Methodological appendix

In the Methodological appendix, we explain in more details the three variations of KR triadic measures used in the analysis. As mentioned in the main article, the purpose of designing these measures was twofold: i) to apply triadic analysis to ties between alters only, excluding the ego; and ii) to enhance the differentiation between networks of the same size. However, it should be noted that the following measures are equally adequate for triadic analysis that includes ego, and for ego-networks that differ in size.

Three versions of KR triads

Table I presents descriptive analysis of two global measures (density and transitivity) and other measures related with triadic closure.

Table I.

Descriptive measures related with triadic closure and KR triads

	Mean	*S.D.*	*Min.*	*Median*	*Max.*	*Skewness*	*Kurtosis*
Density	0,413	0,147	0,146	0,389	0,912	0,896	1,154
Transitivity	0,745	0,104	0,497	0,735	1	0,217	-0,194
Density of Strong Ties	0,144	0,086	0,017	0,134	0,443	1,089	1,221
Density of Weak Ties	0,269	0,119	0,087	0,244	0,779	1,417	3,324
Density of Missing Ties	0,587	0,147	0,088	0,611	0,854	-0,896	1,154
Average tie strength	1,901	0,288	1,275	1,905	2,601	0,024	-0,371
Ratio of All Triads	0,316	0,179	0,041	0,275	0,958	1,214	1,59
Tie Strength of 1 (fq.)	177,5	94,776	37	175	584	1,264	3,139
Tie Strength of 2 (fq.)	84,84	60,431	2	78	374	2,051	7,047
Tie Strength of 3 (fq.)	140,31	85,697	14	130,5	439	1,113	1,31
Proportion of ties of strength 1	0,444	0,158	0,076	0,457	0,788	-0,008	-0,357
Proportion of ties of strength 2	0,211	0,12	0,008	0,203	0,77	1,324	4,235
Proportion of weak ties (strength 1 and 2)	0,655	0,154	0,259	0,664	0,937	-0,316	-0,309
Proportion of strong ties (strength 3)	0,345	0,154	0,063	0,336	0,741	0,316	-0,309

fq. – frequency; S.D. – standard deviation; Min. – minimum score; Max. – maximum score

Operationalization of weak and strong ties – To calculate the percentage of seven triads in an ego-net, a decision about the cut-off value for a strong tie had to be made. We decided to classify all ties with strength value of 3 as strong, in line with the analysis of frequency of all tie values in the whole sample (see table I, the average strength of ties is 1.9), and ties of strength 1 and 2 as weak. Having a lower cut-off score would have resulted in too many strong ties, and hence smaller occurrence of configurations with weak ties (any of triads with letter W in Figure 1 in the main article).

Variant I: Triads as proportions of all possible triads

We started by identifying all unique combinations of three alters in each ego-network (triads of alters *ijk* is the same as *jki* and *kij*). Then, we assigned them a three-letter code according to the strength of the ties among the alters. We proceeded with the count of each of the seven configurations and divided it by the number of all possible unique triads, which was similar for all ego-networks (14190[1]).

[1] This number was not the same for all ego-networks, as it depends on the number of non-isolated alters, that is, the alters that have at least one tie with someone else in ego's network. In our sample of personal networks the number of non-isolated alters was in range of 37 to 45 (*M*=44.5).

Mean values and distributions of seven triads were similar. Triads with weak ties constituted most of the triads, especially weak structural holes (WWN triad), which could be attributed to the method of eliciting the network data that asked for 45 alters. The mean and variance were noticeably smaller for SSW and SSN, showing that weakly closed strong triads (SSW) and open strong triads (SSN, or strong structural holes) were less frequent. Among closed triads, the biggest variation is in the proportion of WWW, with several outliers. In line with the presence of outliers in most of the triads, distributions were mostly skewed. Therefore, in the analysis of the relationship of triadic measures with all other variables, as an alternative to Pearson's coefficient, Spearman's rank coefficient was used, which mitigates the effect of outliers and skewed distributions.

