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Wijnand A. P. van Tilburg

King’s College London

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Wijnand A. P. van Tilburg, Department of Psychology, King’s College London; London, United Kingdom.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. The author declares that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. This research was inspired by a discussion led by Neil deGrasse Tyson on StarTalk Radio; https://www.startalkradio.net/). I thank Michael Aitken Deakin for his helpful feedback on an initial draft of this paper.

Abstract

Personality, and many other psychological constructs, are assumed to be distributed along multiple dimensions. The current research demonstrates an intriguing implication that these multidimensional distributions hold: as dimensionality increases, people are located progressively further away from the average. In other words, multivariate models of personality render people to be rather ‘unusual.’ I review the geometric and statistical basis for this phenomenon and then illustrate its occurrence in real life using large, open-source personality data. This research offers a fresh perspective on the behavior of multivariate distributions for those who are interested in personality, psychological testing, or enjoy a lighthearted (but substantial) take on statistics.

Keywords: personality; multivariate distribution; multidimensionality; Big-5; 16PF

It's not Unusual to be Unusual

(Or: A Different Take on Multivariate Distributions of Personality)

One of the great frustrations of travelers who navigate on a fold-out map is that one seems to find oneself always at the edges of the page, requiring an inconvenient refolding to once again locate oneself near the center. This is no coincidence: the majority of points on a square map are nearer to the edge than to the center of the map. Specifically, for a square map with side length l and surface l^2, the central square (side length ½l), which is the region in which points are closer to the center than to the border, covers an area sized merely $0.25l^2$. The remaining $0.75l^2$ represents an outer region in which all points are closer to the map edge than to the center. It follows that three times as many locations on a square map are closer to the edge than to the center of the map, much to our traveler's despair. This manuscript illustrates that, in charting personality, a similar (but not identical) rationale will cause many people to be unusual.

Before I explain how the above example is a reasonable analogy for understanding why it is not unusual to be unusual, I will initially carry the example somewhat further: Imagine that, instead of a square map with length and width, we consider instead a map that has also height; a cube shaped-map of, let's say, a particular area in our universe. Our now interstellar traveler will find herself disproportionally often to be closer to a map side than to the center. In fact, while a random point was three in four times as likely to be closer to the edge than to the center for the square map, these odds increase to seven out of eight times ($0.875l^3$ over $0.125l^3$) for our cube-shaped map (Figure 1). Formally, the odds for any random point of being closer to the edge than to the center can be expressed as:

$$\frac{l^k - (0.5l)^k}{(0.5l)^k}$$

With k representing the number of map dimensions, and revealing an exponential increase in the odds of being closer to the edge as dimensions increase from square to cube, to tesseract, and to further hypercubes (Figure 2).

Navigating Personality Space

What does the above have to do with personality and ‘unusualness?’ First of all, personality follows a multidimensional structure, and an important goal of psychological science in general, and personality psychology in particular, has been the charting of these dimensions. Over the decades psychologists such as Allport (1937), Cattell (1943), and Eysenck (1952/2013) have proposed, tested, and validated informative ways to describe people’s personalities. A popular, though by no means sole, example is the five factor (‘Big-5’) model of personality (e.g., McCrea & Costa, 1987), which proposes five such personality dimensions—extraversion, agreeableness, neuroticism, conscientiousness, and openness to experience—that predict important psychological, social, behavioral, and health outcomes (e.g., Costa & McCrae, 1992; Prinzie, Stams, Deković, Reijntjes, & Belsky, 2009; Zillig, Hemenover, & Dienstbier, 2002). A more complex model is that of Cattell (1956), which proposes 16 more or less independent personality dimensions (16PF), including reserved/warm, relaxed/tense, trusting/vigilant and many others. While the current paper does not need to restrict itself to any particular model of personality (or solely to personality, for that matter), I will focus on the Big-5 model given its popularity (McCrae & John, 1992), and considerable (though not complete) cross-cultural consistency (Allik, 2002; McCrae & Costa, 1997). I complement this with a focus on the 16PF model which, while its psychometric integrity is debatable (Saville & Blinkhorn, 1981; cf. Cattell, 1982), offers a helpfully illustrative multidimensional structure.

Just as dimensional coordinates on a two-dimensional navigation map identify a specific physical location, scores on a pair of personality dimensions (say, extroversion and agreeableness of the Big-5) identify a specific personality profile. If one were to assume that locations on either personality dimension were uniformly distributed across some finite range with length l then, as for the squares and (hyper)cubes in the starting examples, most people would have a personality profile that is closer to a limit of this range than to its center. Thus, most people would be more similar to some extreme personality profile (a boundary of the dimensional model) then to the average personality; does this mean that most people are indeed unusual?

