Circular Unidimensional Scaling: A New Look at Group Differences in Interest Structure

Patrick Ian Armstrong, Lawrence Hubert, and James Rounds
University of Illinois at Urbana–Champaign

The fit of J. L. Holland's (1959, 1997) RIASEC model to U.S. racial–ethnic groups was assessed using circular unidimensional scaling. Samples of African American, Asian American, Caucasian American, and Hispanic American high school students and employed adults who completed either the UNIACT Interest Inventory (K. B. Swaney, 1995) or the Strong Interest Inventory (L. W. Harmon, J. C. Hansen, F. H. Borgen, & A. L. Hammer, 1994) were obtained from published sources. Two circumplex models were evaluated: a quasi-circumplex model with unconstrained distances between adjacent types and a circulant model constrained to equal distances. Results indicate that a quasi-circumplex model was a good fit with all samples; however, the circulant model may be more appropriate for Asian Americans and Caucasian Americans than for other groups. Circulant model results suggest that distinctions made between Holland's types may be less salient for some groups and that additional work is needed to produce interest measures with improved structural validity.

Holland's (1959, 1997) theory of six interest types and work environments has emerged as the dominant model in vocational psychology. The interrelations among the six interest types—realistic, investigative, artistic, social, enterprising, and conventional (collectively referred to as *RIASEC*)—can be represented by a circumplex structure (Hogan, 1983; Rounds & Tracey, 1993). Research has supported the circumplex structure of RIASEC with Caucasian American samples; however, the support for this structure with other populations is less clear. Differences in model fit across racial–ethnic groups suggest that there may be important group differences in interest structure. Group differences may also be the product of methodological limitations such as poor sampling or the statistical methods used (Rounds & Day, 1999; Rounds & Tracey, 1996). In the present study, the technique of circular unidimensional scaling (CUS; Hubert, Arabie, & Meulman, 1997) is used to reanalyze published data of RIASEC interest structure in large representative samples of U.S. racial–ethnic groups. It is proposed that the CUS technique is well-suited for quantifying differences in RIASEC model fit because it is a more parsimonious and direct approach for investigating circumplex structure and potentially more sensitive to group differences than other techniques used to compare RIASEC model fit.

RIASEC Interest Structure

Holland and colleagues (Holland, Whitney, Cole, & Richards, 1969) proposed using a hexagon to represent the interrelations between the six interest types, producing a circular arrangement (see Figure 1). The hexagon was proposed after the authors noticed a pattern in a correlation matrix of RIASEC interest measures. This pattern is represented visually by the relative position of the six types in Figure 1. Adjacent types are more similar than alternate types, and alternate types are more similar than opposite types. Degree of similarity between the types, as measured by correlations between interest scales, is inversely proportional to the distances between types in Figure 1. Although the resulting arrangement of the six interest types is clearly circular, RIASEC structure is often represented with straight lines between adjacent types, producing a hexagon (see Holland, 1997). Nevertheless, the proper statistical term for a model with a circular arrangement and distances indicating degree of similarity is a *circumplex* (Guttman, 1954; Hogan, 1983; Rounds, Tracey, & Hubert, 1992).

Guttman's (1954) initial presentation of circular structures, or circumplex models, specified two variations: the quasi-circumplex and the circulant. The quasi-circumplex is the less restrictive model because it allows for unequal distances between adjacent types in a circular structure. In comparison, the circulant is more restrictive, due to the constraint that distances between adjacent types must be equal. In the present study, following conventions established by Guttman, the term *circumplex* is used in reference to the general class of all models hypothesizing a circular structure, with the term *quasi-circumplex* used in reference to circumplex models that allow for unequal distances between adjacent types, and the term *circulant* used in reference to circumplex models with the constraint that distances between adjacent types must be equal. In general, the circumplex is effective for representing the interrelations among a set of psychological constructs with a circular arrangement based on degree of similarity. Circumplex structures have been identified in a number of areas of psychological research, including personality (Gurtman, 1997), emotions (Russell

Patrick Ian Armstrong and James Rounds, Department of Educational Psychology, University of Illinois at Urbana–Champaign; Lawrence Hubert, Department of Psychology, University of Illinois at Urbana–Champaign.

Correspondence concerning this article should be addressed to James Rounds, Department of Educational Psychology, University of Illinois at Urbana–Champaign, 230 Education Building, 1310 South Sixth Street, Champaign, Illinois 61820. E-mail: j-rounds@uiuc.edu
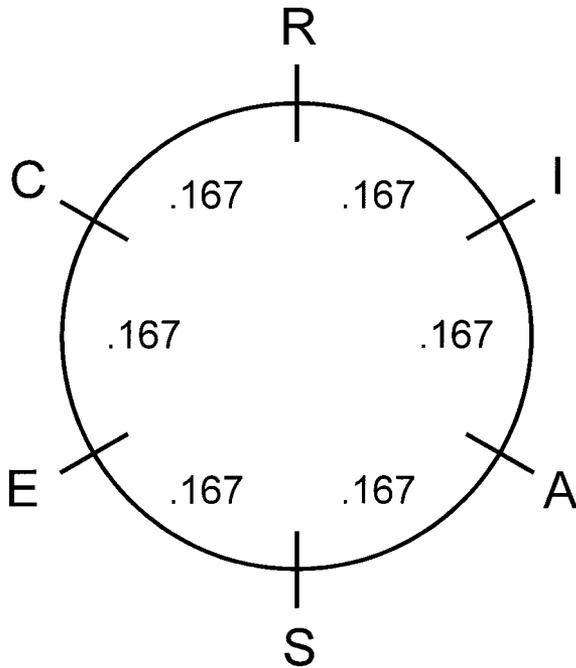
Figure 1. Holland's circumplex model of interests.

Group Differences in RIASEC Structure

Concerns about using Holland's (1959, 1997) model with diverse racial–ethnic groups are often centered in the larger issue of the numerous challenges facing members of these groups when participating in the U.S. labor market. For example, Eby, Johnson, and Russell (1998) have written about institutional challenges and personal challenges. Institutional challenges include others' stereotypes based on group membership, discrimination in selection practices and organizational practices, hostility from coworkers, and glass-ceiling effects. Personal challenges include having limited or stereotyped interests based on group membership, self-efficacy and self-confidence, less career exploration, and more career indecision. Group differences in interest structure may reflect these challenges and limited opportunities available to minority group members. It seems important to develop measures that work consistently across racial–ethnic groups to avoid reinforcing or perpetuating current imbalances in the workplace. Other reviews of the literature (Brown, 1995; Fouad, 1995; Leong & Hartung, 2000) have cited some or all of these concerns, as have studies specifically examining group differences in RIASEC interest structure (Hansen, Sarma, & Collins, 1999; Haverkamp, Collins, & Hansen, 1994; Swanson, 1992).