Variant II: Triads as proportions of all existing triads in the ego-net

The basic logic and one of the advantages of the KR census over other network measures was that it represents, not only a count of the different triad types, but rather the proportions of each type against the total number of possible triads given the number of alters in the ego-network: in this way, egocentric networks of different sizes could be compared. However, in our study, the network size, that is, the number of alters, is fixed to 45, meaning that this method will provide the same results as a simple count of the motifs. Since the number of possible triads is methodologically induced, it does not describe the unique property of an ego-net and has no meaningful interpretation. In other words, we don't have information about true network sizes of our participants, which is crucial for a meaningful interpretation of triadic proportions, as defined in KR method. On the other hand, using this calculation would give the same value for an individual with just one triad in his/her ego-net, e.g. SSS, and to an individual with complete ego-net with ties present between all alters, but where only one of those triad is the SSS configuration. We could argue that the meaning and interpretation of SSS triads in those two networks are very different. We wanted to consider the fact that the number of truly possible triads differs between individuals, and one straightforward way to achieve that is to use the information about existing triads in ego-net. Therefore, we decided to normalize the counts of each triad with the number of all present triads (open and closed - the total of all seven configurations) in the individual ego-net. In the previously mentioned example, the first individual would score 1 on SSS triadic measure, while the second individual would score below 0.001.

Variant III: Triads as Z-scores in comparison to individual null model

We recognize that using the number of the existing ties in the ego-net to compare the occurrence of triads in different ego-nets is just one of many possible ways. In fact, we could have used the number of all non-empty triads, some combination of both, etc. The ultimate purpose of not taking just the frequency of each triad in a network as a measure, is the ability to compare triad occurrence among different networks, while controlling for some structural properties. The quantification of the occurrence of specific configurations in a network is frequently done by comparing the occurrence of certain configuration of interest (a motif) in network with the occurrence of the same motif in a null-model (for introduction see Milo et al. 2002), and we propose a way to generalize this approach in the comparison of ego-networks. As a null model, we defined for each ego-net its specific null-model as a random Erdős–Rényi graph (Erdős & Rényi, 1959) with the same density (the number of links in the ego-net) and the same proportion of weak and strong ties as individual's real ego-network. This means that any association of triadic measures of this kind with any attribute will not include the existing association of density and the proportion of weak and strong ties with the same attribute. Subsequently, we made 100 such randomized graphs with the same specifications for each case (individual) and recorded the occurrence of motifs (triads) of interest in each graph. This results in the distribution of values for each triad/motif which is unique for each case/individual. The real number of triads in each ego-network is expressed as a z-score against that distribution: $Z = \frac{(X - M_{rand})}{\sigma_{rand}}$, where X is the number of occurrence of the motif in the real ego-network, M_{rand} is the mean of occurrence of the motif in 100 randomized networks with the same density and proportion of weak and strong ties as in the real individual network, and σ_{rand} is the standard deviation of those occurrences in the sample of 100 randomized networks[2]. The result of this procedure were seven z-values for each ego-net, one for each triad. Low or high z-scores (lower than -2.58, and higher than 2.58, corresponding to p-value of 0.01) indicate that the configuration appears significantly less or significantly more in the real network than it would be expected by chance. This means it represents a motif[3] – an important characteristic of the real network. In other words, the configuration is less or more frequent than in the sample of random graphs which differ with the individual network only in structure. Furthermore, we used the absolute value of a z-score as a proxy of the prominence of a certain motif in the network.

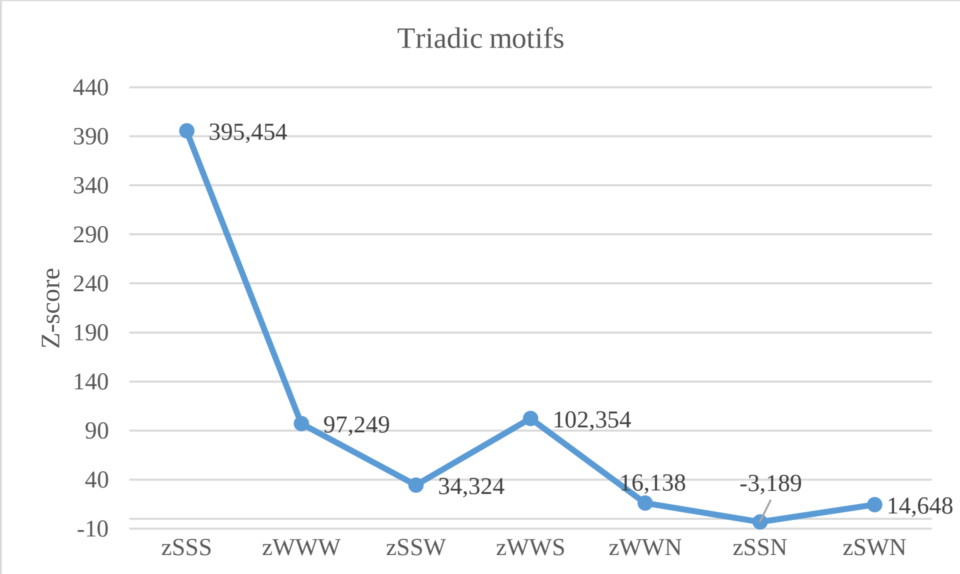

Figure I. Average values of Z cores for real ego-networks in comparison with 100 random networks (tailor-made for each case)