Unfortunately, different from locations on geographic maps, it is incorrect to assume that personality features are uniformly distributed across a finite range, or that these personality dimensions are entirely orthogonal (e.g., East-West is at right angles of North-South, but personalities distributed along extraversion-introversion may not be independent of their distribution along agreeableness-disagreeableness). Personality measures are defined to reflect traits on an approximate normal distribution (e.g., Nettle, 2006), with most people being located near the population average and progressively fewer people further away from this average on any single dimension.[1] Hence, this is where the analogy with the squares and (hyper)cubes breaks down: multidimensional personality models do not theorize a uniform distribution of personality features across a finite range but instead assume a multivariate normal distribution with a theoretical infinite range for each of its possibly correlated dimensions.

The first challenge is that, in the absence of a well-defined range to the personality dimensions, if becomes necessary to offer a more accurate definition of being 'unusual'; after all, it does no longer suffice to describe unusualness as being closer to the 'edge' than to the center. Instead, the *degree* of unusualness of a specific personality profile can be described as how far it is located from all other possible profiles in the dimensional model. For univariate and multivariate normal distributions, this definition assigns the least unusualness to the position that corresponds to the median and mean on all dimensions—the centroid. Unusualness can then be quantified by the Euclidean distance between a particular location and the (multidimensional) centroid (Figure 3).

The second challenge is that personality is not uniformly distributed. Rather, its probability density function is assumed to follow a multivariate normal distribution. The third challenge is that these dimensions may be correlated. For example, people who score high on one dimension may also be likely to score high on another one. Indeed, research shows that small correlations can occur between the personality dimensions (e.g., McCrae et al., 2005).

[1] Statistical distributions, such as the normal distribution, may span from negative to positive infinity. However, conceptually one might of course assume that there is some limit to the presence of a particular personality trait (e.g., *entirely* introverted to *entirely* extroverted) and operationalizations of personality feature a finite range (McCrae, Costa, & Martin, 2005).

Unusual Encounters in Personality Space

Given the differences between squares and (hyper)cubes on the one hand, and the multivariate normal distribution of personality on the other, could it still be that people are often rather 'unusual', and increasingly so if we consider models of higher dimension? Consider first a unidimensional model. In a normally distributed population, we can express 'unusualness' as the absolute distance, in standard deviations (*SD*), between an individual's personality score and the population mean (a *z*-score). To illustrate, Figure 3 represents a two-dimensional model of personality with extraversion and neuroticism. A hypothetical person, George, scores 1.81 standard deviations below mean extraversion in the population and 0.85 standard deviations above the neuroticism mean. Yet, when considering these dimensions in tandem, George is 2 standard deviations removed from the (two-dimensional) centroid ($\sqrt{1.81^2 + 0.85^2} = 2$).

How common (or, indeed, unusual) is it to be some distance removed from the unidimensional extraversion mean versus the two-dimensional extraversion × neuroticism centroid? The probability density functions corresponding to these *absolute* distances from the mean/centroids follow a χ^2-distribution (Wilson & Hilferty, 1931), where distance in *SD* is first squared (e.g., $\chi^2 = 1^2$) and number of dimensions (e.g., $k = 1$) represent degrees of freedom. For example, in the unidimensional personality space (e.g., just extraversion) there is a 68.3% chance of a random individual to be no further than 1 *SD* from the centroid ($p[\chi_1^2 \leq 1^2] = .683$); the odds of a random person to be less than 1 *SD* 'unusual' are roughly 2:1. Now consider what happens when moving into two-dimensional space (i.e. $k = 2$). In this case, the chance that a random individual is located within a 1 *SD* circle around the centroid drops to 39.3% ($p[\chi_2^2 \leq 1^2] = .393$); the odds become roughly 2:5. This phenomenon continues for higher-dimension models, with probabilities of 19.8% for three dimensions ($p[\chi_3^2 \leq 1^2] = .198$), 9.0% for a four-dimensional model ($p[\chi_4^2 \leq 1^2] = .198$), and so forth. With 16 dimensions, as per the 16PF model, the odds of a random individual to be located within the 16-dimensional sphere around the centroid of radius 1 *SD* becomes 1:16,077,969; less than 500 people in the entire world, or roughly one person of the entire population of the