Meta-analyses of studies reporting correlations between RIASEC interest types have generally supported the structure of Holland's theory (Rounds & Tracey, 1993, 1996; Tracey & Rounds, 1993), although there is some question about the fit with U.S. minority group samples and international samples. These studies have generally focused on testing the less restrictive quasi-circumplex model instead of the circulant model. Furthermore, when both quasi-circumplex and circulant model tests are included in the same study, there is a tendency to discount circulant model results that conflict with quasi-circumplex model results. In a comprehensive meta-analysis of the research, Rounds and Tracey (1996) compared the fit of RIASEC correlation matrices from 20 U.S. ethnic group samples and 76 international samples with a U.S. benchmark group of 74 matrices and reported that the fit of the data to a quasi-circumplex model was a better fit for the benchmark samples than for the U.S. ethnic group and international samples. Day, Rounds, and Swaney (1998) examined the fit of Holland's (1959, 1997) model with large representative samples of college-bound students and found a good fit for the quasi-circumplex model with both male and female African Americans, Asian Americans, Caucasian Americans, Hispanic Americans, and Native Americans. Fouad, Harmon, and Borgen (1997) reported similar results to those of Day and colleagues with large representative samples of successfully employed adults from different U.S. racial–ethnic groups, although the fit of the more restrictive circulant model was questionable for some of the female groups and male minority groups. Anderson, Tracey, and Rounds (1997) examined 14 RIASEC matrices and found that the fit of the data to both quasi-circumplex and circulant models to be similar for both men and women.

When examining the results of structural analyses, it is important to remember that interest scales measuring Holland's (1959, 1997) types represent discrete clusters of items. Day and Rounds (1998) demonstrated that the underlying structure of interests at the item level is very similar for large representative samples of male and female college-bound students from different U.S.

& Barrett, 1999), interpersonal behavior (Wiggins, 1996), psychopathology (Widiger & Hagemoser, 1997), and vocational interests (Tracey & Rounds, 1995).

Holland has been somewhat dismissive of the connections between the RIASEC model and the extant literature on circumplex structures and has discounted results from studies focused on group differences in interest structure, noting that "whether or not hexagons in different groups are similar may have little relation to successful tests of other portions of the theory" (Holland & Gottfredson, 1992, p. 168). Although the interrelations among the six RIASEC types are only one aspect of a larger theory, the structure of the theory is an important cornerstone of Holland's (1959, 1997) model. Each of the six RIASEC types is a category used to group together work-relevant information and characteristics, including items used in interest inventories (Campbell & Borgen, 1999), and the interrelations between types are a function of the characteristics grouped together in each category. In a model hypothesizing a circular structure, the most parsimonious set of groupings is one with equal distances between adjacent categories, producing a circulant model. The RIASEC model presented in Figure 1 is an example of a circulant model of interests using six categories, with the distances between each pair of adjacent types accounting for 16.7% of the total circumference of the circle. The issue of deviations from the circulant model caused by unequal distances between adjacent types is one of consistency. Minor differences in distances between types may be tolerable if they occur randomly, thus suggesting normal variation (Rounds & Day, 1999). If deviations from the circulant model vary as a function of group membership, however, then the appropriateness of the model with groups where the fit is poor must be questioned.

racial–ethnic groups. If the underlying interest structure is similar for all groups, then it should be possible to create scales of these items with a similar structure for all groups. Tests of the quasi-circumplex model are not sufficient because this less restrictive model allows for the possibility that results obtained with different groups will be similar on indices of model fit without having similar spatial configurations. Given this possibility, tests of the circulant model are the more appropriate methods. When the fit of RIASEC interest scales to the preferred circulant structure varies between groups, then Holland's (1959, 1997) theoretical partitioning of the interest circumplex into six scales may be less than ideal for some racial–ethnic groups.

Tests of Circumplex Structure

Tests of circumplex models in general, and Holland's (1959, 1997) interest structure specifically, can be divided into two general categories representing the quasi-circumplex and circulant models. The important distinction between the two categories is the number of constraints placed on the interrelations between types (Rounds et al., 1992). Tests for a quasi-circumplex model assume only that adjacent types are more similar than nonadjacent types, as measured by larger positive correlations or smaller distances in a spatial representation. Tests of the circulant model are more restrictive because the additional constraint of equal correlations or distances between adjacent types is imposed. Present methods for evaluating both circulant and quasi-circumplex models share the limitation of being indirect strategies for fitting data to circumplex structures.

A frequently used method for evaluating the fit of Holland's (1959, 1997) model is the correspondence index (CI; Hubert & Arabie, 1987), which provides a normalized descriptive index of the extent to which the hypothesized ordering of types is met by a RIASEC correlation matrix (Rounds et al., 1992). The CI is based on comparing pairs of correlations between types according to a set of order predictions specified by Holland's model. This model specifies that correlations between adjacent types (R-I, I-A, A-S, S-E, E-C, C-R) should be larger than those between alternate types (R-A, A-E, E-R, I-S, S-C, C-I) and opposite types (R-S, I-E, A-C) and that correlations between alternate types should be larger than those between opposite types. The CI does not, however, evaluate whether correlations between either adjacent, alternate, or opposite types are equal. Therefore, Holland's model, being evaluated with the CI, is more constrained than the models fit by other quasi-circumplex methods, but it is not as restrictive as a circulant model. CI results are often combined with a randomization test to determine the exact probability of obtaining the number of order predictions met in the correlation matrix. The CI does not translate directly into a spatial representation, and researchers will often use other techniques such as multidimensional scaling to produce spatial representations of their results (see Fouad et al., 1997; or see Day et al., 1998). An issue with Hubert and Arabie's approach is that it is possible for a matrix with a high CI value to produce a spatial representation that does not resemble a circumplex (Rounds, 1995).

Multidimensional scaling (MDS) can be used to investigate circumplex structure as either an exploratory technique to examine the spatial model that best represents the obtained data using an unconstrained solution or as a confirmatory technique using a set of spatial coordinates specified in advance (Rounds & Tracey, 1993; Tracey, 2000). Although MDS can be used to produce a spatial representation of the structure of a data matrix, any inferences made specifically about circular structures are indirect extensions of the obtained results (Hubert et al., 1997). An additional concern when analyzing measures of Holland's (1959, 1997) types is the ratio of types to dimensions in the MDS solution. Kruskal and Wish (1978) reported that measures of model fit become unreliable when the ratio of stimuli to dimensions is less than 4:1, and Shepard (1974) recommended a minimum of 10 stimuli for a two-dimensional solution, conditions not met when representing six RIASEC scales in two dimensions. Interpretation of results with MDS can be ambiguous because solutions produced with different RIASEC data matrices could have similar indices of model fit, but not necessarily similar spatial representations (Arabie, Carroll, & DeSarbo, 1987).

