Table 4); five of the differences reached statistical significance at *p* < .05, and one difference was marginal at *p* < .08. Thus, the non-centered value types result in correlations with the external variables that followed the sinusoidal pattern better than the centered value scores.

With regard to the issue of the tradition and conformity values, all of the SFIs were better for the security-tradition-conformity-benevolence order, albeit the differences did not always reach statistical significance. The difference between this order and the fits for the version in which tradition and conformity were merged was not significant.

Overall, the majority of the SFIs indicated that sinusoidal fit was unlikely to occur by chance at $\hat{p}$ < .05 (third column of Table 4) and was often at least acceptable (i.e., < .30). For example, 18 out of the 23 factors (78%) that had been centered, revealed an SFI of < .30, for the tradition-conformity order. When we consider the analyses that yielded the best fit – non-centered value computations withthe security-tradition-conformity-benevolence order – the four external variable factors that best followed the sinusoidal pattern (SFI ≤ .10) were TV watching time, subjective general health, amount of political activity, and attitudes towards immigrants, and the four external variables with the worst fit in our sample (SFIs > .37) were relationships to neighbors, relationships to close others, and two factors addressing the perception of democracy (Table 5). In general, better fit emerged from the variables that refer more directly to personal behaviors (e.g., TV viewing), attitudes (e.g., immigrants), and emotion (e.g., well-being). Relatively contextual and cognitive factors (e.g., neighbor relations, perceptions of democracy) exhibited weaker sinusoidal links to values (Table 5).

*Model comprehensiveness*. To probe the comprehensiveness of Schwartz’s (1992) model, we examined the correlations between values and all 66 external variable items that revealed a good sinusoidal fit (i.e., SFI < .20), using the security-tradition-conformity-benevolence order for the centered value types. (We used the single items in calculations of SFI because this is more powerful than using the 23 factors.) We then created a 66x10 matrix with differences in correlation coefficients between two adjacent value types in the columns, For example, security and tradition correlated with the item “Total TV watching time on average weekday” with *r* =.16 and *r* = .12, respectively, yielding an absolute difference of .04 between the two correlations. The mean absolute difference across all value types was .06 (*SD* = .03). The smallest difference was between the correlation coefficients for stimulation and hedonism (.03); the largest difference was between conformity and benevolence (.12). These standardized absolute differences were robustly different from each other, *t*(130) = 11.94, *p* < .001, *d* = 2.08, 95% CI of the mean difference [.08, .11], suggesting that the proximity between stimulation and hedonism is much closer than the proximity between conformity and benevolence. These findings raise the possibility that benevolence should be shifted further away from conformity in the circular model, or that another value type should appear between these values. We consider this issue in Study 3.

# Study 3

As expected, Study 2 found a lot of variance in the SFI. Some variables were more systematically related to values, in the sinusoidal waveform, than others. In Study 3, we focused on external variables that are theoretically linked to values. We drew upon two studies wherein Schwartz and colleagues asked participants to create a list of behaviors that are typical for each of the value types (Bardi & Schwartz, 2003; Schwartz & Butenko, 2014). In a next step, participants reported how often they had performed those behaviors relative to their opportunities to perform it. Behaviors for each value type were averaged. This method has been used to test both the original theory (Schwartz, 1992) with ten value types (Bardi & Schwartz, 2003), as well as with the refined theory (Schwartz et al., 2012) with 19 value types (Schwartz & Butenko, 2014). It was predicted and found that the behaviors that are considered to be typical for a specific value type correlated highest with the importance of this value type, while the behaviors correlated negatively with the opposing value types; in other words, the pattern suggested a sinusoidal waveform in the correlations between each of the behaviors and the value types. Schwartz and Butenko additionally calculated how well the behaviors fit the proposed sinusoidal waveform using the method described in the Introduction. This allowed us to examine the relation between their approximations of a sinusoidal curve and our calculation of the SFI.

We predicted that we would find the sinusoidal pattern for all of the behaviors as external variables. Furthermore, an interesting additional test was made possible by the fact that both the values and the value-relevant behaviors could be classified by value type. Thus, we could replicate Schwartz and Butenko’s (2014) analysis of sinusoidal fit using the values on the x-axis with the value-relevant behaviors as the external variables *and* test sinusoidal fit using the value-relevant behaviors on the x-axis with the values as the external variables. Both tests should reveal good sinusoidal fit if the behaviors are linked to each other in a manner similar to how the values are interlinked, because the behaviors have been derived systematically from the values.

## Method

The correlation matrices used by Bardi and Schwartz (2003; Study 1)[[2]](#footnote-2) and reported in Schwartz and Butenko (2014) were used to calculate the SFIs. Bardi and Schwartz (2003) presented their measure of value-relevant behaviors to 102 undergraduate students. Many of the participants then completed the Schwartz (1992) Value Survey a few weeks later. Participants were asked to indicate on a 9-point scale how much each of 56 values is a guiding principle in their life. Examples include “FREEDOM (freedom of action and thought)“ and “FAMILY SECURITY (safety for loved ones)”.

Schwartz and Butenko (2014) presented the revised version of the Portrait Value Questionnaire measure of values (PVQ-R; cf. Schwartz et al., 2012), as described in Study 2, and a revised version of the Bardi and Schwartz measure of value-relevant behaviors to 266 participants; most of whom have been university students. Data were collected within a single session.

## Results and Discussion

*10 Value Types* (*Bardi & Schwartz, 2003).* We computed SFIs for the correlations of each value type with all 10 behavior sets and SFIs for the correlations of each behavior set with all 10 value types. When the 10 value types were placed on the x-axis and the value-relevant behaviors were the external variables, the average SFI was .23, with 8 SFIs having a low number of false-positives (i.e., $\hat{p}$ < .05) and providing at least an acceptable fit (i.e., SFIs ≤ .30; Table 6, second column). The best sinusoidal pattern emerged when tradition-promoting behaviors were correlated with the 10 value types (SFI = .07). When the 10 behavior types were placed on the x-axis and the value types were the external variables, the average SFI was .21, with all 10 SFIs being significant at $\hat{p}$ < .05 and nine SFIs providing at least an acceptable fit (Table 6). Thus, the analyses did not reveal better SFIs when the values were used as the waveform predictors than when the behaviors were used as the waveform predictors. This result is consistent with the assumption that the behaviors are linked to each other in a manner similar to how the values are interlinked, because the behaviors have been systematically derived from the values.

*19 Value Types* *(Schwartz & Butenko 2014).* As reported above, a pre-requirement for testing the sinusoidal pattern is that the value types constitute a motivational continuum (Boer & Fischer, 2013). Because the two benevolence value types in Schwartz’s refined theory are in the middle of the two-dimensional plot and hence do not follow the motivational continuum, Schwartz and Butenko (2014) excluded them from their ‘sinusoidal’ analysis, leaving 17 value types. We followed this suggestion and calculated the SFI for the remaining 17 value types and behavior sets, respectively. (The analysis with the 19 value types can be found in the supplemental materials; the SFIs for the 19 value types were larger, as Schwartz and Butenko predicted.)

We computed SFIs for the correlations of each behavior set with all 17 value types and SFIs for the correlations of each value type with all 17 behavior sets (Schwartz & Butenko, 2014). Out of the 34 computed SFIs, 30 were below $\hat{p}$ < .05, but only three SFIs were below .30 (Tables S1 and S2). The smallest SFI of .16 resulted from the analysis correlating the value type self-direction-thought with all 17 behavior sets. The SFIs for each value type with all behaviors (*M*SFI = .47, *SD* = .16) were not better than the SFIs of each behavior set with all the value types (*M*SFI = .46, *SD* = .14; *t*[16] = 0.25, *p* = .81). This result is again consistent with the assumption that the behaviors are linked to each other in a manner similar to how the values are interlinked, because the behaviors have been derived from the values.