Netherlands.[2] Figure 4 illustrates this phenomenon for distances around the mean of 1 *SD* and 2 *SD*, and shows that people become progressively more unusual when the number of dimensions under consideration increases, even if all dimensions are correlated with as much as, $\rho = .50$.[3]

An Empirical Test

The above sections suggest the existence of a counter-intuitive statistical phenomenon: as the number of dimensions of personality that we consider increases, there will be more and more people with an ‘unusual’ personality profile. Does this phenomenon hold-up in the real world? I investigated whether it did using large and anonymous samples of Big-5 personality scores (*N* = 19,719) and 16PF scores (*N* = 49,159) from the Open Source Psychometrics Project (https://openpsychometrics.org/). These data were collected online using 50 self-report items from Goldberg’s (1992) Big-5 measure (e.g., “I don't talk a lot”; 1 = *disagree*, 5 = *agree*), and using 163 self-report items from Cattell’s 16 Personality Factors test (1956; e.g., “I know how to comfort others”; 1 = *disagree*, 5 = *strongly disagree*). These tests were administered independently, though participants were not prohibited for taking part in both.

Scores on each of the 5 or 16 personality factors were standardized. Next, I computed absolute ‘unusualness’ scores (*L*) for the first 1 to all 5 dimensions of the Big-5, and for the first 1 to all 16 dimensions of the 16PF (in *SD*). Table 1 shows the specific personality variables that each dimension represented. These unusualness scores were computed using the multidimensional Pythagoras Theorem (e.g., Alvarez, 1997):

$$L = \sqrt{\sum_{j=1}^{k} l_j^2}$$

Here, unusualness score *L* represents the absolute distance between a point and the centroid in *k*-dimensional personality space on the basis of unidimensional distances l_j between a

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[2] And *this* person might have left to work at [Author’s Institution].

[3] Results for correlated dimensions were estimated using simulations featuring 1,000,000 individual profiles following a (multivariate) standard normal distribution with variances of 1 and covariances equal to 0.5.

particular point on dimension *j* and that dimension's mean. For example, in the two dimensional model of Figure 3, the two-dimensional unusualness score is: $L = \sqrt{(1.81^2 + 0.85^2)} = 2$ *SD*.

Figure 5 displays the predicted and observed proportions of individuals who possess personality profiles in excess of $L = 1$ *SD*, and $L = 2$ *SD* from the mean. In this graph, the predicted proportions follow the χ^2 probability density distributions mentioned earlier, assuming orthogonal dimensions (Figure 4). The observed proportions in Figure 5 reflect the percentiles scores for $L = 1$ *SD*, and $L = 2$ *SD* in the data. Clearly, the predicted and observed trends are highly similar: as dimensionality increases, a progressively larger proportion of people have personality scores more than 1 or 2 standard deviations from the mean; which indicates that the difference between their and others' personality profiles increases with the amount of dimensions added. Note that some deviations between predicted and observed values likely stem from a combination of non-zero correlations between dimensions in the observed data and small deviations from normality in the sample. Nevertheless, predicted and observed patterns converged to a considerable degree (Big-5: $r_{1SD} = .996$, $r_{2SD} = .999$; 16PF: $r_{1SD} = .997$, $r_{2SD} = .998$). As dimensionality grows, people 'become' progressively more unusual.

The same phenomenon is illustrated differently in Figure 6. Here, the average 'unusualness' for models with increasing dimensions is illustrated by placing corresponding scores on each personality dimension. For example, in the two-dimensional Big-5 model, the average 'unusualness' in the sample equaled 1.27 *SD*. This corresponds to a score of 0.90 *SD* on each one of the two dimensions in question (extraversion & neuroticism; $1.27^2 = \sum_{j=1}^{2} 0.90_j^2$). Likewise, the average observed 'unusualness' in the 11-dimensional 16PF model (3.92 *SD*) corresponds to an approximate score of 1.18 *SD* on each of these 11 dimensions ($3.92^2 = \sum_{j=1}^{11} 1.18_j^2$). As dimensions increase, the average unusualness increases, corresponding to more and more extreme corresponding scores on the individual dimensions. Higher dimensional models render the average (and all other) persons more unusual.

Finally, consider the Kernel Density estimates in Figure 7. These graphs illustrate the estimated proportion of distances to the centroid in the Big-5 and 16PF samples, for progressing more dimensions. These results illustrate that, with increasing dimensional complexity, the distances between participants and the centroid increases. With distance to the centroid as measure of 'unusualness', these results illustrate that being 'unusual' (i.e. being at a remote location from the centroid, and thus having a very different personality profile than other participants, expressed in *SD* difference) becomes more and more the norm. Simultaneously, the proportion of people close to the centroid—those with personality profiles that are (literally) pretty average—become smaller as dimensions increase. Hardly anybody remains 'usual.'