The final technique used frequently to investigate circumplex structures is confirmatory factor analysis (CFA). To represent a circumplex model in a data matrix of interest measures, three factors are generally extracted. The first factor extracted is often referred to as a *general factor* (Jackson, 1977; Prediger, 1982; Rounds & Tracey, 1993), with the second and third factors extracted representing the circumplex structure. This CFA technique is limited to the circulant model and is unable to evaluate the less restrictive quasi-circumplex model. Browne (1992) has developed a new technique based on factor analysis that allows for the estimation of both quasi-circumplex and circulant models. Browne's technique is a notable improvement because it allows for direct comparison of the quasi-circumplex and circulant models by using inferential tests of relative fit (Tracey, 2000). A potential limitation of CFA-based techniques is the large number of different indices of model fit available, which creates the possibility of ambiguous or conflicting results (Tanaka, 1993).

CUS

The development of CUS (Hubert et al., 1997) represents a new strategy for investigating circumplex structures that addresses many of the limitations of previous techniques. CUS directly assesses the two essential elements of a circumplex structure, the ordering and spacing of objects (such as Holland's [1959, 1997] interest types) around a circle. Previous spatial techniques for evaluating circumplex structures represent "indirect attacks on the CUS task through the fitting of (transformed) proximities by non-linear monotonic functions of the minimum distances calculated around a circular structure" (Hubert et al., 1997, p. 257). An additional advantage of the CUS technique is its use of an easily interpreted Variance Accounted For (VAF) measure of model fit similar to R^2 values obtained in regression analyses. In comparison with the CI, CUS is more flexible in that both circular order and circulant models can be tested and represented spatially. In comparison with MDS, CUS is a more direct approach to investigating circumplex structures and has a better ratio of Holland's (1959, 1997) types to dimensions. In comparison with techniques based on factor analysis, the CUS model is more parsimonious, with the added advantage of a single index of model fit.

Despite the potential advantages offered by CUS over other techniques for evaluating circumplex structures, this new method is not without limitations. Although the VAF measure of model fit

used with the CUS technique is easily interpreted, an objective minimum VAF that would represent a good model fit has not been established. In comparison, critical values and other guidelines have been developed for measures of model fit used with MDS and CFA techniques. An additional concern with the CUS technique is the potential for local optima to produce different results contingent on the starting permutation used in the data analysis, which requires the adoption of multiple starting permutations to identify best-fitting solutions. The CUS analyses may also require a substantial time investment when a large number of objects are analyzed repeatedly because heuristic search methods are relied on to identify both the optimal ordering and the distances between objects in a circular structure.

The Present Study

The purpose of the present study was to use the technique of CUS to investigate the circumplex structure of RIASEC interest measures in large representative samples of U.S. racial–ethnic groups. The CUS technique provides more stringent criteria for evaluating the structural validity of RIASEC interest measures, with the potential of producing a clearer picture of group differences in RIASEC interest structure. Two circumplex models are evaluated: The first represents a quasi-circumplex model using an unconstrained form of CUS that allows for unequal distances between adjacent types; the second represents a circulant model using a constrained form of CUS with equal distances between adjacent types. Consistent with the results of Day et al. (1998) and Fouad et al. (1997), it is predicted that the optimal circular RIASEC ordering with all groups will be the order specified by Holland's (1959, 1997) theory and that the fit of the data to a quasi-circumplex model will be good for all groups. On the basis of the results of Rounds and Tracey (1996), it is expected that if differences in model fit between groups are observed for the more restrictive circulant model, the fit will be better for Caucasian American samples than for U.S. racial–ethnic minority group samples. Consistent with the results of Anderson et al. (1997), the fit of quasi-circumplex and circulant models are expected to be similar for both male and female samples.

Method

Data Sources

Data were obtained from published sources for use in the present study in the form of 6 × 6 correlation matrices of RIASEC interest scales. The work of Day et al. (1998) was used to obtain RIASEC correlation matrices from groups of college-bound high school students who completed the revised unisex edition of the ACT Interest Inventory (UNIACT; Swaney, 1995). The work of Fouad et al. (1997) was used to obtain RIASEC correlation matrices from groups of successfully employed adults who completed the Strong Interest Inventory (SII; Harmon, Hansen, Borgen, & Hammer, 1994). Sixteen matrices were analyzed, representing male and female samples of African American, Asian American, Caucasian American, and Hispanic American individuals who completed either the UNIACT or the SII.

Participants

Demographic information was provided originally in Day et al. (1998) and Fouad et al. (1997). Day and colleagues' data were obtained from

randomly selected samples of college-bound students in grades 11 and 12 who completed the UNIACT in October 1989. Participants were divided into groups based on self-reported demographic information: African American (1,043 men, 1,702 women), Asian American (890 men, 1,069 women), Caucasian American (1,007 men, 1,447 women), and Hispanic American (741 men, 1,068 women). Data obtained for Native American students were not included in the present analyses because equivalent matrices representing the SII were not available. Fouad and colleagues' data were obtained from successfully employed adults who completed the research form of the SII for its 1994 revision. Participants were divided into groups based on self-reported demographic information: African American (368 men, 437 women), Asian American (393 men, 402 women), Caucasian American (18,666 men, 17,966 women), and Hispanic American (372 men, 314 women).

Measures

The UNIACT is a 90-item interest inventory developed to help individuals identify relevant future career options. A three-choice response format (like, indifferent, dislike) is used. There are six 15-item scales corresponding to the six Holland (1959, 1997) RIASEC types. Internal consistency reliability estimates for the UNIACT scales range from .83 to .93 for nationally representative samples of students in grades 8, 10, and 12 (Swaney, 1995). Participants in the Fouad et al. (1997) study completed the 379-item research version of the SII, with a three-choice response format (like, neutral, dislike). This measure includes six scales measuring Holland's interest types, referred to as *general occupational themes* (GOT). Internal consistency reliability estimates for the SII–GOT scales range from .90 to .94 (Harmon et al., 1994).

Analysis

Quasi-circumplex model. The quasi-circumplex model is evaluated by using an unconstrained CUS model that allows for distances between the six types to be optimally determined by a least squares loss function. The CUS analyses are performed with MATLAB programs[1] based on the techniques presented in Hubert et al. (1997). Correlation matrices are converted to distance measures with a linear transformation $(1-r)$ of the correlation values. There are three steps in the CUS data analysis procedure. First, the optimal ordering of types is determined by using quadratic assignment, a heuristic-based technique for identifying the optimal ordering of types according to a set of structural constraints specified by a target matrix. The fit of the proximity matrix to the specified structure is measured by using a cross-product index (CPI; the sum of the products of corresponding entries in the data and target matrices), with larger values indicating a better fit (see Hubert & Schultz, 1976, for a detailed presentation of the CPI and its use in quadratic assignment to identify optimal orderings). The CUS data analysis begins with a random permutation of the data matrix and a target matrix that specifies a circular structure. From the random starting permutation, a baseline value for the CPI is calculated, and then a series of local operations are used to make changes to the ordering of types in the data matrix with the objective of improving the fit of the data to the specified structure, as measured by increases in the CPI. The entire data matrix is reordered in a series of iterations until no improvements can be made to the CPI value, producing a final ordering of the types. Depending on the starting permutation, a local optima may be reached where the obtained ordering does not maximize the CPI, but no improvements can be made to the ordering of objects in the data matrix through the series of local operations. To address this possibility, 300 random starting permutations were sampled for each data matrix analyzed.