The resulting average z-scores for each triad are shown in Figure I. As can be seen in the figure, on average all motifs are statistically significantly overrepresented in ego-nets, while open strong triad (SSN) is underrepresented. This implies that all closed and open triads are far more (or for one motif, far less) frequent than it would be expected by chance, that is, in a random network with the same density and ties composition. Strong closed triads (SSS) are the most prominent motif. This is expected in real social networks as they are characterized by higher clustering than random networks. The next most prominent motif describes weak structural holes (weak open triads). This implies that even after we control for individual tendencies to assign strong versus weak ties, the finding that WWN is one of most frequent triads persists. The third most prominent motif is WWS, followed by WWW. The strong open triads (so-called forbidden triads) is the least prominent motif, and the only motif that occurs less frequently in real ego-networks than in their corresponding random networks. This is not a surprising finding, as it is well established in the social network research (e.g. Granovetter, 1983) that this configuration is underrepresented in social networks, as it naturally leads to the triadic closure.

In addition to inspection of the specific motifs, we used seven obtained Z-scores for each individual ego-network to try to quantify the "randomness" of a given ego-network. We aimed to express the randomness of an ego-net by calculating the mean of the absolute values of seven scores:

$$(|Zsss| + |Zwww| + |Zssw| + |Zwws| + |Zwwn| + |Zssn| + |Zswn|)/7$$

[2] The distributions of average occurrences of motifs were normally distributed, allowing for the use of z-scores.

[3] The use of the term motif can be slightly confusing, as some research prefer to address certain configuration as a motif only when analysis shows it to be statistically significant. While appreciating this distinction between motif and configurations that some researchers make, we will address all investigated configurations as motifs, and describe them as significant if their occurrence is found to be statistically significant.

The higher score would imply less randomness as it shows that the network differs from a random network to a higher degree; hence the measure is named Non-randomness. However, before averaging the scores, we did the min-max transformation that resulted in the range of values between 0 and 1 since the original z-scores showed to be extremely skewed and had a noticeably different mean.

Relationship of triadic measures with psychological attributes

We have not preformed corrections for multiple testing, as it would lead to a considerate limitation of statistical power. Figures II and III show heatmaps of significant correlations between the two groups of network measures (KR variant II, and KR variant III) and psychological attributes (Big Five personality traits and Sense of Community).

- *KR variant I and its relationship with psychological attributes*

Weakly closed strong (SSW) and open strong triads (SSN) are not related with any of 11 investigated psychological attributes. In the group of personality traits, only Emotional Stability is positively correlated with strong closed triads (SSS), and with the triad with one strong and two weak ties (WWS). Composite measure of Mean TIPI10 is negatively correlated with "mixed" triad (SWN).