Discussion

This research demonstrates that when the dimensions along which personality is characterized increases, then people's personality profiles become increasingly further removed from the mean (centroid). This means that, as more dimensions are added, people's personality profiles tend to differ more and more. This results in the counter-intuitive phenomenon that upon examining more personality features, people become more likely to be rather unusual; the difference between their own and others' personality profiles increases. After reviewing the statistical basis for this phenomenon, I illustrated that this occurred in actual personality data from large, open-source samples. It turns out that, when examining sufficient dimensions of personality, it is probably not unusual to be unusual.

In the case of uncorrelated dimensions, people tend to become more 'unusual' as the number of dimensions increases. But what happens if dimensions are instead correlated? The same 'unusualness' phenomenon occurs, albeit that this increase in 'unusualness' with more dimensions is somewhat slower; it required a larger number of correlated dimensions than uncorrelated dimensions to render someone equally 'unusual.' Note, however, that only when dimensions are very strongly correlated does this seem to make a substantial impact on the 'uniqueness' effect of adding more dimensions (e.g., $|\rho| = 0.50$; Figure 4). In models of personality the correlations between dimensions within one model are typically small or moderate in size instead (McCrae et al., 2005).

What are the implications of these findings, and what practical use might they have? The results seem relevant to areas in psychology where evaluations are based on characteristics that might be distributed along more or fewer dimensions, whether in context of personality or not. Consider, for example, social comparison processes, where people evaluate themselves against others on one or more dimensions (e.g., Suls, Martin, & Wheeler, 2002). One could expect that as the number of comparison dimensions (or the number of attributes on the basis of which the comparison is made) increases, then the difference between oneself and the other ought to be perceived as larger, *even* if the differences on any single dimension do not increase. To illustrate, let's say that the current author compares himself upwards with his academic colleague down the hall to assess the difference in academic productivity, on the basis of number of publications (dimension 1) and average impact factor (dimension 2). Let's further assume that the colleague outperforms the current author on each dimension with 1 standard deviation. Jointly using these two comparison dimensions, the performance difference equals $\sqrt{(1^2 + 1^2)} = \sqrt{2}$; the colleague is approximately 1.41 *SD* more productive then me. This difference exceeds either one of the differences on the single dimensions (1 *SD*). The more dimensions I consider, the further I and my colleague will tend to be apart. Thus, upward comparisons might hurt the ego more if multiple dimensions are considered. One might expect accordingly that people who seek to self-enhance through downward comparison (Sedikides & Gregg, 2008) may favor multiple over few comparison dimensions. Following a similar reasoning one could expect that, on your first date, describing yourself on many dimensions (e.g., 16 personality factors) might leave your date with the impression that the two of you are not alike at all, with this perceived dissimilarity subsequently undermining your chances to succeed in a romantic relationship (Klohnen & Luo, 2003).

How might the current multidimensional approach to personality, and in particular the multidimensional distance from the centroid (L) measure (i.e. 'unusualness'), be used in context of personality classification or clinical diagnostics? The multidimensional evaluation of personality profiles (or test scores on distinct dimensions, for that matter) may complement more traditional methods of classification. A notorious challenge in evaluating scores on multiple tests is of course a risk of inflated Type-I error. Usually, some post-hoc correction is (or should be) applied to remedy this issue and to keep the overall family-wise Type-I error at an acceptable level. An appealing aspect of using multidimensional distance scores is that it essentially circumvents the need for Type-I error correction, given that only a single score is evaluated.

Importantly, classifying individuals using their multidimensional distance scores ('unusualness') works differently than using a series of separate (post-hoc corrected) tests. Because the squared multidimensional distance in multivariate normal distributions follow a chi-square distribution, it is essential that this multivariate distance is evaluated as such. Failure to do so might lead to severe miss-classification. For example, if five tests each apply some classification to people who score in excess of 2.56 *SD* below/above the test means—corresponding to 5% of the population (i.e. family-wise $\alpha_f \approx 0.05$)—then applying the same classification criteria of +/-2.56 *SD* for the five-dimensional distance measure would cause one to apply the classification to 26% of the population ($p[\chi^2_5 \geq 2.56^2] = 0.256$), which might well be an overly liberal application of this classification. Instead, the multidimensional distance that corresponds to the 5% population with most extreme scores is approximately 3.32 *SD* ($p[\chi^2_5 \geq 3.33^2] = 0.050$). These estimates illustrate an important point: when using multidimensional distance from the centroid (L)—or 'unusualness'—for classification or diagnostic purposes, then it is essential that corresponding cut-off points and classification boundaries are updated. Not doing so could cause misclassification of individuals into more extreme ranges of the classification spectrum.