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[1] The MATLAB files necessary to perform the analyses presented in this article are available at the ftp site: ftp://www.psych.uiuc.edu/pub/cda in the zipped file cus_jcp.zip.

The second step in the CUS analysis is the estimation of inflection points in the circular structure using an iterative projection strategy presented in Hubert and Arabie (1995b). The determination of inflection points is essential when estimating minimum distances between types in a circular structure because for each pair of types, there are two possible connecting paths (i.e., distances can be generated for both clockwise and counterclockwise directions), one of which will be shorter unless the two types are exactly opposite in the circular structure. The third and final step in the process is the estimation of distances between types in the circular structure. This step uses iterative projection to minimize a least squares loss function (see Hubert & Arabie, 1994, 1995a, 1995b) that accounts for the presence of inflection points and minimizes the squared discrepancies between the original data values and the transformed values representing distances between types in a circular structure. In short, iterative projection is a heuristic-based method for identifying the set of distances between types in a circular structure that is most representative of the observed data, producing the best model fit. The data analysis occurs in a series of iterations, during which different sets of distances between the types are evaluated and a series of incremental improvements are obtained for the fit of the data to a circular model. When no additional improvements can be made to the fit of the model, a final set of distances between types in the circular structure is produced. An additive constant is included in the model to allow for the legitimate calculation of the VAF statistic.

As discussed by Hubert et al. (1997), minor discrepancies in the final solution may be obtained due to variations in the estimation of inflection points. These variations are a consequence of using a heuristic search strategy (such as iterative projection) for identifying a set of coordinates because the final solution may be influenced by the presence of local optima in the data. In other words, circular orderings equivalent in their representation of Holland's (1959, 1997) theory, such as R-I-A-S-E-C and S-E-C-R-I-A, may produce slightly different results in a CUS analysis. To address this concern, all of the possible RIASEC orderings consistent with Holland's theory are considered in the present analysis, and the solution with the best model fit (as measured by VAF) is presented.

Circulant model. To evaluate the fit of the data to a circulant model, a constrained form of CUS with equal distances between types was used. When the constraint of equal distances is added to the model, the use of iterative projection is not necessary to identify optimal distances between the types. Instead, least squares regression can be used to identify an optimal set of equal distances between types, again minimizing the squared discrepancies between the original data and the transformed values representing distances between types. Model fit is again measured by a VAF statistic, comparing the original data values with the fit distances between types obtained in the analysis.

Evaluation of VAF results. One potential limitation of using CUS techniques is the lack of guidelines for evaluating the significance of VAF results. There are three issues related to this limitation. First, it would be valuable if a minimum VAF value that represented a good model fit could be determined. Second, some notion of an expected change in VAF when comparing unconstrained and constrained forms of CUS would be useful in providing a baseline for evaluating the relative fit of quasi-circumplex and circulant models for a group. Third, criteria might be proposed for comparing the fit of either quasi-circumplex or circulant models across different groups. To address these areas, a Monte Carlo study using randomly generated data matrices was conducted to estimate the expected VAF for both the unconstrained and constrained versions of CUS. This information is combined with effect size criteria provided in Cohen (1988) to establish guidelines for evaluating obtained results.

Results

Monte Carlo Study Results

To estimate expected VAFs for unconstrained and constrained CUS analyses, we analyzed 600 randomly generated 6×6 data matrices in a Monte Carlo study. The mean VAF for the unconstrained CUS model was .346 (*SD* = .18); the mean VAF for the constrained CUS model was .073 (*SD* = .09), so the average change between models is 27.3%. These results suggest that if the change in VAF for a given data set is less than .27, then the more parsimonious circulant model may be more appropriate because decrease in VAF associated with the simpler model is less than expected under some notion of randomness. If the change in VAF is larger than .27, however, then the quasi-circumplex model may be more appropriate. We obtained effect size criteria for R^2 comparable to the VAF measure used with CUS, from Cohen (1988), with small, medium, and large effect sizes of .01, .09, and .25, respectively. The large effect size criteria (.25) can be combined with the average VAF estimates for unconstrained (.346) and constrained (.073) CUS analyses to create some crude guidelines as a starting point for evaluating results, with a minimum VAF of .60 representing a good fit for the quasi-circumplex model and a minimum VAF of .33 representing a good fit for the circulant model. Cohen's criteria for small, medium, and large effect sizes is also used when comparing results for the same CUS model obtained with different samples.

Ordering of RIASEC Types

The results of the quadratic assignment analyses evaluating the optimal circular ordering of RIASEC types are presented in Table 1, including the different orderings of types obtained, CPI values, and frequencies of occurrence. For several samples, the only ordering identified in 300 trials was Holland's (1959, 1997) RIASEC ordering, including equivalent orderings that begin with other letters such as *ASECRI.* For example, with the African American men who completed the UNIACT, all 300 trials produced a RIASEC ordering with a CPI of 30.82. In other cases, we obtained some non-RIASEC ordering results, but for each of the 16 samples tested, the ordering of types that produced the highest CPI was RIASEC. For example, with the Caucasian American men who completed the UNIACT, 94% of trials produced a RIASEC order with a CPI of 37.97, and 6% of trials produced an alternative ordering of RIASEC with a lower CPI of 36.82. There was a tendency for SII samples to be more susceptible to the effects of local optima, as seen by the relative number of final orderings with non-RIASEC orderings and lower CPI values. However, the most frequently obtained ordering value was invariably RIASEC. In short, the optimal ordering of the six types for all groups is the RIASEC ordering specified by Holland's theory.