- *KR variant II and its relationship with psychological attributes*

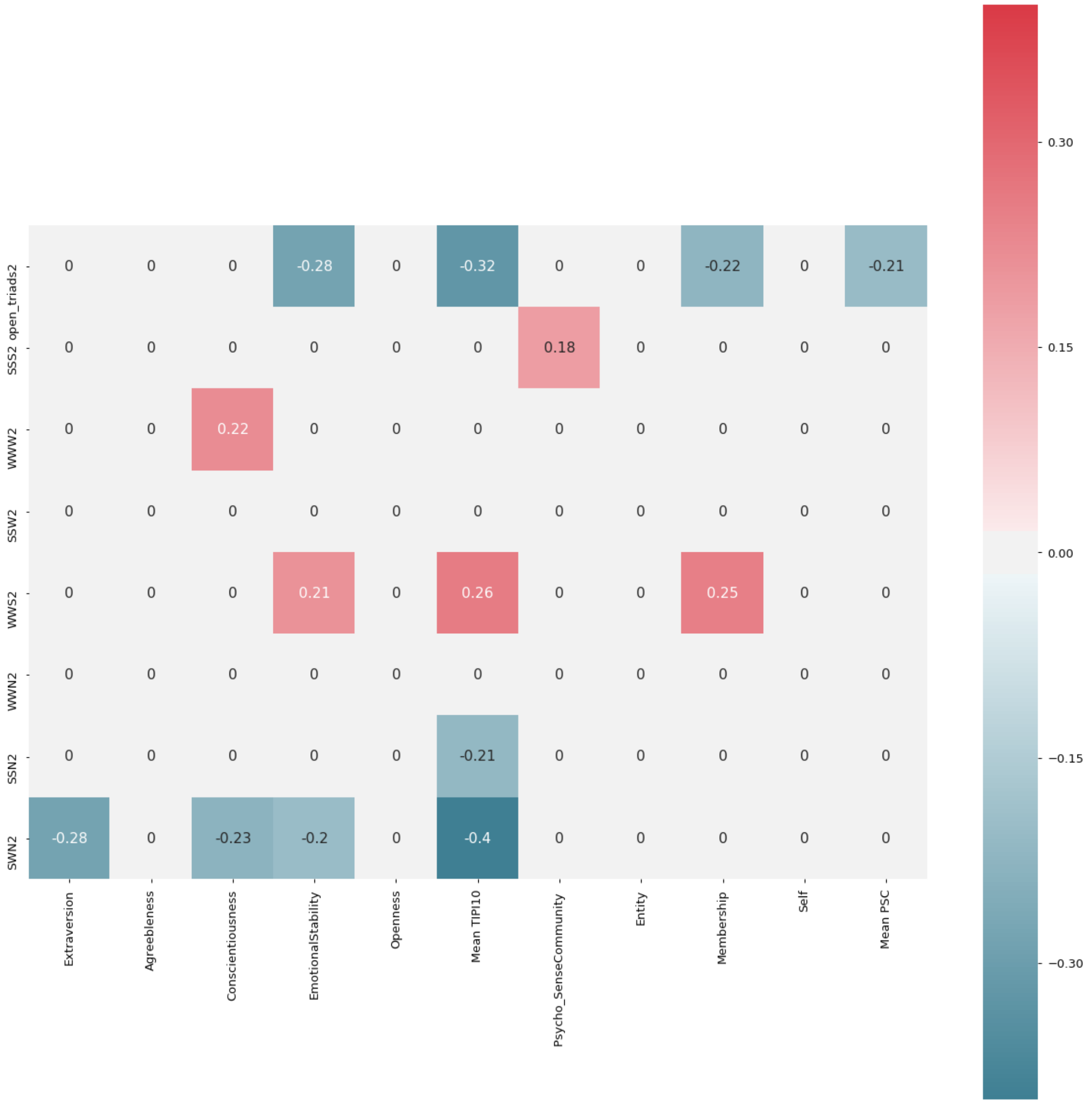

Figure II. Significant correlations between KR variant II measures and psychological attributes (based on 1000 permutations)

In Figure II, correlation coefficients of KR triads of ego's alters as proportions of all existing triads are shown. In comparison with first variant, we can see that significant coefficients are shifted more from Sense of Community variables (right) to the Big Five Personality variables (Figure II, left side). We also found significant relationship between WWW and C, WWS and both Mean TIPI10 and Membership. As with the first variant of triadic measures, we can also see here that all psychological attributes have a similar pattern (direction and strength) of the association with a given triad.