*Relations between Schwartz and Butenko’s (2014) estimates and the SFIs.*  To probe the convergent validity of our method, we correlated Schwartz and Butenko’s (2014) estimates of sinusoidal fit with our SFIs. Recall that their estimates of sinusoidal fit were based on correlations between the obtained value-behavior correlations and estimates derived by applying polynomial, quadratic curve coefficients to a manual ordering of values for each analysis. The correlations between their correlations with the polynomial curve and our SFIs were large for both sets of 17 SFIs, *r*(15) = -.84, *p* < .0001 and *r*(15) = -.83, *p* < .0001. Therefore, both approaches are related, providing further convergent validity for the SFI.

However, one important difference between the approaches is in the interpretation of the degree of fit. The correlations with the polynomial curve reported by Schwartz and Butenko are large (mean *r*s .68 and .69), making it appear as though they are strong support for the sinusoidal waveform. However, the magnitude of the correlations with the polynomial curve is partly due to the liberal nature of this test. For example, the value type “face” was highly correlated with the polynomial prediction derived from all 17 behavior sets, *r*[15] = .63, *p* = .007 (Schwartz & Butenko, 2014), supporting the proposed sinusoidal pattern. However, the respective plot has notable deviations from a sinusoidal waveform, especially for the face behavior set (see Figure 4). Indeed, the SFI indicates a bad fit (SFI = .61), albeit significant at $\hat{p}$ < .05. If the principal outlier correlation (r = .88) is reduced to a correlation more in line with the others (e.g., to *r* = .28), it barely reduces the polynomial profile correlation as calculated using Schwartz and Butenko’s procedure (*r* = .6270 vs. *r* = .6266), but the SFI is substantially better (.61 to .48). Put simply, the SFI is more sensitive to deviations from the sinusoidal waveform.

*Summary across the tests*. Acceptable fit was revealed in many of the analyses using the original model, but fewer analyses using the revised model. At the same time, however, there were reliable associations between Schwartz and Butenko’s (2014) estimates of sinusoidal fit and the SFIs, providing evidence for the convergent validity of the SFI. Nonetheless, the polynomial correlations set more liberal thresholds than the SFIs, and the SFIs are more systematic and model-consistent in their derivation. In this case, the SFI show that the original model works well and, on the surface, better than the revised model. However, it is inappropriate to use SFIs to compare different models tested with different external variables, and we return to this issue in our General Discussion.

# Study 4

Past research has found sinusoidal waveforms in associations with the circumplex models of interpersonal traits (Alden et al., 1990, for interpersonal problems circumplex; Griesinger & Livingston, 1973, for motivational orientation; Locke, 2014, for interpersonal circle model). Consequently, in Study 4, we tested whether the SFI would reveal a sinusoidal waveform in the relations between the circumplex model of interpersonal problems (Alden et al., 1990) and external variables. This circumplex model was chosen because it is widely used and often based in a clinical context, which provides a further opportunity to test for sinusoidal relations. Based on qualitative and quantitative assessments of interpersonal problems, two higher-order factors were found: hostility vs friendliness and submissiveness vs dominance (Horowitz, 1979; Horowitz, Rosenberg, Baer, Ureño, & Villaseñor, 1988). These factors resembled the dimensions found by other interpersonal theorists (Kiesler, 1983; Wiggins, 1979). By adding two more orthogonal dimensions, rotated by 45° from the original ones, Alden et al. (1990) have designed a circumplex model with eight elements, while devising the inventory of interpersonal problems (IIP-C) to measure them. The eight scales in this inventory assess domineering, vindictive, cold, socially avoidant, non-assertive, exploitable, overly nurturant, and intrusive interpersonal styles (see supplementary materials for a definition of each scale).

Of particular interest here are associations between the IIP-C and two other measures: the revised interpersonal adjective scale (IAS-R; Wiggins, Trapnell, & Phillips, 1988) and personality disorder scales (Monsen, Hagtvet, Havik, & Eilertsen, 2006). These associations are interesting because researchers have reported the entire matrix of correlations with these measures, enabling tests of sinusoidal fit using the SFI. Specifically, high correlations have been expected and found between the IIP-C and the IAS-R (Alden et al., 1990) and with personality disorders such as histrionic and avoidant (Monsen et al., 2006). Because the IIP-C and IAS-R measure closely related constructs, they should exhibit similar sinusoidal patterns of correlations with each other. Indeed, Monsen et al. described a sinusoidal pattern of correlations with elements of the interpersonal problems circumplex model, but did not apply any test of sinusoidal fit. If the SFI reveals a sinusoidal pattern of associations, this would more directly reveal important implications of the interpersonal problem model.

## Material

We used the correlation matrices as reported in two papers to compute the SFI. First, we examined the correlations of the IIP-C with the IAS-R scale (Wiggins et al., 1988) as reported in Alden et al. (1990). Participants were 974 undergraduate psychology students. They completed both measures in two 1-hr sessions one week apart in small groups. Participants completed the 127-item IIP of Horowitz et al. (1988), which was used by Alden et al. (1990) to derive their 64-item measure IIP-C. The IIP-C reflects a range of interpersonal behavior which are either “’hard for you to do’ (e.g., ‘It is hard for me to join in on groups’)” or that “’you do too much’ (e.g., ‘I fight with other people too much’)” (Alden et al., 1990, p. 524). Responses are given on a 5-point Likert scale ranging from 0 (not at all) to 4 (extremely), and were then averaged to form the eight IIP-C scales: domineering, vindictive, cold, socially avoidant, non-assertive, exploitable, overly nurturant, and intrusive. The IAS-R scale measures the interpersonal circumplex structure with eight scales: assured-dominant, arrogant-calculating, cold-hearted, aloof-introverted, unassured-submissive, unassuming, ingenuous, warm-agreeable, and gregarious-extraverted (Wiggins et al., 1988). It includes 64 adjectives, 8 for each octant of the interpersonal circumplex. Responses were given on a 8-point Likert scale ranging from 1 (characteristic) to 8 (uncharacteristic).

The second correlation matrix was taken from Monsen et al. (2006), who have correlated the IIP-C with four personality disorders: avoidant, dependent, histrionic, and paranoid. Participants were 374 outpatients. The IIP-C was as described above. The personality disorders were scored using the Structured Clinical Interview for DSM-IV (SCID-II), completed by experienced clinicians and researchers. The sum of the diagnostic criteria was used as an index for the strength of each personality disorder and then correlated with the eight IIP-C scales.

## Results and Discussion

*Revised interpersonal adjective scale.* We computed SFIs for the correlations of all eight IPP scales with each IAS-R scale separately. The SFIs were very good in all eight cases (*range* = .01 – .04, *M*SFI = .02, see Table S3) and significant at $\hat{p}$ < .001.

*Personality disorder scales.* We computed the SFIs for the correlations of all eight IPP-C scales with each of the four personality disorders separately. The SFIs ranged from very good to good (*range* = .03 – .18, *M*SFI = .10, see Table S3), with all SFIs being significant at $\hat{p}$ <.05.

*Summary*. All 12 external variables followed the proposed sinusoidal structure in a good to very good fashion. These findings further illustrate the utility of the SFI, using another circumplex model and a clinical sample. Although the results in this case do not suggest a need for any modifications to the circumplex model of interpersonal problems (Alden et al., 1990), they help research on the model by providing a more robust test of its pattern of associations. At the same time, the results provide a foundation for considering similar tests of the model in the future, using different external variables that may vary in their degree of relatedness to specific interpersonal problems in the model.