Quasi-Circumplex Model

The unconstrained CUS analyses VAF results are presented in Table 2. Visual representations of the obtained quasi-circumplex structures are presented in Figure 2 for African American samples, Figure 3 for Asian American samples, Figure 4 for Caucasian American samples, and Figure 5 for Hispanic American samples. The numeric values within circular structures indicate the proportion of the circle represented by the distances between each pair of adjacent types. Overall, the mean VAF obtained across 16 samples was .79 (*SD* = .11), with a range of .61–.95, higher than the proposed .60 cutoff value for a good model fit with all samples. The mean VAF with male samples was .75 (*SD* = .11) and with

Table 1
Quadratic Assignment Results for UNIACT and SII Samples

Sample	Ordering	CPI	Frequency	Proportion
UNIACT–Male				
African American	R-I-A-S-E-C	30.82	300	1.00
Asian American	R-I-A-S-E-C	34.52	300	1.00
Caucasian American	R-I-A-S-E-C	37.97	282	.94
	R-A-I-E-C-S	36.82	18	.06
Hispanic American	R-I-A-S-E-C	35.96	286	.95
	R-A-I-E-C-S	34.87	14	.05
UNIACT–Female				
African American	R-I-A-S-E-C	32.96	300	1.00
Asian American	R-I-A-S-E-C	37.73	300	1.00
Caucasian American	R-I-A-S-E-C	40.41	300	1.00
Hispanic American	R-I-A-S-E-C	36.53	300	1.00
SII–Male				
African American	R-I-A-S-E-C	32.64	231	.77
	R-I-A-E-S-C	32.48	69	.23
Asian American	R-I-A-S-E-C	35.12	175	.58
	R-A-E-S-C-I	34.82	53	.17
	R-A-I-S-C-E	34.38	32	.11
	R-E-A-S-I-C	34.28	41	.14
Caucasian American	R-I-A-S-E-C	43.42	300	1.00
Hispanic American	R-I-A-S-E-C	36.46	300	1.00
SII–Female				
African American	R-I-A-S-E-C	37.32	281	.94
	R-A-I-S-C-E	36.16	19	.06
Asian American	R-I-A-S-E-C	38.68	172	.57
	R-A-E-S-C-I	38.32	60	.20
	R-A-I-S-C-E	37.48	68	.23
Caucasian American	R-I-A-S-E-C	46.24	253	.84
	R-A-I-S-C-E	44.69	47	.16
Hispanic American	R-I-A-S-E-C	44.70	231	.77
	R-A-I-S-C-E	43.74	46	.15
	R-E-A-S-I-C	42.54	23	.08

Note. UNIACT = revised unisex edition of the ACT Interest Inventory; SII = Strong Interest Inventory; CPI = cross product index.

female samples was .82 (SD = .11). The male–female VAF difference shows a small effect (.07), according to Cohen's (1988) R^2 criteria. The moderate effect sized difference in model fit between the two RIASEC measures (.17) indicates that the SII data (mean VAF = .87, SD = .06) fit the quasi-circumplex model better than the UNIACT data (mean VAF = .70, SD = .06). An examination of the results obtained across groups suggest that a quasi-circumplex model of interest structure holds for all four racial–ethnic groups. It should be noted that comparisons of VAFs between groups may reveal some moderate sized differences; however, these differences do not clearly favor one group over the others.

When fitting a quasi-circumplex model, it is possible to obtain similar VAF results from two different samples, although distances between adjacent types in the circular structures are not similar. For example, as illustrated in Figure 5, the results for the Hispanic American men who completed the SII and for the Hispanic American women who completed the UNIACT have similar VAFs (.81 and .83, respectively). Despite this similarity in the measure of model fit, the distances between interest types in the two quasi-circumplex structures are not equivalent. For the Hispanic American men who completed the SII, the Artistic scale is effectively isolated on one half of the circular structure (the I-A and A-S distances represent 62% of the circle's circumference), with the

other five types grouped together on the opposite side. In comparison, the quasi-circumplex structure for the Hispanic American women who completed the UNIACT is almost a mirror-opposite, with the Conventional scale isolated on one half of the circular structure. To formally evaluate the fit of a circular structure that is common to all groups, a common structure must be specified; in the present study, we used a circulant model with equal distances between adjacent types.

Circulant Model

The VAFs obtained with the constrained form of CUS to represent the circulant model are presented in Table 2. Overall, the mean VAF obtained across 16 samples was .52 (SD = .10), with a range of .37–.72, higher than the proposed .33 cutoff for all samples. The mean VAF with male samples was .52 (SD = .09) and with females samples was also .52 (SD = .12), which suggests that the fit of the circulant model is similar for both male and female samples. The moderate difference (.14) in model fit between the two RIASEC measures indicates that the SII data (mean VAF = .59, SD = .10) fit the circulant model better than the UNIACT data (mean VAF = .45, SD = .05). When comparing VAF results for different groups who completed the UNIACT, the differences between groups do not clearly favor one group over the others, which suggests that the circulant model is equally appropriate for all racial–ethnic groups. When comparing results for groups who completed the SII, however, the differences between groups suggest that the circulant model fits better for the Caucasian American male (.72) and the Asian American (.68) and Caucasian American female samples (.70) than for the other groups, with a range from .43 for the Hispanic American men to .59 for the African American women.

Table 2
Variance Accounted For (VAF) in Circular Unidimensional Scaling Analyses

Sample	U-CUS	C-CUS	Δ VAF
UNIACT–Male			
African American	.70	.50	.20
Asian American	.61	.49	.12
Caucasian American	.68	.48	.20
Hispanic American	.68	.48	.20
UNIACT–Female			
African American	.69	.41	.28
Asian American	.66	.49	.17
Caucasian American	.72	.41	.31
Hispanic American	.83	.37	.46
SII–Male			
African American	.95	.57	.38
Asian American	.76	.53	.23
Caucasian American	.85	.72	.13
Hispanic American	.81	.43	.38
SII–Female			
African American	.90	.59	.31
Asian American	.91	.68	.23
Caucasian American	.93	.70	.23
Hispanic American	.90	.52	.38

Note. U-CUS = unconstrained circular unidimensional scaling; C-CUS = constrained to equal distances between adjacent types; SII = Strong Interest Inventory.
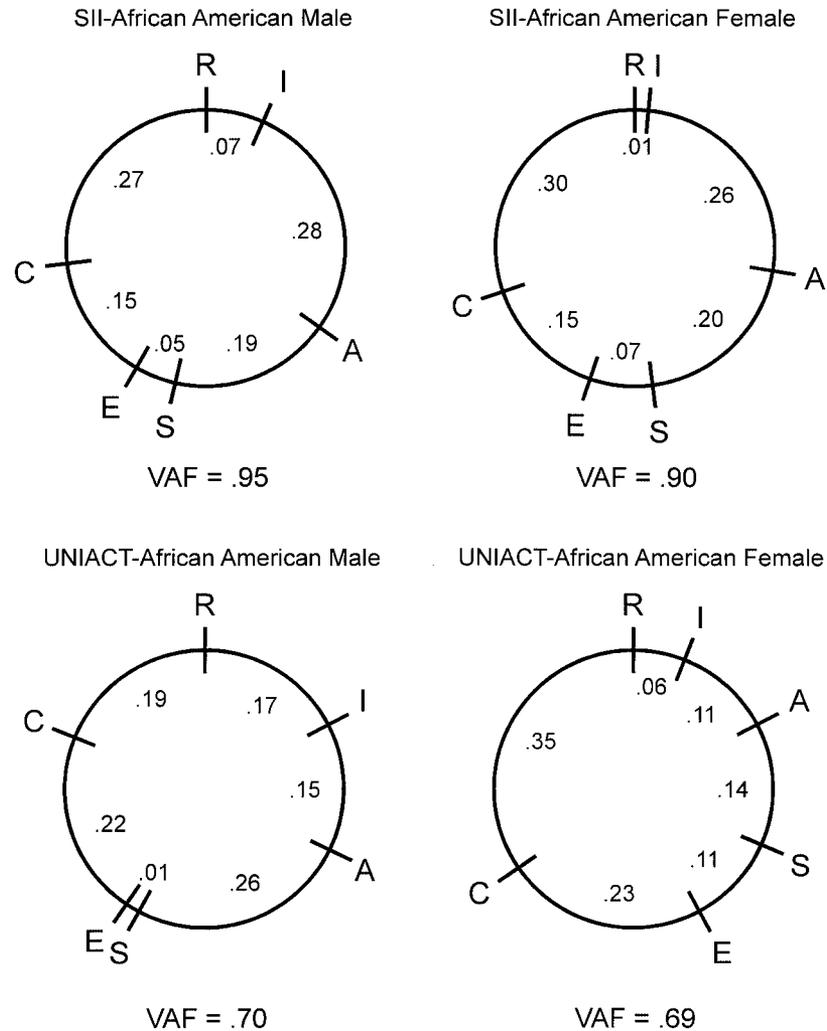
Figure 2. Circular unidimensional scaling results for African American samples. SII = Strong Interest Inventory; UNIACT = revised unisex edition of the ACT Interest Inventory; VAF = variance accounted for.