I hope that by illustrating the relationship between multivariate dimensionality and unusualness in personality profiles I could bring the reader to appreciate the interesting predictions that can be made solely by relying on statistical patterns. After all, my ‘unusualness’ hypothesis is not based on any relevant theory from psychology, biology, neuroscience or other relevant discipline. Instead, by simply examining the characteristics of a multivariate distribution and geometry, a surprising (and perhaps mildly entertaining) prediction could be made about the nature of personality. By doing so, this paper might contribute to an appreciation of the relevance of statistical artefacts and regularities in understanding psychological phenomena. Perhaps these insights may stimulate further curiosity into how phenomena might stem from the probabilistic nature of psychological variables and samples (see also Fiedler, 2014; Murayama, Pekrun, & Fiedler, 2014).

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Table 1: *Dimensions Used to Compute Distance to the (Multidimensional) Mean.*

Dimension	Big-5 Model	16PF Model
1	Extraversion	Warmth (A)
2	Neuroticism	Reasoning (B)
3	Agreeableness	Emotional stability (C)
4	Conscientiousness	Dominance (D)
5	Openness to experience	Liveliness (E)
6		Rule-conscientiousness (F)
7		Social boldness (G)
8		Sensitivity (H)
9		Vigilance (I)
10		Abstractness (J)
11		Privateness (K)
12		Apprehension (L)
13		Openness to change (M)
14		Self-reliance (N)
15		Perfectionism (O)
16		Tension (P)