# General Discussion

Circumplex models in psychology have great potential for helping to elucidate patterns of association between the constructs they assess and relevant judgments of behavior. By predicting a circular structure and not some other two-dimensional structure (e.g., square, ellipse, triangle), these models have the potential to yield a specific, sinusoidal pattern of associations with variables external to the models. However, past research has attempted to demonstrate these sinusoidal patterns with widely varying procedures, with no consensus on a single reliable approach free from the vagaries of subjective visual inspections and parsing of data. The present research addressed this issue by developing an easy-to-implement procedure for testing whether a set of variables in a circumplex model predicts an external variable in a sinusoidal waveform.

We began by describing the derivation of the SFI index and its thresholds. Then, in Study 1, we used Monte-Carlo simulations to predict and find that the SFI and its thresholds exhibited useful measurement properties (e.g., low false-positives, normally distributed residuals). Study 2 applied our test to a large European data set that measured human values and diverse additional variables. We found that Schwartz’s (1992) circular model of values revealed adequate to good fit for some variables (e.g., attitudes towards immigrants), but not for others (e.g., perception of democratic rights). The majority of the tested variables followed the proposed sinusoidal pattern above chance. Following up this pattern, Study 3 applied the SFI to behaviors that should exhibit a sinusoidal pattern of associations with values. The degree of fit was acceptable when we examined the original 10-value-type model (Schwartz, 1992), but lower than expected with the recent 19(17)-value-type model (Schwartz et al., 2012). Finally, in Study 4, we applied our test to another popular circumplex model, assessing interpersonal problems, and found very good fit.

The calculation of SFIs across the data sets in Studies 2-4 revealed a number of findings that have ramifications for research on circumplex models of individual differences. Our discussion will focus on the implications derived from our studies examining values, because these revealed the most variability in SFIs. One of these implications is made salient by the relations between SFI and R2 in our data. Most past research on values has concentrated on the amount of explained variance from particular values or value types. With the SFI, researchers can also consider the extent to which a range of value types follows the predictions of the circumplex model, without relying on a visual inspection that is easily biased by theoretical viewpoints. One important feature of this test is that it enables a quantitative comparison of the success of a model across different external variables, thereby facilitating the detection of interesting exemplars of correspondence to the sinusoidal waveform. One example emerged in the analysis of TV viewing (cf. Study 2). This external variable follows the predicted sinusoidal pattern strongly, even though the values explain less than 5% of the variance in this variable (cf. Table 4). Human values may not explain a lot of variance in TV watching behavior, but the variance they do capture is systematic across the values. If we were to focus only on the individual correlations or on the *R2,* TV watching may have been prematurely dismissed as being unrelated to values. In fact, the utility and importance of a very good SFI across an array of values becomes even more evident when we consider the frequent assertion that value-behavior relations are much more psychologically meaningful if they show patterns across sets of values than for a single value in isolation (Allport, Vernon, & Lindzey, 1960; Rokeach, 1973; Schwartz, 1992).

Comparisons of the SFI with the amount of explained variance, *R2*, from all of the value types can be informative for another reason. This approach helps us to see whether certain external variables are related to *independent* (orthogonal) value types. External variables are likely to be strongly related to at least two (orthogonal or opposing) value types when the external variables are strongly predicted by the ten value types, but do not follow the sinusoidal pattern. Given that values are considered as guiding principles in our life (Schwartz, 1992), the term *multioriginated* seems to be appropriate for these kind of external variables that are similarly predicted by at least two non-adjacent value types (Table 7). One example was given above: Conscientiousness is correlated positively with the achievement and conformity (Parks-Leduc et al., 2014). However, in our studies, no multi-originated external variable was found. All of the external variables that had a low fit (SFI ≥ .30) were only weakly predicted by the 10 value types (*R2* ≤ .06). Thus, the higher SFIs may be indicative of lower relevance of the external variables to values than of a multioriginated influence of values. Nonetheless, when a multioriginated instance is found, it would be psychologically interesting and useful for a deeper understanding of value-behavior relations.

Other aspects of the evidence revealed potential adjustments to the models of values and their application. Perhaps the most surprising finding was in Study 3’s evidence for better sinusoidal fit in the original, 10-value-type model than for the revised, 19-value-type model (Bardi & Schwartz, 2003; Schwartz & Butenko, 2014). This weaker fit in the revised model occurred because of many deviations from the proposed sinusoidal pattern: Although most behavior sets correlated strongly with the value type they were derived from, they correlated somewhat randomly with one or more of the other value types. This indicates that variables that are strongly associated with one value type do not need to be associated in the predicted way with other value types. Of importance, this does not provide a compelling argument against the value compatibilities and conflicts predicted by Schwartz’s revised model. In the two datasets we examined and in many other published studies, there are significant differences between *opposing* values that are highly relevant to the external variable (e.g., see Maio, 2010). This pattern indicates that the motivational conflicts captured by the two dimensions in Schwartz’s model are detectable. The lack of a sinusoidal fit, when it emerges, does not refute the idea that the opposing points are at alternate ends of a two-dimensional structure.

One way to address this issue is to repeat the analysis, but averaging across adjacent constructs in the model. In this case, the values in the 17-value-types model could be compressed to a smaller number of merged value types. More specifically, we merged those value types that have been divided from the classic to the refined theory (e.g., self-direction thought and self-direction action to self-direction), while leaving benevolence excluded and the two new value types, face and humility, separate. (This approach is somewhat akin to item parceling in latent variable models.) This approach helps to smooth out some random irregularities around the circle. When we performed this supplementary analysis, we found that SFIs for the revised model decreased from .47 and .46 to .35 and .39, respectively, when the value types were correlated with the single behaviors as external variables and vice versa (cf. Study 3). Thus, there is reason to expect that the worse fit for the revised model is at least partly due to random fluctuations in relations with external variables at different points around the value circle.

Another important finding was the evidence for a potential change to the ordering of the values around the circle: the value type tradition should be placed next to security, and conformity should be placed next to benevolence: The correlation coefficients follow the proposed sinusoidal waveform better when this order is used to calculate the SFI*s* (cf. Study 2, Table 4). This result indicates that with regard to the relations of external variables, tradition is more closely linked to security than conformity, and/or conformity is more closely linked to benevolence compared to tradition. Related to this observation is the finding that stimulation and hedonism are related to many external variables in almost the same way (cf. Study 2), although the correlation between the two is only moderate in size (*r* = .36). In contrast, of all the other adjacent value types, conformity and benevolence correlated least consistently with the external variables. This may indicate that there is potentially one value type missing in between the two. Indeed, in the refined theory Schwartz et al. (2012) have added a new value type in between benevolence and conformity: humility.

 The results also provided important information about the prevalent method of value scoring. Most researchers follow Schwartz’s (1992) recommendation that value scores are centered around each respondent’s mean for all values. This recommendation facilitates a focus on relative value priorities, controlling for individual difference in endorsement of values. This procedure helps to reveal oppositions between values. However, to our surprise, the SFIs for the centered value types were slightly worse compared to the fit of the non-centered scores. To the best of our knowledge, these results are the first systematic comparison of centered vs. non-centered value scores. These empirical findings contradict Schwartz’s claim that “failure to make the necessary scale use correction typically leads to mistaken conclusions” (Schwartz, 2003, p. 2), as the postulated sinusoidal pattern is slightly better for non-centered scores. However, centering did not eliminate most of the acceptable SFIs that were revealed by the non-centered value data, suggesting that there is little risk from continuing this practice for the time being. Nonetheless, the present findings make clear that more research is needed to determine when it is beneficial to center and when it is not.