Comparisons of Quasi-Circumplex and Circulant Models

The results obtained comparing VAF measures of model fit for the quasi-circumplex and circulant models obtained with each group are presented in Table 2. The mean change in VAF across the 16 samples was .26 (*SD* = .10), a result very close to the expected change in VAF of .273 obtained in the Monte Carlo study. This suggests that the circulant model may be the more appropriate structure for representing the interrelations among the six RIASEC types because the changes in VAF associated with the less restrictive quasi-circumplex model can be attributed to the increased number of parameters being estimated. However, a more detailed examination of these results suggests that the circulant model may not be appropriate for all racial–ethnic groups. Of the 16 samples examined, the changes in VAF for nine groups were less than the expected .27, with a VAF range of .12–.23, including all 4 Asian American samples, 3 Caucasian American samples, 1 African American sample, and 1 Hispanic American sample. The changes in VAF for the remaining seven groups were

larger than the expected .27, with a VAF range of .28–.46, including 3 African American samples, 3 Hispanic American samples, and 1 Caucasian American sample. The larger changes in VAF for African American and Hispanic American samples may indicate that the circulant model is a less appropriate model for representing the interrelations among Holland's (1959, 1997) types for members of these racial–ethnic groups.

Discussion

The obtained results provide support for quasi-circumplex interest structures for African American, Asian American, Caucasian American, and Hispanic American college-bound high school students and successfully employed adults. The prediction that the best circular ordering of the six interest types would be the RIASEC order specified in Holland's (1959, 1997) theory is supported because the results of the quadratic assignment procedure demonstrate that Holland's RIASEC ordering is an optimal circular ordering, with no other orderings producing higher CPI values.
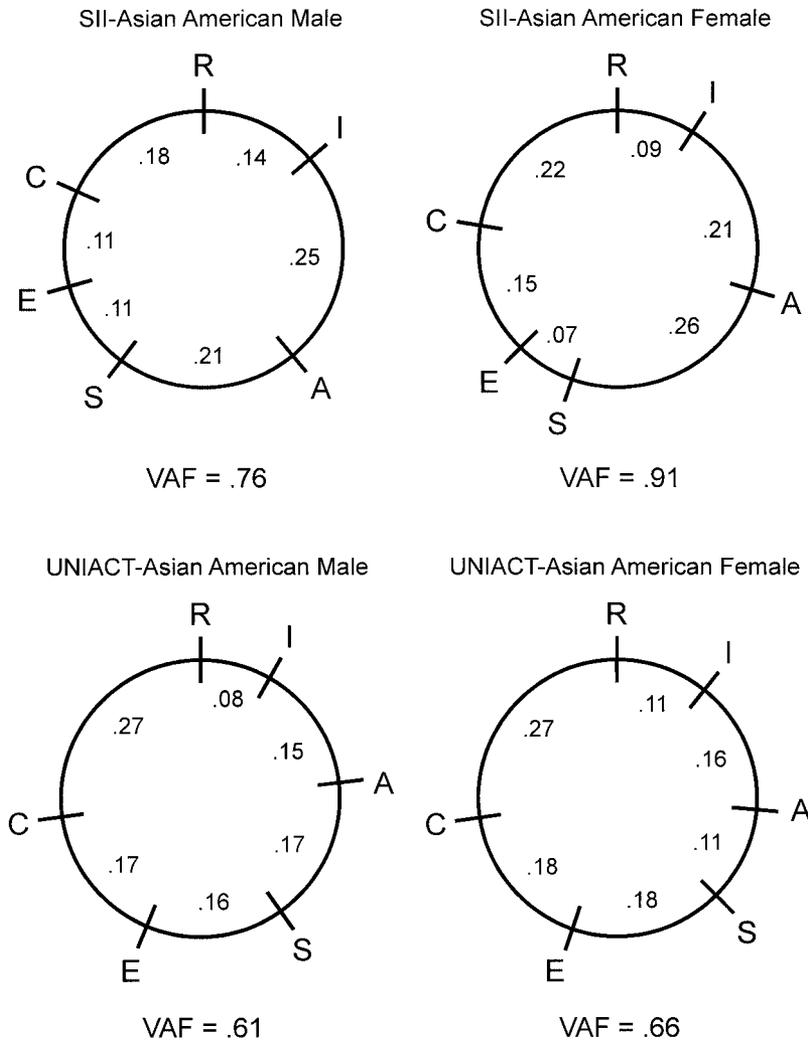
SII-Asian American Male

R
.18   .14
C   I
.11   .25
E   .11
S   .21   A

VAF = .76

SII-Asian American Female

R
.22   .09   I
C   .21
.15   A
.07   .26
E
S

VAF = .91

UNIACT-Asian American Male

R
.08   I
.27   .15
C   A
.17   .17
E   .16   S

VAF = .61

UNIACT-Asian American Female

R
.27   .11   I
.16
C   A
.18   .11
.18
E   S

VAF = .66

Figure 3. Circular unidimensional scaling results for Asian American samples. SII = Strong Interest Inventory; UNIACT = revised unisex edition of the ACT Interest Inventory; VAF = variance accounted for.