- *KR variant III and its relationship with psychological attributes*

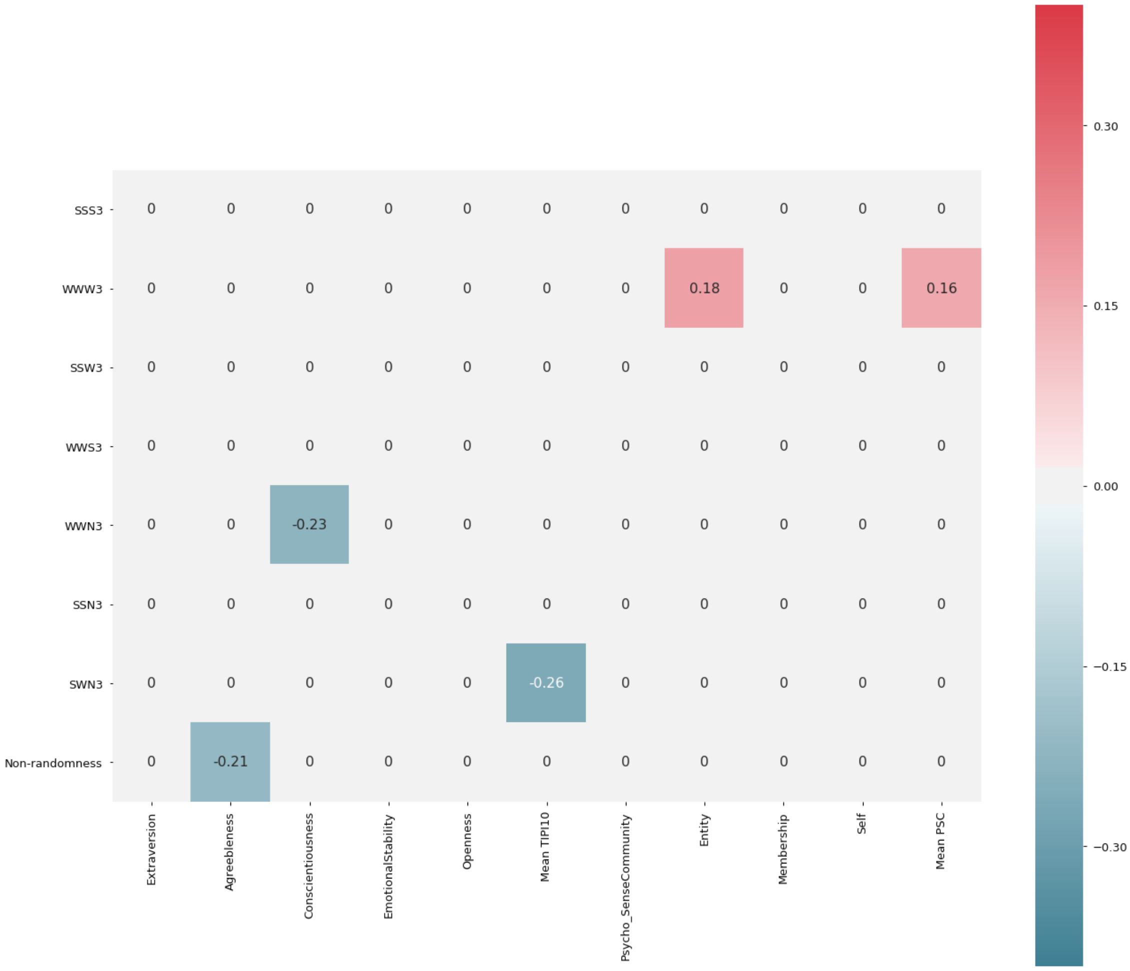

Figure III. Significant correlations between KR variant III measures and psychological attributes (based on 1000 permutations)

The third variant, where we control for the density and individual tendency to assign ties as strong and weak, results in noticeably sparser significant correlations and a clearer picture of two groups of attributes regarding their relation to specific triads. Entity and Mean PSC are positively correlated with WWW configurations.

C is negatively associated with WWN triad, suggesting that individuals with a higher C are less likely to perceive, live in, or report on weak and open triads. Only in this variant of triadic measure, trait A shows any, in this case negative, correlation with a measure derived from triadic configurations – Non-randomness. Non-randomness was constructed in an attempt to capture the relations of psychological attributes with non-random patterns among alters in social network. According to this finding, the more agreeable a person is, the more likely s/he lives in/perceives/reports being surrounded with random network of ties. This may be the result of different mechanisms acting simultaneously: it may be that more agreeable egos are more likely to have alters that are more heterogeneous (less like each other) and therefore less likely to show some systematic clustering; it may be that they are also more tolerant towards non-structured social environment and less likely to induce or force some changes in it. This finding is in accordance with the result showing negative correlation between A and centralization and it is possible that the lack of centralization (an absence of an alter who is directly connected with many other alters – a hub) in ego's network contributes to an apparent higher randomness of alters' ties of more agreeable people. Non-randomness showed no relation with Emotional Stability, indicating that this personality dimension is not related in any way with the degree of randomness in ties between alters.

Reference

Erdős, P., & Rényi, A. (1959). On Random Graphs I. *Publicationes Mathematicae, 6,* 290–297.

Granovetter, M. (1983). The strength of weak ties: A network theory revisited. *Sociological theory*, 201-233.

Milo, R., Shen-Orr, S., Itzkovitz, S., Kashtan, N., Chklovskii, D., & Alon, U. (2002). Network Motifs: Simple Building Blocks of Complex Networks. *Science*, 298, 824-827.

Supplementary Material

To provide more detailed information about the results we present the descriptive and bivariate analyses of variables used in this study. As in the analysis presented in the main text, all correlations are Spearman's rho coefficients, and significance testing is based on the 1000 permutations. If the value of coefficient had a percentile value higher than 97.5 or lower than 2.5, it was considered significant at the level of p =<.05.