The SFI can be easily extended to other circumplex models in psychology, beyond the models of values and interpersonal relations considered here (see Plutchik & Conte, 1997, for an overview). By helping to summarize the pattern of association between an external variable and a single set of variables, such as values, the SFI provides incentive for researchers to consider such broader patterns instead of focusing on one or two associations in particular. Also, by examining many correlations at once, the SFI enables a theoretically precise prediction that attenuates the issues arising from multiple-comparisons. Instead of testing, for example, 8 or 10 single correlations and subjectively comparing them, researchers can better substantiate their conclusions by calculating both, the *R2* and SFI. This would provide a general overview of the amount of explained variance and whether the external variable is related to a model’s variables in the predicted manner.

In sum, the present research developed and validated a new test of the existence of a sinusoidal waveform in data, enabling more powerful tests of circumplex models’ associations with other variables. The new procedure helped to reveal deviations from a sinusoidal waveform that are informative for our understanding of human values and interpersonal problems, while illustrating the potential of this test for understanding of other constructs to which circumplex models have been applied. Circumplex models provide a high degree of precision in the theoretical image they offer, and tests of sinusoidal fit will help to increase the utility of these models for understanding relevant processes.

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# Appendix A: Recommendations of how to use the test

We recommend the following steps to apply the test:

1. Compute the correlation coefficients with the external variable.
2. Just as for any tests look at the raw data to discover outliers or irregularities.
3. Insert the correlation coefficients in the function as described in Appendix B.

# Appendix B: Optimization function

|  |
| --- |
| ################################################# If you have got the correlation coefficients ################################################## How to use the function below# 1) Copy + paste the function below into R# 2) Enter the correlation coefficient into the function, e.g., sfi(c(-.06, .11, .09, .36, .52, .33, .13, -.27, -.31, -.24)). The numerical values entered should be between -1 and 1. The number of numerical values does not matter, the SFI works for all. But keep in mind that the likelihood of false positives increases when the number decreases! Important: The order of the correlation coefficient must be in line with the circumplex model.# 3) The computational process takes around 2 minutes (with an i7 processor and 8GB-RAM with 10 numerical values) and returns the SFI. sfi <- function(val){ low.c <- ((length(val)\*2)-3)/(length(val)\*2) # lower limit for parameter c. For 10 value types it is 17/20 up.c <- ((length(val)\*2)-1)/(length(val)\*2) # upper limit for parameter c. For 10 value types to 19/20 val.l.R <- function(val){  g <- function(par, val, x=1:length(val)){ vari <- c() for(i in x){ vari <- cbind(vari, par[,1]+par[,2]\*sin(i\*par[,3] + par[,4])) } distance <- rowSums(abs(sweep(vari, 2, val, FUN="-"))) return(distance) } best.fit <- as.numeric(mat[which.min(g(mat, val)),]) # Best fitting results of the 'brute force' approach g1 <- function(par, x){ return (par[1]+par[2]\*sin(x\*par[3] + par[4]) ) } rss.g <- function(data, par, x){ ## residuals sum square of g with data return (sum((g1(par, x)-data)^2)) }  fit.8595 <- optim(par = c(best.fit[1], best.fit[2], best.fit[3], best.fit[4]), rss.g, x = 1:length(val), data=val, lower = c(-1, -1, (2\*low.c\*pi)/(length(val)-1), 1-length(val)/2), upper=c(1, 1, (2\*up.c\*pi)/(length(val)-1), 1+length(val)/2), method= "L-BFGS-B") sin.fit.8595 <- ((fit.8595$value)/(length(val) - 1))/var(val) # Sum of the squared residuals, i.e., SFI  res <- cbind(sin.fit.8595) # results return(cbind(res)) } mat <- expand.grid(seq(-1,1, length=50), seq(-1,1, length=50), seq((2\*low.c\*pi)/(length(val)-1),(2\*up.c\*pi)/(length(val)-1), length=50), seq(1-length(val)/1.8, 1+length(val)/1.8, length=100)) # 'brute force' estimates for parameters a, b, c, and d. Reduce length= to reduce computational power. # Loop to calculate the median: Each correlation is used once as the starting point of the computation, while mainting the order of the elements:  ring.R <- c(val, val)  n <- (length(val) - 1) x<-matrix(data=NA, nrow=length(val),ncol=1) for(i in 1:(length(val))){ x[i,] <- val.l.R(ring.R[i:(i+(length(val) - 1))]) } #x # matrix of the single values for each of the 10 orders and R.square print(apply(x, 2, median)) # The median for the SFI  }  |

Table 1

Schwartz (1992, 1994) value types and definitions

|  |  |  |
| --- | --- | --- |
| Value type | Definition | Values |
| Universalism | Understanding, appreciation, tolerance, and protection for the welfare of all people and for nature. | Broadminded, wisdom, a world of beauty, equality, unity with nature, a world at peace, social justice, protecting the environment |
| Self-Direction | Independent thought and action-choosing, creating, exploring | Creativity, freedom, independent, curious, choosing own goals |
| Stimulation | Excitement, novelty, and challenge in life. | A varied life, daring, an exciting life |
| Hedonism | Pleasure and sensuous gratification for oneself | Pleasure, enjoying life |
| Achievement | Personal success through demonstrating competence according to social standards | Successful, ambitious, capable, influential |
| Power | Social status and prestige, control or dominance over people and resources | Social power, wealth, authority, preserving my public image |
| Security | Safety, harmony, and stability of society, of relationships, and of self | Family security, national security, reciprocation of favors, social order, clean |
| Tradition | Respect, commitment, and acceptance of the customs and ideas that traditional culture or religion provide | Respect for tradition, humble, accepting my portion in life, devout, moderate |
| Conformity | Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms | Self-discipline, obedient, politeness, honoring of parents and elders |
| Benevolence | Preservation and enhancement of the welfare of people with whom one is in frequent personal contact. | Honest, loyal, helpful, forgiving, responsible |

*Note*. Definitions are verbatim quotes from Schwartz (1994, p. 21).

Table 2

*Percentage of false positives for various distributions assumptions and numbers of correlation coefficients, based on the simulated data*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Distribution | *k* = 4 | *k* = 7 | *k* = 8 | *k* = 10 | *k* = 17 | *k* = *19* |
| SFI < .30 | *~U*(-.5, .5) | 68.69 | 12.97 | 7.39 | 2.49 | 0.06 | 0.01 |
| ~N(0, .1) | 68.43 | 11.39 | 6.28 | 1.88 | 0.02 | 0.01 |
| ~N(0, .3) | 67.81 | 10.90 | 5.93 | 1.92 | 0.03 | 0.01 |
| SFI < .20 | *~U*(-.5, .5) | 60.37 | 6.78 | 3.13 | 0.77 | 0.01 | 0 |
| ~N(0, .1) | 59.33 | 5.48 | 2.42 | 0.46 | 0 | 0 |
| ~N(0, .3) | 58.57 | 5.04 | 2.27 | 0.47 | 0 | 0 |
| SFI < .10 | *~U*(-.5, .5) | 48.32 | 2.15 | 0.69 | 0.12 | 0 | 0 |
| ~N(0, .1) | 47.02 | 1.57 | 0.49 | 0.04 | 0 | 0 |
| ~N(0, .3) | 46.20 | 1.38 | 0.45 | 0.05 | 0 | 0 |