Although the quasi-circumplex model was supported, an examination of the unconstrained CUS results suggest that the quasi-circumplex models obtained for different samples may not be equivalent to each other, despite the overall similarity in VAFs between groups. Furthermore, the unconstrained CUS results for some groups appear to deviate substantially from the preferred circulant model with equal distances between adjacent types, which is confirmed by the results of constrained CUS analyses and by the changes in VAF observed when comparing unconstrained and constrained analyses. These results suggest that additional work is needed to develop interest measures with a consistent structure across the diverse range of participants in the U.S. labor market. The CUS technique provides a potentially useful statistical tool for the development of interest measures with improved structural validity.

One possible interpretation of the present results is that the distinctions between interest types made in Holland's (1959, 1997) theory are somewhat culture bound and therefore not equally meaningful to all of the groups represented in the present analyses. Alternatively, these results may reflect the restricted opportunities for minority group members in the U.S. labor market, and it becomes important to develop interest measures that do not reinforce or perpetuate the inequities of the workplace. Irrespective of the preferred interpretation of the group differences in interest structure, there should be some concern over using RIASEC interest measures without a clear understanding of their structural limitations with different racial–ethnic groups. Counseling psychologists and other professionals who use interest measures in applied settings such as career counseling should benefit from the improved picture of group differences in RIASEC interest structure obtained in the present study. As noted by Eby et al. (1998), when using interest measures with diverse populations, a balance must be found between creative application of a measure and skepticism regarding the validity of its results.

Previous studies of Holland's (1959, 1997) interest structure using techniques such as MDS have produced results that occa-
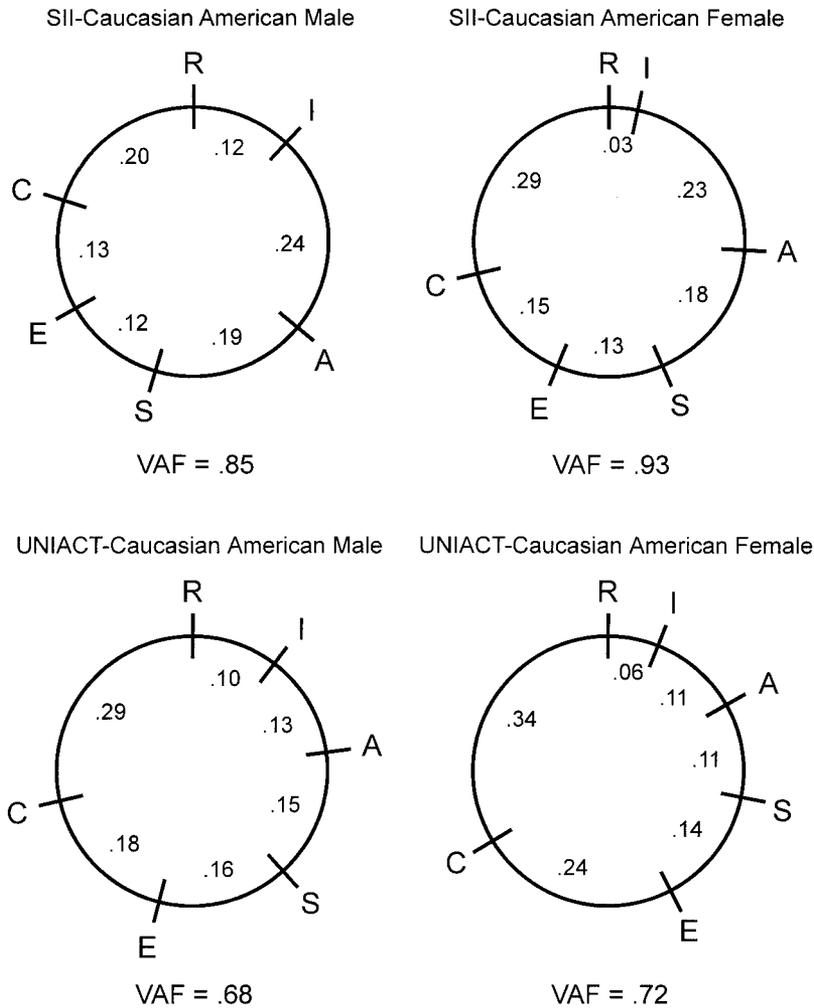
Figure 4. Circular unidimensional scaling results for Caucasian American samples. SII = Strong Interest Inventory; UNIACT = revised unisex edition of the ACT Interest Inventory; VAF = variance accounted for.

sionally do not bear a strong resemblance to the theoretical model of RIASEC. In fact, this happens with sufficient frequency for the term *misshapen polygons* to be coined in reference to the phenomenon (see Holland, 1997; Holland & Gottfredson, 1992; Rounds & Day, 1999). Researchers have been reluctant to interpret the significance of unequal distances between adjacent types as well as group differences in distances between adjacent types. This has led to the criticism by Tinsley (2001) that investigators of Holland's theory will accept the validity of the model irrespective of the results obtained. A reluctance to interpret unequal distances between adjacent types is justified, however, because the techniques previously used are indirect methods for fitting data to a circumplex model, and the number of parameters estimated with these techniques is quite high relative to a set of six RIASEC scales. The use of CUS techniques, which represents a more direct and parsimonious approach to analyzing circumplex structures, addresses this limitation.

By examining the pattern of unequal distances between types for samples in which the fit to the circulant model was questionable