Section I: Other network measures

Table 1. *Descriptives of other network measures of ego-nets (N=100)*

	Mean	*S.D.*	*Mdn*	*Min.*	*Max.*	*Skew.*	*Kurt.*
Average Degree	17,90	6,728	16,98	6,44	40,13	0,808	0,888
Average Strength of Tie	1,90	0,288	1,91	1,27	2,60	0,024	-0,371
Average Clustering	0,57	0,081	0,57	0,32	0,79	0,115	0,602
Degree Centralization	0,44	0,134	0,45	0,03	0,72	-0,48	0,218
Weighted Degree Centralization	0,67	0,209	0,63	0,19	1,13	0,129	-0,592
Components	1,78	1,481	1,00	1,00	10,00	3,072	11,822
Cliques	21,34	12,832	20,00	2,00	72,00	1,128	1,811
Constraint (Ego)	0,09	0,004	0,09	0,07	0,10	-0,768	3,553
Effective Size (Ego)	27,10	6,728	28,02	4,87	38,56	-0,808	0,888

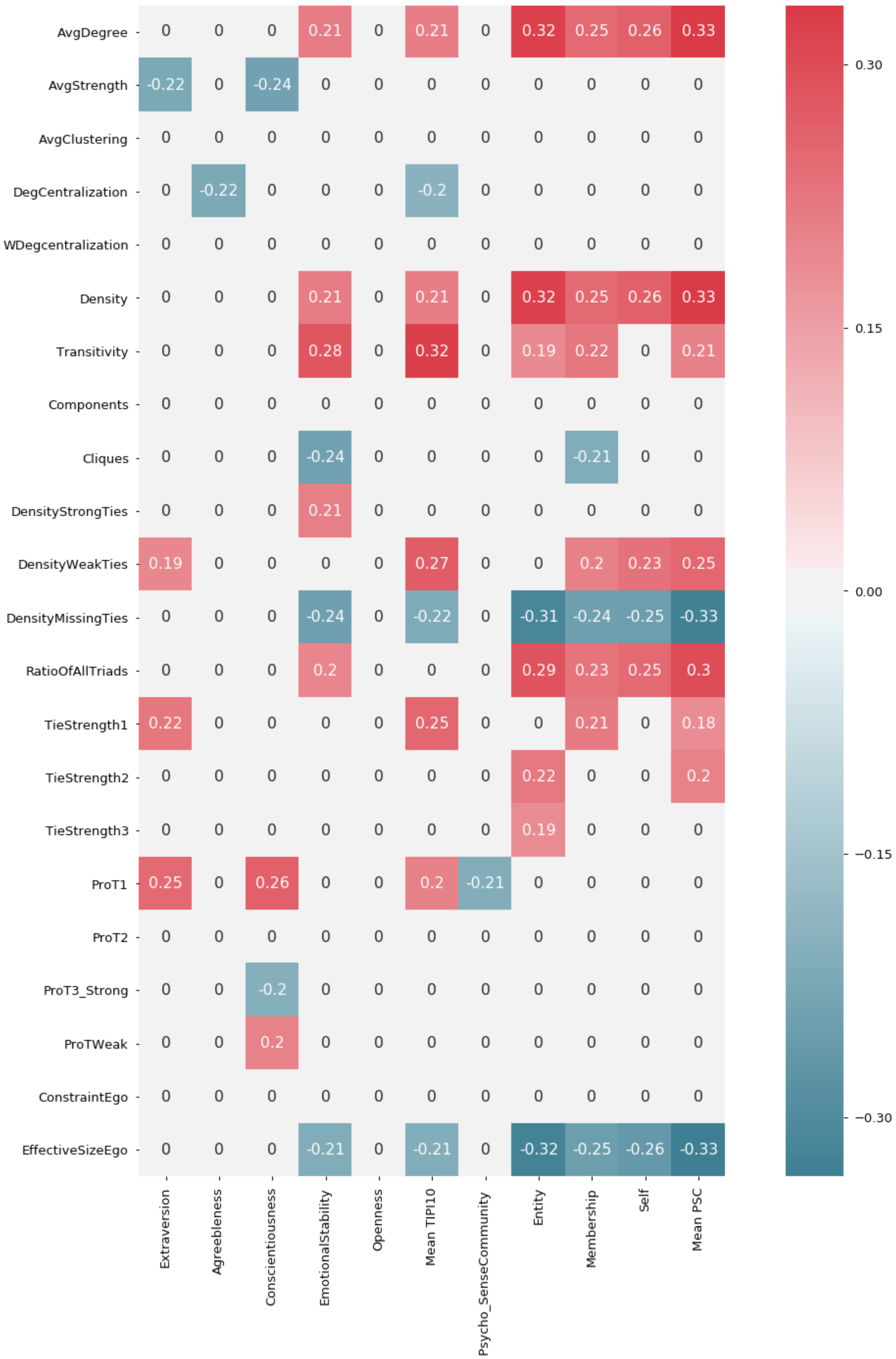

Figure 1. Significant Spearman's correlation coefficients of 22 network variables and psychological attributes