Figure 1: *Illustration of Inner and Outer Regions of a Square and a Cube.*

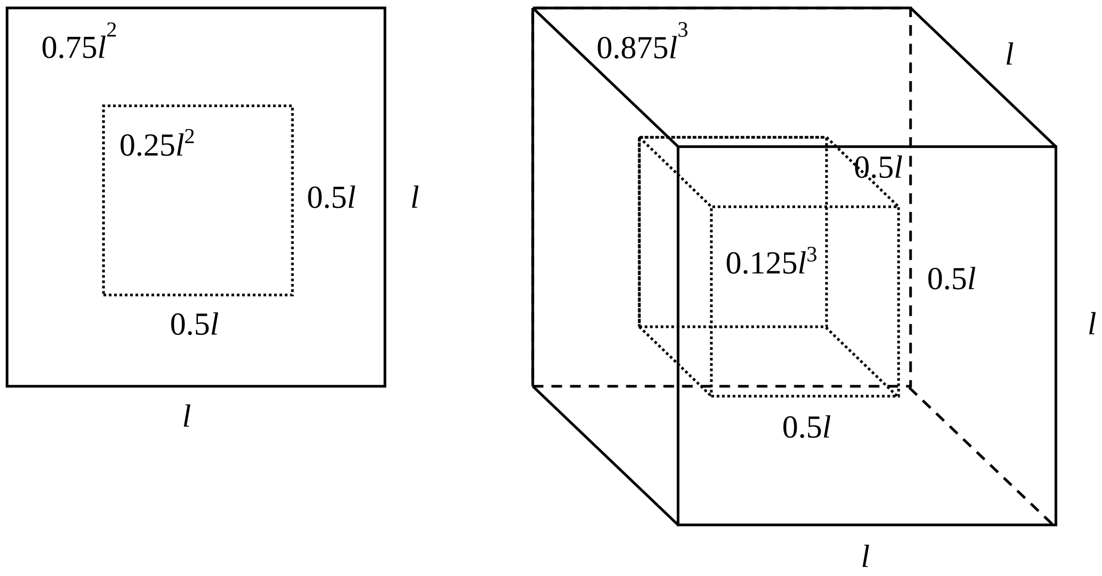


Figure 2: *Odds of Being Closer to the Edge of a Square or (Hyper)Cube.*

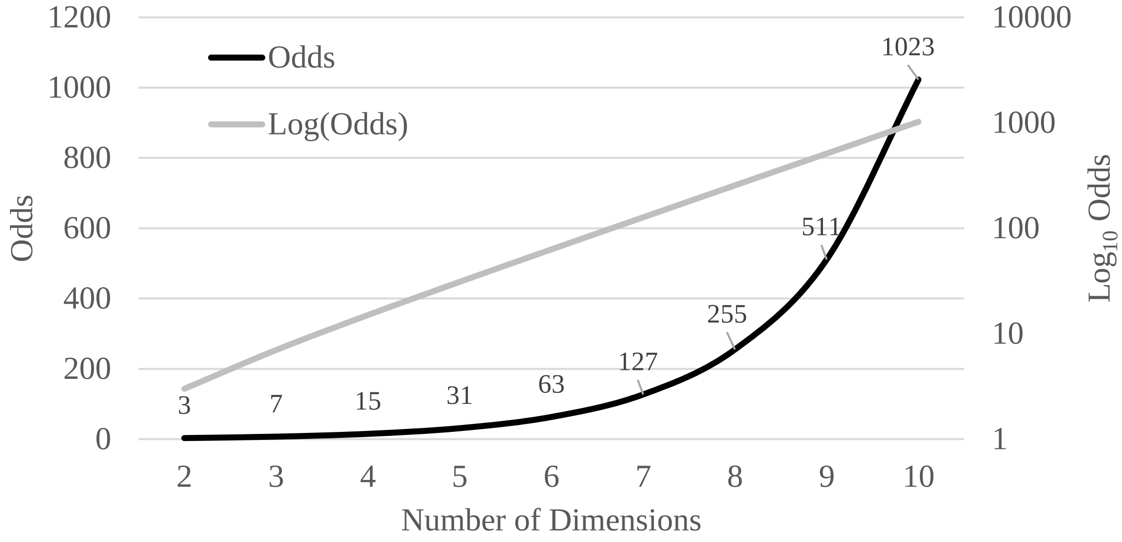


Figure 3: *Illustration of Degree of Unusualness in Two-Dimensional Space*

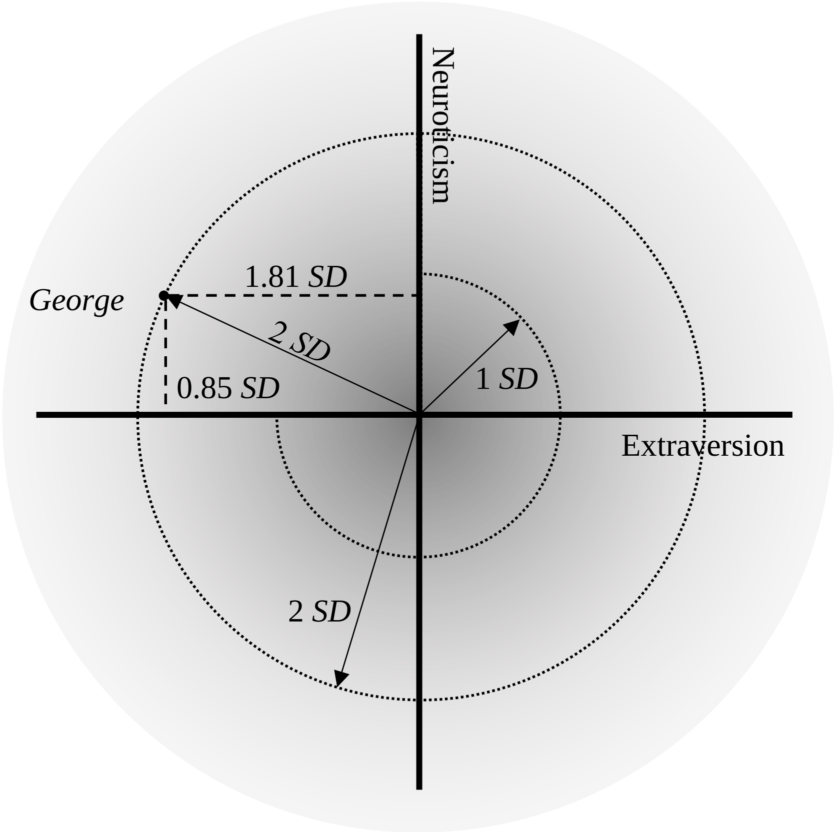


Figure 4: *Proportion of Population with More Unusual Profiles than 1* SD *and 2* SD *as Dimensions Increase.*