*Note*. *k*: Numbers sample, ~U(-.5, .5): Uniform distribution with range between -.5 and .5, ~N(0, .1) normal distribution with μ = 0 and σ = 0.1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 3 |  |  |  |  |  |  |
| *Thresholds for SFIs for different numbers of false-positives, based on the simulated data* |
|  | Distribution | *k* = 4 | *k* = 7 | *k* = 8 | *k* = 10 | *k* = 17 | *k* = 19 |
| $\hat{p}$ < .05 | *~U*(-.5, .5) | 0 | .17 | .25 | .38 | .63 | .67 |
| ~N(0, .1) | 0 | .19 | .27 | .40 | .64 | .68 |
| ~N(0, .3) | 0 | .20 | .28 | .41 | .65 | .68 |
| $\hat{p}$ < .01 | *~U*(-.5, .5) | 0 | .06 | .11 | .22 | .49 | .53 |
| ~N(0, .1) | 0 | .08 | .14 | .25 | .51 | .55 |
| ~N(0, .3) | 0 | .08 | .14 | .25 | .51 | .56 |
| $\hat{p}$ < .001 | *~U*(-.5, .5) | 0 | .02 | .04 | .09 | .34 | .37 |
| ~N(0, .1) | 0 | .02 | .05 | .13 | .36 | .42 |
| ~N(0, .3) | 0 | .02 | .05 | .13 | .36 | .41 |

*Note*. *k*: Numbers sample, $\hat{p}$ estimated probability, ~U(-.5, .5): Uniform distribution with range between -.5 and .5, ~N(0, .1) normal distribution with μ = 0 and σ = 0.1.

Table 4

*Mean SFIs for the optimization functions and R2*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Order of the values | SFI | %SFIs < .40 | *R2* | *r* |
| SE-CO-TR-BE (*F-c*) | .240a0, d1 | 87 | .066b2, d2 | -.42\* |
| SE-TR-CO-BE (*F-c*) | .224a0, e2 | 87 | .066c2, e2 | -.45\* |
| SE-TR+CO-BE (*F-c*) | .231f0 | 91 | .062b2, c2, f2 | -.41¬ |
| SE-CO-TR-BE (*ALL-c*) | .310g3, h3, j3 | 70 | .037h3, j3 | -.53\*\*\* |
| SE-TR-CO-BE (*ALL-c*) | .292g3, k3 | 73 | .037i3, k3 | -.52\*\*\* |
| SE-TR+CO-BE (*ALL-c*) | .291h3, l3 | 80 | .035h3, i3, l3 | -.50\*\*\* |
| SE-CO-TR-BE (*F*) | .228d1, m1 | 91 | .087d2, n1 | -.11 |
| SE-TR-CO-BE (*F*) | .208e2, m1 | 87 | .087e2, o1 | -.00 |
| SE-TR+CO-BE (*F*) | .215f0 | 100 | .083f2, n1, o1 | -.00 |
| SE-CO-TR-BE (*ALL*) | .298j3, p3, q3 | 73 | .049j3, q3 | -.42\*\*\* |
| SE-TR-CO-BE (*ALL*) | .279k3, p3 | 75 | .049k3, r3 | -.37\*\*\* |
| SE-TR+CO-BE (*ALL*) | .272l3, q3 | 85 | .049l3, q3, r3 | -.41\*\*\* |

*Note.* %SFIs < .40 is the percentage of SFIs < .40, i.e., with an estimated probability of < .05, *r* is the correlation between the SFI and the *R2*; *F* is the average SFI for the 23 Factors; *ALL* is the average SFI for all the 151 external variables; *c* is the centered value types. SE is the Security value type, CO is Conformity, TR is Tradition, BE is Benevolence (cf. Fig. 1), TR+CO is the average of Tradition and Conformity. Same (letter) superscript indicates columnwise differences. 0: p< .08, 1: *p* < .05, 2: *p* < .01, 3: *p* < .001 (paired *t*-tests, two-sided). All the *R2s* are significant at *p* < .001.

¬ p < .06

\* p < .05

\*\* p < .01

\*\*\* p < .001

Table 5

SFI, R2, and Chronbach’s α for 23 Factors derived from 151 items using PCA

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | SFI | *R2* | Cronbach’s α |
| TV watching time (2) | 0.080 | 0.040 | 0.576 |
| Sum of political activities (6) | 0.097 | 0.079 | 0.638 |
| Attitude towards immigrants (6) | 0.100 | 0.087 | 0.888 |
| General health (2) | 0.105 | 0.083 | 0.716 |
| Religiosity (4) | 0.120 | 0.129 | 0.850 |
| Interest in politics (2) | 0.122 | 0.040 | 0.345 |
| Pessimistic world-view (4) | 0.125 | 0.103 | 0.610 |
| Self-direction at work (3) | 0.126 | 0.065 | 0.719 |
| Feeling depressed (7) | 0.132 | 0.061 | 0.836 |
| Happiness (4) | 0.140 | 0.052 | 0.786 |
| Trust in people (3) | 0.162 | 0.066 | 0.782 |
| Feeling optimistic and fulfilled (6) | 0.174 | 0.081 | 0.760 |
| Frequency of social interactions (3) | 0.177 | 0.128 | 0.562 |
| Satisfaction with life (2) | 0.203 | 0.085 | 0.827 |
| Perception of some freedom rights (4) | 0.209 | 0.058 | 0.787 |
| Acceptance of political system (11) | 0.246 | 0.066 | 0.923 |
| Enthusiastic about things you are doing (4) | 0.270 | 0.054 | 0.849 |
| Attitudes towards supranational institutions (EU & UN) (3) | 0.281 | 0.015 | 0.688 |
| Perception of citizen rights (6) | 0.303 | 0.049 | 0.886 |
| Relationship to neighbors (3) | 0.376 | 0.023 | 0.660 |
| Relationship to other people you are close to (3) | 0.472 | 0.060 | 0.722 |
| Perception of democratic rights (7) | 0.491 | 0.056 | 0.850 |
| Perception of democratic processes (6) | 0.612 | 0.031 | 0.830 |

*Note*. Numbers in brackets in first column indicate number of items summarized for a score.*Table 6*

*SFI for 10 value types with behaviors and vice versa (Bardi & Schwartz, 2003)*

|  |  |  |
| --- | --- | --- |
| Value types / behavior | SFI for value types with behavior as EVs | SFI for behavior with value types as EVs |
| Power | .22 | .27 |
| Achievement | .20 | .35 |
| Hedonism | .13 | .15 |
| Stimulation | .12 | .24 |
| Self-direction | .15 | .19 |
| Universalism | .54 | .26 |
| Benevolence | .43 | .07 |
| Tradition | .07 | .24 |
| Conformity | .16 | .18 |
| Security | .24 | .14 |

*Note*. EV: External Variable.

Table 7

Schematic overview of the possible combinations of R2 and the SFI

|  |  |  |
| --- | --- | --- |
|  |  | SFI |
|  |  | ≤ .30 |  | > .30 |
| *R2* | High | External variable is related to values |  | *Multioriginated*: External variable is likely related with at least two non-adjacent (sub-)dimensions of the circumplex model |
|  |  |  |  |
| Low | External variable is related to (sub-) dimensions of circumplex model. May be worth looking at subdimensions of external variable or related variables for a higher *R2* |  | External variable is not related to values |

*Note*. The *R2* depends on the number of predictors and their relation among each other. Therefore, the meaning of a “high” and “low” *R2* has to be decided on a case-to-case basis.