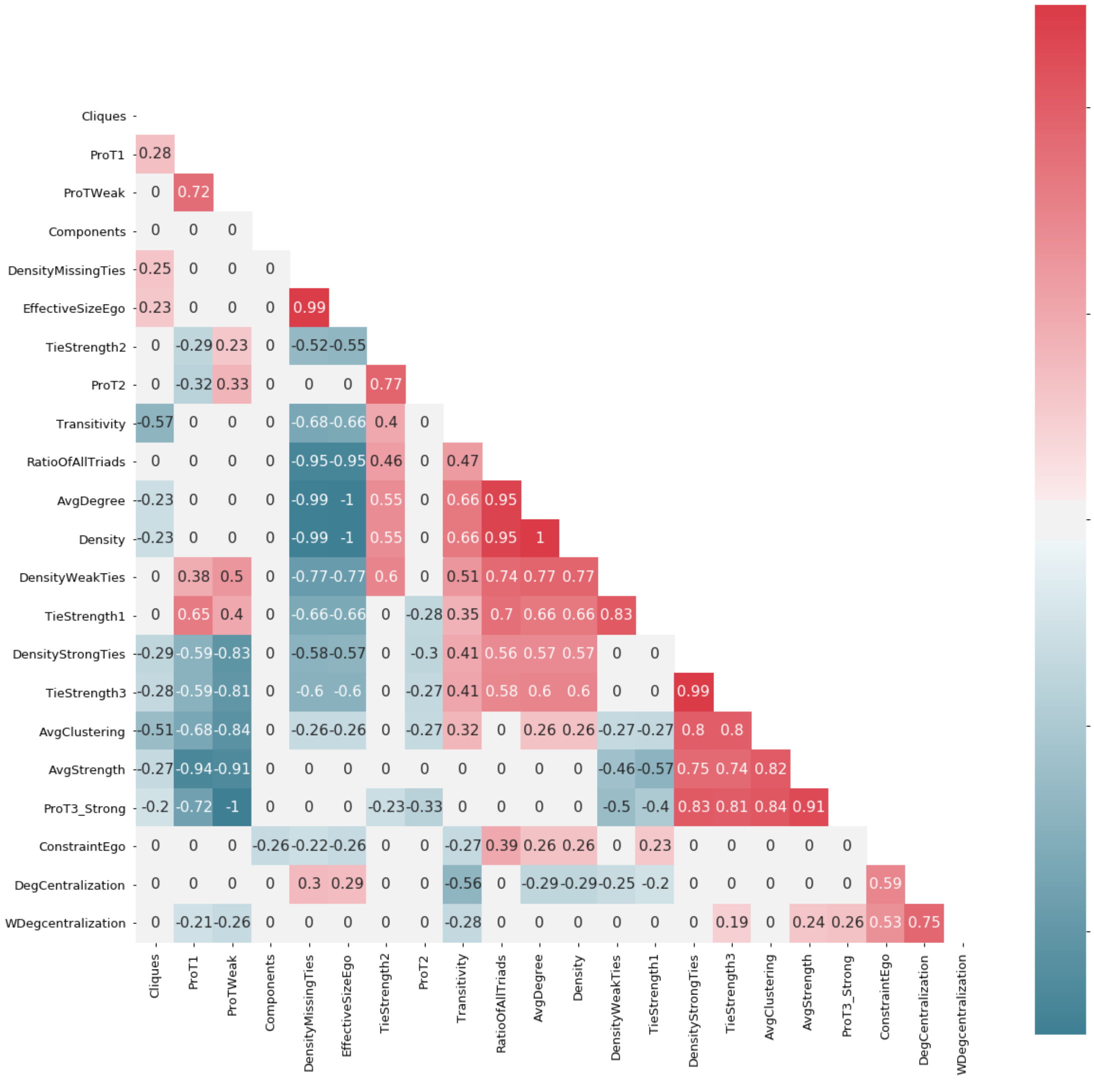

Figure 2. Significant Spearman's correlation coefficients between 22 network measures

Section II: Three variants of KR measure

The KR measures have been calculated in Python. The second author will provide the code for the identification of triads upon request.