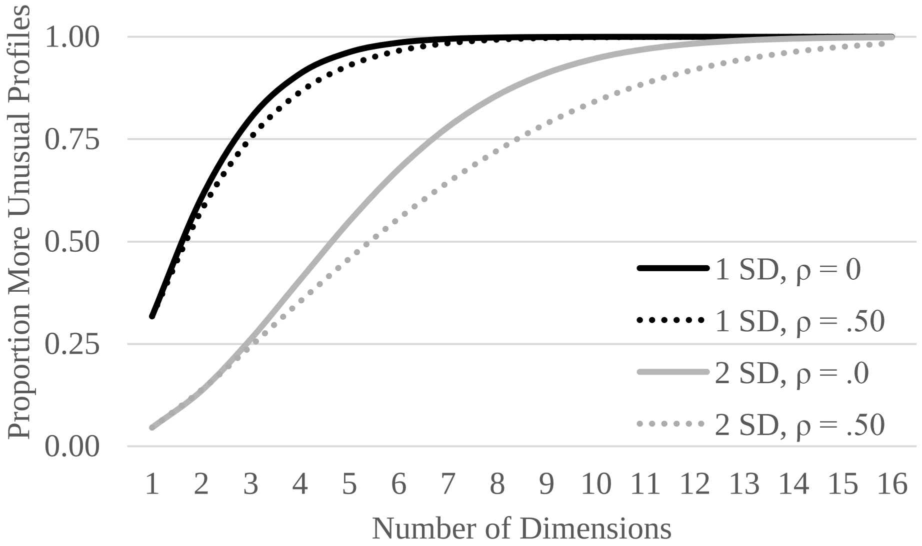


Figure 5: *Predicted and Observed Proportions with more Unusual Profiles than 1* SD *and 2* SD *on the Big-5 and 16PF Models of Personality.*

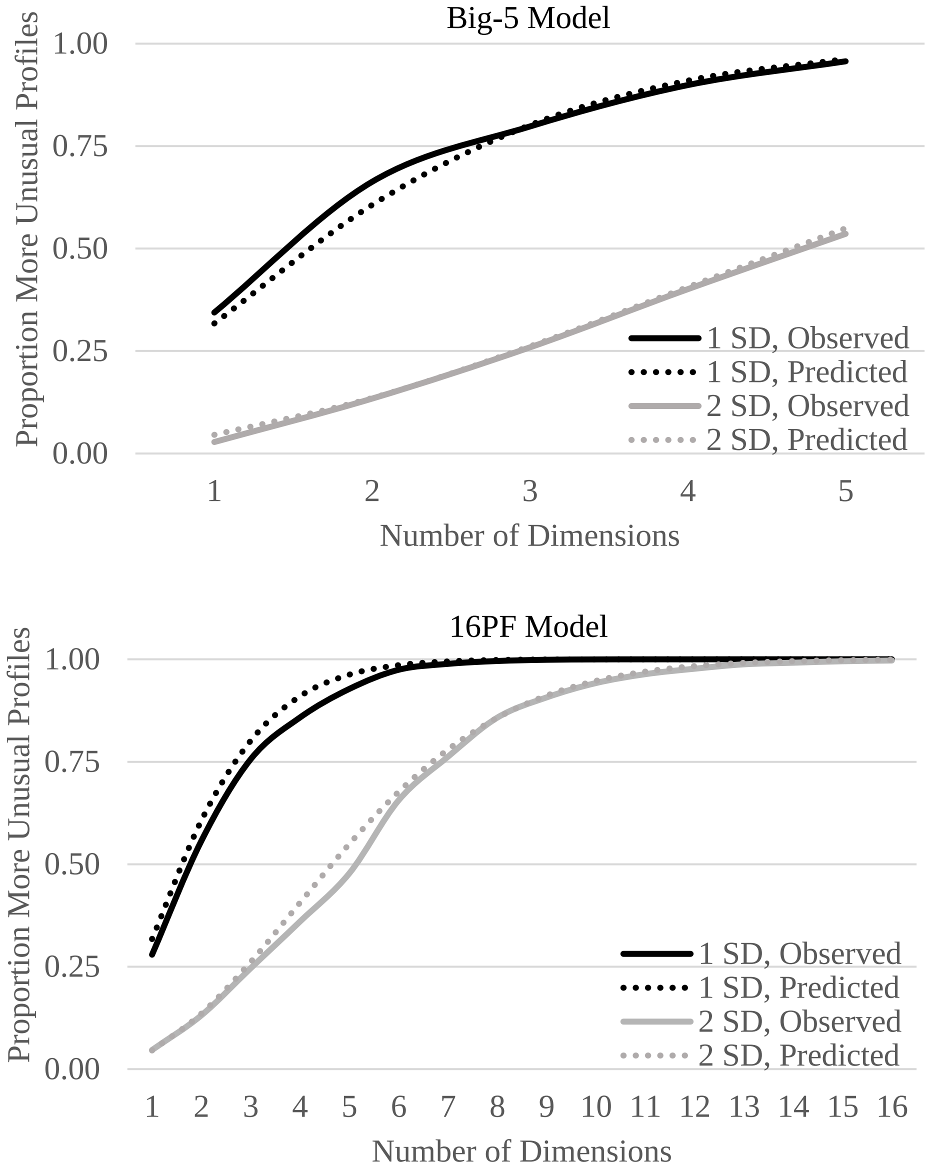
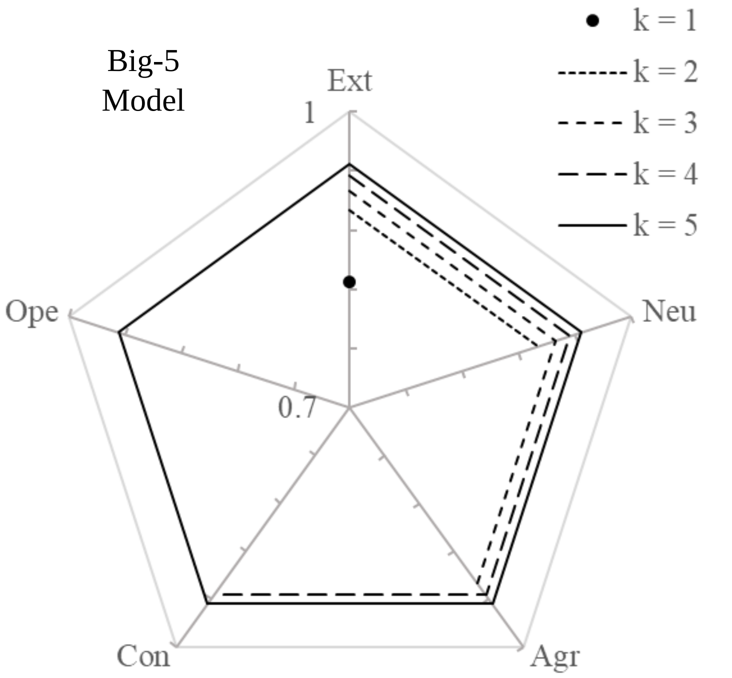