*Figure 1.* Schwartz (1992) quasi-circumplex structure of human values.



*Figure 2.* Different sinusoidal relations of the 10 value types with external variables (y-axis). See text for explanations.

*Note*. SE: Security, TR: Tradition, CO: Conformity, BE: Benevolence, UN: Universalism, SD: Self-direction, ST: Stimulation, HE: Hedonism, AC: Achievement, PO: Power.



*Figure 3.* Example Sinusoidal Fit Indices (SFIs) using data taken from the European Social Survey. The lines are the best fitting ones based on the developed function. External variable for panel A: TV watching, panel B: feeling optimistic and fulfilled, panel C: relationship with other people.

*Note*: SE = Security, TR = Tradition, CO = Conformity, BE = Benevolence, UN = Universalism, SD = Self-direction, ST = Stimulation, HE = Hedonism, AC = Achievement, PO = Power.



Figure 4. Correlations of 17 behavior sets with the value type Face.

Note. SDT = self-direction-thought; SDA = self-direction-action; ST = stimulation; HE = hedonism; AC = achievement; POD = power-dominance; POR = power-resources; FAC = face; SEP = security-personal; SES = security-societal; TR = tradition; COR = conformity-rules; COI = conformity-interpersonal; HUM = humility; UNN = universalism-nature; UNC = universalism-concern; UNT = universalism-tolerance.

# Supplemental Materials - Table of Contents

* **Rationale for parameter restrictions of the sine function**
* **Comparison of SFI with Multidimensional Scaling (MDS)**
* **Item-labels of the 23 components derived from the European Social Survey (Study 2)**
* **Study 3**
* **Result tables**
* **Results for the 19 value types**
* **Study 4**
* **Definitions of the Inventory of Interpersonal Problems Scales**
* **Result table**
* **References**

## Rationale for Parameter Restrictions of the Sine Function

In the equation, y = f(x) = a + b\*sin(c\*x + d), we restricted the four parameters *a*, *b*, *c*, and *d.* This helps to overcome several problems in identifying the correct sinusoidal function. The most obvious problem with using a sine function with the Schwartz (1992) value model is that the 10 correlation coefficients may follow a sine function, but not follow the pattern predicted by Schwartz (see Figure 2, line C); Schwartz predicts only one period of a sine wave (i.e., one positive and one negative peak). To overcome this problem, we restricted the period of the sinusoidal function (i.e., the number of peaks) using the parameter *c*. This parameter stretches the function if *c* < 1 and compresses it when *c* > 1. According to the postulated structure of the 10-value-type model (see Schwartz, 1992, p. 55), the period of the sinusoidal function should not exceed 90 percent of the x-axis comprising the value types. Line C in our Figure 2 illustrates 2.25 waves, and Line D illustrates .90 of one complete wave. However, if we restricted the sinusoidal function to exactly .90, we would have neglected the assumption that “[t]he distances between the values around the circle may not be equal” (Schwartz et al., 2012, p. 669).[[3]](#footnote-3) We therefore decided to add an interval of 50 percent of the distance between two value types around the .90 restriction, yielding potential periods between .85 and .95 of the axis for the 10-value-type model. This allows the distance of the value types to vary up to 10 percent of a period in the 10-value-type model. The formula that we have used for computing the restrictions is for the lower limit (K\*2 – 3)/K\*2 and (K\*2 – 1)/K\*2 for the upper limit, with K being the number of correlation coefficients. A broader interval from .80 to 1 period, for example, would have challenged the claim that all 10 value types are distinct (Schwartz, 1992, p. 59). Also, because of this issue with the distance between the value types, we decided not to simply repeat the first value type at the end of the x-axis and then calculate the fit for one exact full period. This approach would not enable the fit index to ‘penalize’ when the distance between the last and first value type is very small, i.e. below 5 percent. Take the correlations of the 10 value types with openness again as an example (Figure 2, line A): as can be seen, the distance between the correlation coefficients varies. For example, security and tradition are closer to each other than security and power (Parks-Leduc, Feldman, & Bardi, 2014). If the first correlation would have simply been repeated at the end, we could not have penalized this variation in the distances between the correlations.

In addition, parameter *a*, the y-offset, was restricted to between -1 and 1 which is the potential range of the correlation coefficients. The same restrictions were applied to parameter *b*, the amplitude. Given that the first value type is plotted at x = 1, the parameter *d* (x-offset) moved the sinusoidal function along the abscissa in the interval from 1 + K/2 to 1 – K/2, whereas K/2 is half of the number of value types (i.e., correlation coefficients).

To optimize the four parameters of the sine function (equation [1]), we first used a brute force method approach to determine the starting points for the actual optimization function, which was done with the R command *optim*. This is because the R command optim that is often used for optimizations, only searches for local minima – as do all optimization algorithms. We tested which of 12,500,000 combinations of the parameters *a*, *b*, *c*, and *d* of the sinusoidal function results in a sine function that has the smallest deviation to the empirical data. For the parameters *a, b*, and *c,* 50 numerical values were selected; for the parameter *d*, 100 numerical values were selected, resulting in 50x50x50x100 = 12,500,000 combinations. The selection of numerical values (i.e., the 12,500,000 combinations) was done to achieve both a range that is not too large for computational memory (as some commercially available computers would be unable to compute the SFI). For each parameter, the numerical values were selected from a specific range according to the theoretical predictions. For example, the 50 selected numerical values for the parameter *a* (which was restricted from -1 to 1; see below) were -1, -.96, -.92, …, .96, 1. To define a lower and upper interval-bound for each of the four parameters in *R*, we used Byrd, Lu, Nocedal, and Zhu’s (1995) method for allowing constraints.

One further issue is raised by Schwartz et al.’s (2012) postulate that the distances between value types do not have to be equal. Adding an interval around the parameter c as described above only has an effect on the first and last value type on the x-axis. In general, through restriction of the period c, the SFIs may vary slightly depending on the starting value type. For example, the SFI can be slightly different for several EVs when the sequence of values begins in the order of tradition, conformity,…, power, security than in the order of benevolence, universalism,…, tradition, conformity. As can be seen in Figure 2, line A, the distance between security and tradition is smaller (r = -.24 and -.31, resp.) than between conformity and benevolence (-.27, and .13). This means that the first and last data point will not be reached by a sine wave of .95 of a period (it would require .98) in the example where the first and last data point are too close to each other. On the other hand, conformity and benevolence are probably too far away to be reached by a sine wave restricted to .85 of a period. Such order re-arrangements can lead to small changes in SFI of around .02 for any EV. Although this variability is small, the most rigorous approach is to account for the variance by calculating the SFI for all of the possible starting configurations (e.g., 10 for 10 value types) and report the median. This is the approach we follow in the present research, as it allows us to address the issue of varying distances between the value types (Schwartz et al., 2012).

# Comparison of SFI with Multidimensional Scaling (MDS)

There are several differences between testing sinusoidal fit and multidimensional scaling (MDS). Applying a sinusoidal test is about the relations of a set of variables (e.g., values types) to another variable (the external variable), whereas MDS focuses on the relations of a set of variables. In research on social values, MDS is often used to test whether the relations between values can be described in a two-dimensional quasi-circumplex model (Figure 1; Bilsky, Janik, & Schwartz, 2011; Schwartz et al., 2012). These two tests are distinct. For example, if an EV is only weakly related to all value types, but nevertheless follows the sinusoidal pattern well (SFI = .08, Figure 3, line A), then it will be far away from the value types in a common space plot of the MDS (see Figure S1 for a common space plot). Figure S1 also shows that a sinusoidal pattern can arise when the data do not follow a (two-dimensional) circular pattern according to MDS. In other words, an MDS cannot lead to reliable conclusions about the pattern of relations with an EV. Nevertheless, a replication of the proposed circular structure is an important first step for verifying that the underlying circular model has support, prior to applying a sinusoidal test (Boer & Fischer, 2013).