(i.e., when the change in VAF between the unconstrained and constrained CUS analyses was larger than expected), it may be possible to identify areas of improvement for RIASEC-based measures. For example, one pattern in the results could be described as *type isolation,* occurring when the distances between a type and its two adjacent types account for more than 50% of the circumference of the circular structure, effectively isolating that type on one half of the circumplex. This occurs for the conventional type with the African American, Caucasian American, and Hispanic American women who completed the UNIACT and for the artistic type with the Hispanic American men and women who completed the SII. These results suggest that some additional work may be necessary to increase the integration of the isolated types into the work continuum being represented by the six RIASEC scales for members of these groups. A second pattern in the results could be described as *type compression,* occurring when the distances between two types are very small. This occurs for realistic-investigative and for enterprising-conventional with the African American men and women and the Hispanic American women
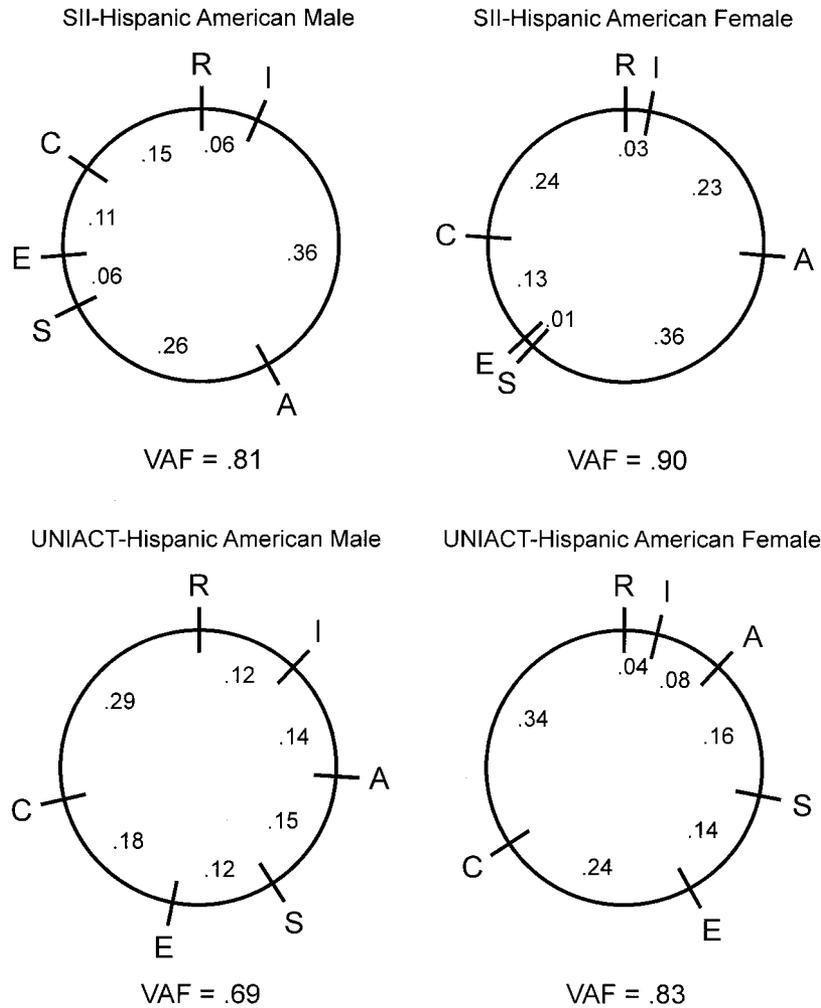
Figure 5. Circular unidimensional scaling results for Hispanic American samples. SII = Strong Interest Inventory; UNIACT = revised unisex edition of the ACT Interest Inventory; VAF = variance accounted for.

who completed the SII. These results suggest that the distinctions between types made in Holland's (1959, 1997) model may not be as salient for members of these groups.

A natural comparison point for the results obtained in the present analyses is the original analyses presented in Day et al. (1998) and Fouad et al. (1997). Consistent with CUS results, both original studies found support for the quasi-circumplex model with all groups using the CI and MDS. Day et al. did not evaluate a circulant model; however, Fouad et al. reported that the fit of the circulant model was questionable for some female and minority group samples but then discounted these results in favor of the quasi-circumplex model. Neither study explored the issue of expected changes in model fit when comparing quasi-circumplex and circulant structures. When we examined these changes in the present study, the results suggested that the circulant model is appropriate for Asian American and Caucasian American samples but not for African American and Hispanic American samples. The differences in model fit between the SII and UNIACT were not predicted because in a meta-analysis by Rounds and Tracey (1993), the fit of the SII and UNIACT measures to a circulant

model measured using CFA were very similar. The similarity of model fit for the circulant model with male and female samples, however, is consistent with results reported in a meta-analysis by Tracey and Rounds (1993) using the CI to measure model fit.

One of the most interesting results of the present study are the unpredicted differences in the fit of the circulant model between the SII and UNIACT samples. With the SII, the fit of the circulant model appears to be reasonable for the Asian American women and for the Caucasian American men and women but appears to be somewhat less reasonable for the other groups represented in the analyses. The fit of the circulant model with the UNIACT is similar for all four groups, but in all cases the VAF values are lower than the corresponding results with the SII. One interpretation of the circulant model results is an apparent trade-off between representing Holland's (1959, 1997) interest structure and providing an unbiased representation of the circumplex model of interests with measures of Holland's interest types. The SII provides a good representation of the circulant model but does not do this effectively across a diverse set of racial–ethnic groups, whereas the UNIACT does not fit the circulant model as well as the SII but

displays smaller between-group differences in circulant model fit. It is interesting to note that the UNIACT and the SII were designed with different strategies. UNIACT items were selected to minimize gender differences (see Swaney, 1995, pp. 17–28), a strategy not used in the item selection process for the SII (see Harmon et al., 1994, pp. 43–63). Connections between gender-neutral interest items and racial–ethnic group differences in interest structure may be worth pursuing in future research.

A second interpretation of the circulant model results is that the obtained differences reflect characteristics of the samples from the Day et al. (1998) and Fouad et al. (1997) studies. The overall difference in VAFs between the UNIACT and SII, which are seen in both the quasi-circumplex and circulant model results, may reflect differences in interest structure between college-bound high school students and successfully employed adults. Differences in circulant model fit between the racial–ethnic groups who completed the SII may also reflect the restricted range of options available to members of these groups in the U.S. labor market. Although high school-aged members of minority groups are aware of the inequities of the U.S. labor market and encounter barriers in educational settings, the full effect of the institutional challenges identified by Eby et al. (1998) may not become apparent at the interest structure level until members of minority groups encounter these barriers when they enter the labor market. A proper evaluation of the measure- and sampling-based interpretations of group differences in circulant model results will require samples of participants who complete both measures.

Holland has generally been dismissive of the debate surrounding the fit of RIASEC model-data fit (see Holland & Gottfredson, 1992). His point that interest structure is a part of a larger theory of matching people and environments is well taken. Nevertheless, it is worth questioning the merits of a system that provides a clear separation between types for some groups, providing excellent coverage of the circumplex structure of interests, but appears to provide a less effective separation between types for other groups and questionable coverage of the circumplex structure of interests. The finding that interest structure is invariant at the item level (Day & Rounds, 1998) suggests that it should also be possible to produce interest scales with an invariant structure. Although the interest measures analyzed here fit a quasi-circumplex model, this does not ensure an invariant structure, and the fit to circulant model with these measures could be improved. Perhaps it is time to explore the potential for developing interest measures that offer a more consistent fit to a circulant model across racial–ethnic groups.

The development of an alternative set of scales would allow for the creation of new clusters of interest items that minimize group differences in the fit to an equal-distances circumplex model. For example, Tracey and Rounds (1995) demonstrated that a set of eight interest scales was an effective alternative to Holland's (1959, 1997) six scales for representing the circumplex model of interests (see also Tracey, Watanabe, & Schneider, 1997). An alternative to developing new scales would be the revision of current Holland-based interest measures, with the goal of minimizing group differences in circulant model fit. There is already some precedent for the use of bias-reducing criteria in the development of interest measures, as demonstrated by the development of UNIACT (see Swaney, 1995). If it is possible to develop an interest measure with reduced gender bias through the use of bias-reducing item and scale construction criteria, then it should also be possible to develop an interest measure with reduced racial–ethnic group bias through the implementation of appropriate criteria (see Einarsdottir, 2001). CUS provides a new method for evaluating the circumplex structure of interest scales that may facilitate the process of developing new measures or refining current measures to reduce racial–ethnic group bias in interest measurement and improving structural validity.

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