Figure 6: *Average Unusualness with Increasing Dimensionality for the Big-5 and 16PF Models of Personality.*



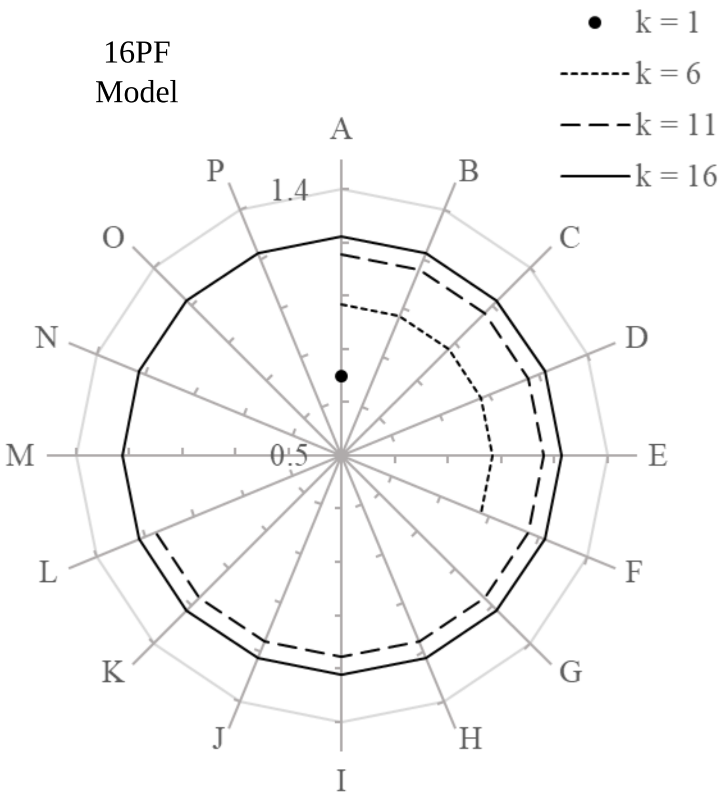


Figure 7: *Kernel Density Plots for the Big-5 and 16PF Models of Personality*.