*Illustrations*. In Figure S1, the 10 centered value types have been plotted along with an external variable that has revealed very good sinusoidal fit, but is only weakly correlated with all the value types r < |.15| (TV watching behavior from the ESS data; cf. Study 2 and Table 5 in the main manuscript). A similar common space plot can be obtained with other variables of the ESS that are described in Table 5. For Figure S2, we simulated 54,000 participants from a multivariate normal distribution using the original correlation matrix of the ESS and added an external variable that was only correlated with security (r = .70), but unrelated to the other values. Simulations were conducted with the R package mnornmt (Genz & Azzalini, 2013). Because the 11x11 starting matrix was not positive definite with these starting configurations, we attenuated all the correlation coefficients that have been > |.3| to < |.3|. This did not change the proposed structure (Figure S2). Although the external variable was only correlated with security, but uncorrelated with the other values, it emerged not only close to security in the common space plot, but also relatively close to the adjacent value types power and conformity.



Figure S1. MDS plot of 10 value types with an external variable (TV watching) that is weakly related to the values.

 

Figure 2. MDS plot of 10 value types with an external variable (EV) that is strongly related to one set of values.

## Items of the 23 Components Derived from the European Social Survey

The items for the 23 components have been taken from the questionnaire, provided on <http://www.europeansocialsurvey.org/docs/round6/fieldwork/source/ESS6_source_main_questionnaire.pdf>. All items are verbatim quotes and were answered on Likert-scales.

TV watching time

1. On an average weekday, how much time, in total, do you spend watching television?
2. And again on an average weekday, how much of your time watching television is spent watching news or programmes about politics and current affairs?

Sum of political activities

There are different ways of trying to improve things in [country] or help prevent things from going wrong. During the last 12 months, have you done any of the following? Have you…

1. …contacted a politician, government or local government official?
2. …worked in a political party or action group?
3. …worked in another organisation or association?
4. …worn or displayed a campaign badge/sticker?
5. …signed a petition?
6. …taken part in a lawful public demonstration?

Attitude towards immigrants

1. To what extent do you think [country] should allow people of the same race or ethnic group as most [country]’s people to come and live here?
2. How about people of a different race or ethnic group from most [country] people?
3. How about people from the poorer countries outside Europe?
4. Would you say it is generally bad or good for [country]’s economy that people come to live here from other countries?
5. And, using this card, would you say that [country]’s cultural life is generally undermined or enriched by people coming to live here from other countries?
6. Is [country] made a worse or a better place to live by people coming to live here from other countries?

General health

1. How is your health in general?
2. Are you hampered in your daily activities in any way by any longstanding illness, or disability, infirmity or mental health problem?

Religiosity

1. Do you consider yourself as belonging to any particular religion or denomination?
2. Regardless of whether you belong to a particular religion, how religious would you say you are?
3. Apart from special occasions such as weddings and funerals, about how often do you attend religious services nowadays?
4. Apart from when you are at religious services, how often, if at all, do you pray?

Interest in politics

1. How interested would you say you are in politics?
2. How close do you feel to this party?

Pessimistic world-view

1. In my daily life I get very little chance to show how capable I am.
2. When things go wrong in my life, it generally takes me a long time to get back to normal.
3. The way things are now, I find it hard to be hopeful about the future of the world.
4. For most people in [country] life is getting worse rather than better.

Self-direction at work

1. In your main job, do/did you have any responsibility for supervising the work of other employees?

Please say how much the management at your work allows/allowed you…

1. …to decide how your own daily work is/was organised?
2. …to influence policy decisions about the activities of the organisation?

Feeling depressed

I will now read out a list of the ways you might have felt or behaved during the past week. Please tell me how much of the time during the past week…

1. …you felt depressed?
2. …you felt that everything you did was an effort?
3. …your sleep was restless?
4. …you felt lonely?
5. …you felt sad?
6. …you could not get going?
7. …you felt anxious?

Happiness

I will now read out a list of the ways you might have felt or behaved during the past week. Please tell me how much of the time during the past week…

1. …you were happy?
2. …you enjoyed life?
3. …you had a lot of energy?
4. …you felt calm and peaceful?

Trust in people

1. Generally speaking, would you say that most people can be trusted, or that you can’t be too careful in dealing with people?
2. Do you think that most people would try to take advantage of you if they got the chance, or would they try to be fair?

Feeling optimistic and fulfilled

1. I’m always optimistic about my future.
2. In general I feel very positive about myself.
3. I feel I am free to decide for myself how to live my life.
4. Most days I feel a sense of accomplishment from what I do.
5. I generally feel that what I do in my life is valuable and worthwhile.
6. There are lots of things I feel I am good at.

Frequency of social interactions

1. How often do you meet socially with friends, relatives or work colleagues?
2. How many people, if any, are there with whom you can discuss intimate and personal matters?
3. Compared to other people of your age, how often would you say you take part in social activities?

Satisfaction with life

1. All things considered, how satisfied are you with your life as a whole nowadays?
2. Taking all things together, how happy would you say you are?

Perception of some freedom rights

Please tell me how important you think it is for democracy in general…

1. …that national elections are free and fair?
2. …that voters discuss politics with people they know before deciding how to vote?
3. …that opposition parties are free to criticise the government?
4. …that the media are free to criticise the government?

Acceptance of political system

1. How democratic do you think [country] is overall?
2. On the whole how satisfied are you with the present state of economy in [country]?
3. Please say what you think overall about the state of education in [country] nowadays?
4. Please say what you think overall about the state of health services in [country] nowadays?
5. And on the whole, how satisfied are you with the way democracy works in [country]?
6. Now thinking about the [country] government, how satisfied are you with the way it is doing its job?

Please tell me on a score of 0-10 how much you personally trust each of the institutions I read out.

1. ...[country]’s parliament?
2. …the legal system?
3. …the police?
4. …politicians?
5. …political parties?

Enthusiastic about things you are doing

How much of the time would you generally say you are…

1. …interested in what you are doing?
2. …absorbed in what you are doing?
3. …enthusiastic about what you are doing?
4. On a typical day, how often do you take notice of and appreciate your surroundings?

Attitudes towards supranational institutions (EU & UN)

1. Now thinking about the European Union, some say European unification should go further. Others say it has already gone too far. What number on the scale best describes your position?

Please tell me on a score of 0-10 how much you personally trust each of the institutions I read out.

1. …the European parliament.
2. …the United Nations.

Perception of citizen rights

Please tell me to what extent you think each of the following statements applies in [country]

1. Citizens in [country] have the final say on the most important political issues by voting on them directly in referendums.
2. The courts in [country] treat everyone the same.
3. Governing parties in [country] are punished in elections when they have done a bad job.
4. The government in [country] protects all citizens against poverty.
5. The government in [country] explains its decisions to voters.
6. The government in [country] takes measures to reduce differences in income levels.

Relationship to neighbors

Please tell me to what extent…

1. …you feel that people in your local area help one another?
2. …you feel that people treat you with respect?
3. Please say to what extent you agree or disagree with the following statement: I feel close to the people in my local area.

Relationship to other people you are close to

1. To what extent do you feel appreciated by the people you are close to?
2. To what extent do you receive help and support from people you are close to when you need it?
3. And to what extent do you provide help and support to people you are close to when they need it?

Perception of democratic rights

And still thinking generally rather than about [country], how important do you think it is for democracy in general…

1. …that citizens have the final say on the most important political issues by voting on them directly in referendums?
2. …that the courts treat everyone the same?
3. …that the courts are able to stop the government acting beyond its authority?
4. …that governing parties are punished in elections when they have done a bad job?
5. …that the government protects all citizens against poverty?
6. …that the government explains its decisions to voters?
7. …that the government takes measures to reduce differences in income levels?

Perception of democratic processes

And still thinking generally rather than about [country], how important do you think it is for democracy in general…

1. …that national elections are free and fair?
2. …that voters discuss politics with people they know before deciding how to vote?
3. …that different political parties offer clear alternatives to one another?
4. …that opposition parties are free to criticise the government?
5. …that the media are free to criticise the government?
6. …that the media provide citizens with reliable information to judge the government?

## Study 3

**Result tables for Study 3**

Table S1

SFIs for correlations of values with behaviors (Schwartz & Butenko 2014)

|  |  |  |
| --- | --- | --- |
|  | SFI for all 19 value types | SFI for 17 value types |
| SDT | 0.44 | 0.16 |
| SDA | 0.40 | 0.22 |
| ST | 0.55 | 0.40 |
| HE | 0.74 | 0.61 |
| ACH | 0.49 | 0.44 |
| POD | 0.51 | 0.60 |
| POR | 0.59 | 0.69 |
| FAC | 0.59 | 0.61 |
| SEP | 0.81 | 0.70 |
| SES | 0.32 | 0.29 |
| TR | 0.65 | 0.49 |
| COR | 0.62 | 0.45 |
| COI | 0.54 | 0.60 |
| HUM | 0.54 | 0.42 |
| UNN | 0.57 | 0.47 |
| UNC | 0.52 | 0.45 |
| UNT | 0.43 | 0.34 |
| BEC | 0.85 |  |
| BED | 0.89 |   |

Note. SDT = self-direction-thought; SDA = self-direction-action; ST = stimulation; HE = hedonism; AC = achievement; POD = power-dominance; POR = power-resources; FAC = face; SEP = security-personal; SES = security-societal; TR = tradition; COR = conformity-rules; COI = conformity-interpersonal; HUM = humility; UNN = universalism-nature; UNC = universalism-concern; UNT = universalism-tolerance.

Table S2

SFIs for correlations of behavior sets with value types

|  |  |  |
| --- | --- | --- |
|  | SFI for 19 behavior sets | SFI for 17 behavior sets |
| bSDT | 0.77 | 0.48 |
| bSDA | 0.29 | 0.25 |
| bST | 0.51 | 0.40 |
| bHE | 0.34 | 0.37 |
| bAC | 0.86 | 0.74 |
| bPOD | 0.39 | 0.42 |
| bPOR | 0.45 | 0.39 |
| bFAC | 0.74 | 0.51 |
| bSEP | 0.66 | 0.52 |
| bSES | 0.49 | 0.45 |
| bTR | 0.62 | 0.46 |
| bCOR | 0.60 | 0.41 |
| bCOI | 0.75 | 0.74 |
| bHUM | 0.35 | 0.29 |
| bUNN | 0.85 | 0.56 |
| bUNC | 0.88 | 0.54 |
| bUNT | 0.54 | 0.22 |
| bBEC | 0.81 |  |
| bBED | 0.64 |   |

Note. SDT = self-direction-thought; SDA = self-direction-action; ST = stimulation; HE = hedonism; AC = achievement; POD = power-dominance; POR = power-resources; FAC = face; SEP = security-personal; SES = security-societal; TR = tradition; COR = conformity-rules; COI = conformity-interpersonal; HUM = humility; UNN = universalism-nature; UNC = universalism-concern; UNT = universalism-tolerance.

## Results for the 19 value types (Study 3)

We computed 19 SFIs for the correlations of each value type with all 19 behavior sets and 19 SFIs for the correlations of each behavior set with all 19 value types (Schwartz & Butenko, 2014). An example for the former is the SFI of self-direction-thought with all 19 behavior sets, which was .44. Only of the 38 SFIs were below of the acceptable SFI of <.30 (Tables S1 and S2). The SFIs for each value type with all behaviors (*M*SFI = .58, *SD* = .15) were not better than the SFIs of each behavior with all the value types (*M*SFI = .61, *SD* = .19; *t*[18] = 0.50, *p* = .63, *d* = .15). Further, the two sets of SFIs were uncorrelated (*r*[17] = .16, *p* = .51). Next, we correlated the SFI with the sinusoidal approximation of Schwartz and Butenko (2014). These correlations were very high (*r*[17] = -.93, *p* < .0001 and *r*[17] = -.78, *p* < .0001), indicating that both approaches are related and that they provide convergent validity for the SFI.

## Study 4

## Definitions of the Inventory of Interpersonal Problems Scales

All definitions are verbatim quotes from Alden et al. (1990, p. 528).

*Domineering*. High scorers report problems related to controlling, manipulating, aggressing toward, and trying to change others.

*Vindictive*. High scorers report problems related to distrust and suspicion of others and an inability to care about others' needs and happiness.

*Cold*. High scorers report an inability to express affection toward and to feel love for another person, difficulty making long-term commitments to others, and an inability to be generous to, get along with, and forgive others.

*Socially Avoidant*. High scorers feel anxious and embarrassed in the presence of others and have difficulty initiating social interactions, expressing feelings and socializing with others.

*Nonassertive*. High scorers report difficulty making their needs known to others, discomfort in authoritative roles, and an inability to be firm with and assertive toward others.

*Exploitable*. High scorers find it difficult to feel anger and to express anger for fear of offending others. They describe themselves as gullible and readily taken advantage of by others.

*Overly nurturant*. High scorers report that they try too hard to please others and are too generous, trusting, caring, and permissive in dealing with others.

*Intrusive*. High scorers are inappropriately self-disclosing, attention seeking, and find it difficult to spend time alone.

**Results table**

Table S3

SFI of interpersonal problem circumplex scales with IAS-R (row 1-8) and personality disorders

|  |  |
| --- | --- |
| External variable | SFI |
| Assured-Dominant | .01 |
| Arrogant-Calculating | .01 |
| Cold-hearted | .01 |
| Aloof-introverted | .04 |
| Unassured-submissive | .01 |
| Unassuming-ingenuous | .01 |
| Warm-agreeable | .01 |
| Gregarious-extraverted | .04 |
| PD: Avoidant | .05 |
| PD: Dependent | .14 |
| PD: Histrionic | .17 |
| PD: Paranoid | .03 |

Note. PD: Personality Disorder. See main text for explanation.

# References

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1. We chose the sine function over the mathematically equivalent cosine function because of its prominence. Further, the extant research referring to predictions from Schwartz’s (1992) circular model refers specifically to sine functions. [↑](#footnote-ref-1)
2. We thank Anat Bardi for sending us the correlation matrix. [↑](#footnote-ref-2)
3. This assumption contradicts the postulate of a (perfect) sinusoidal pattern. A perfect sine wave requires that the distances between the elements of a circumplex model are equal. Unequal distances create a ragged pattern of correlations. Nevertheless, from an empirical point of view, it seems reasonable to assume that the distances are not necessarily equal. Visual inspections of common space plots support this view, as they show that distances between value types are not entirely equal (e.g., Bilsky, Janik, & Schwartz, 2011; Schwartz, 1992). We address this issue below. [↑](#footnote-ref-3)