Table 2. *Descriptives of KR variant I*

	Mean	*S.D.*	*Mdn*	*Min.*	*Ma.x*	*Skew.*	*Kurt.*
Proportion of no-triads	0,25	0,146	0,242	0	0,617	0,297	-0,448
All triads 1 (proportion)	0,33	0,179	0,275	0,041	0,958	1,214	1,59
Closed triads 1 (proportion)	0,18	0,139	0,142	0,015	0,783	2,029	5,307
Open triads 1 (proportion)	0,14	0,072	0,13	0	0,307	0,516	-0,374
SSS1	0,03	0,042	0,017	0	0,276	3,019	12,241
WWW1	0,05	0,073	0,034	0	0,488	3,617	16,634
SSW1	0,02	0,017	0,009	0	0,096	2,098	5,477
WWS1	0,07	0,063	0,053	0,004	0,334	2,161	5,564
WWN1	0,08	0,053	0,067	0	0,272	1,206	1,583
SSN1	0,01	0,009	0,003	0	0,057	2,814	10,94
SWN1	0,06	0,037	0,049	0	0,178	0,979	0,651

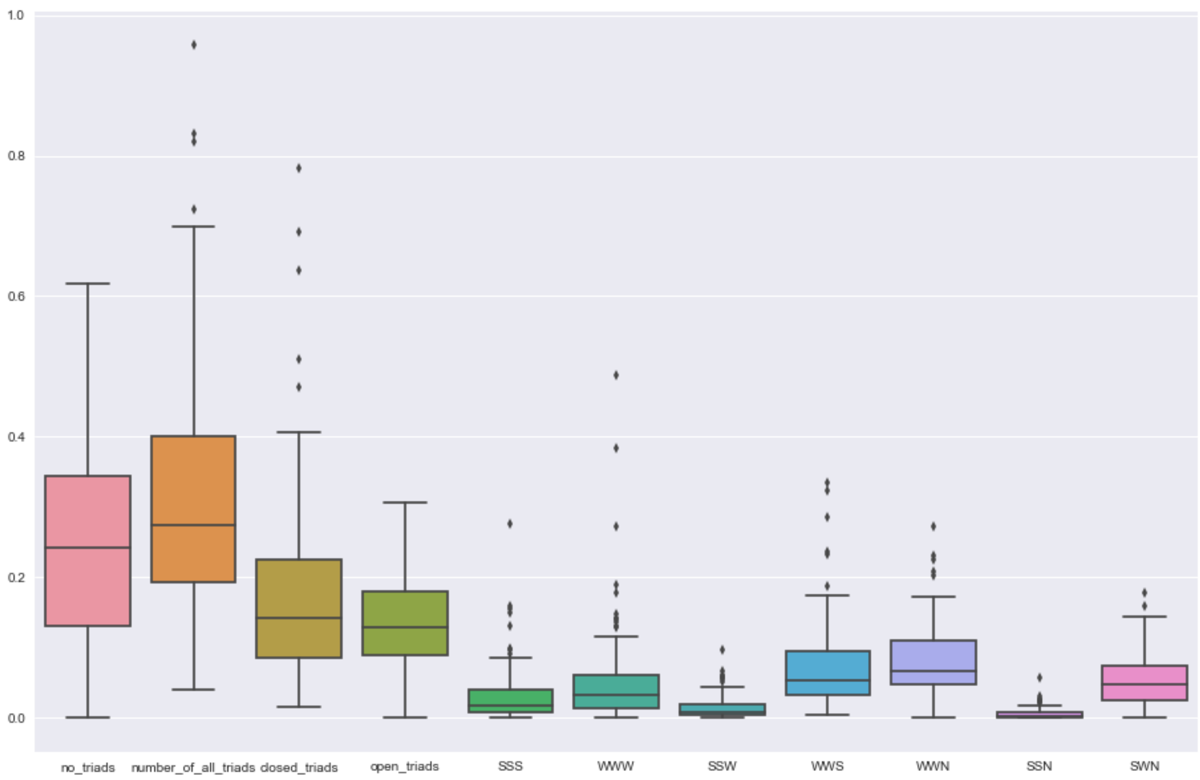

Figure 3. Box plots of KR variant I as proportions of all possible triads in an ego-net

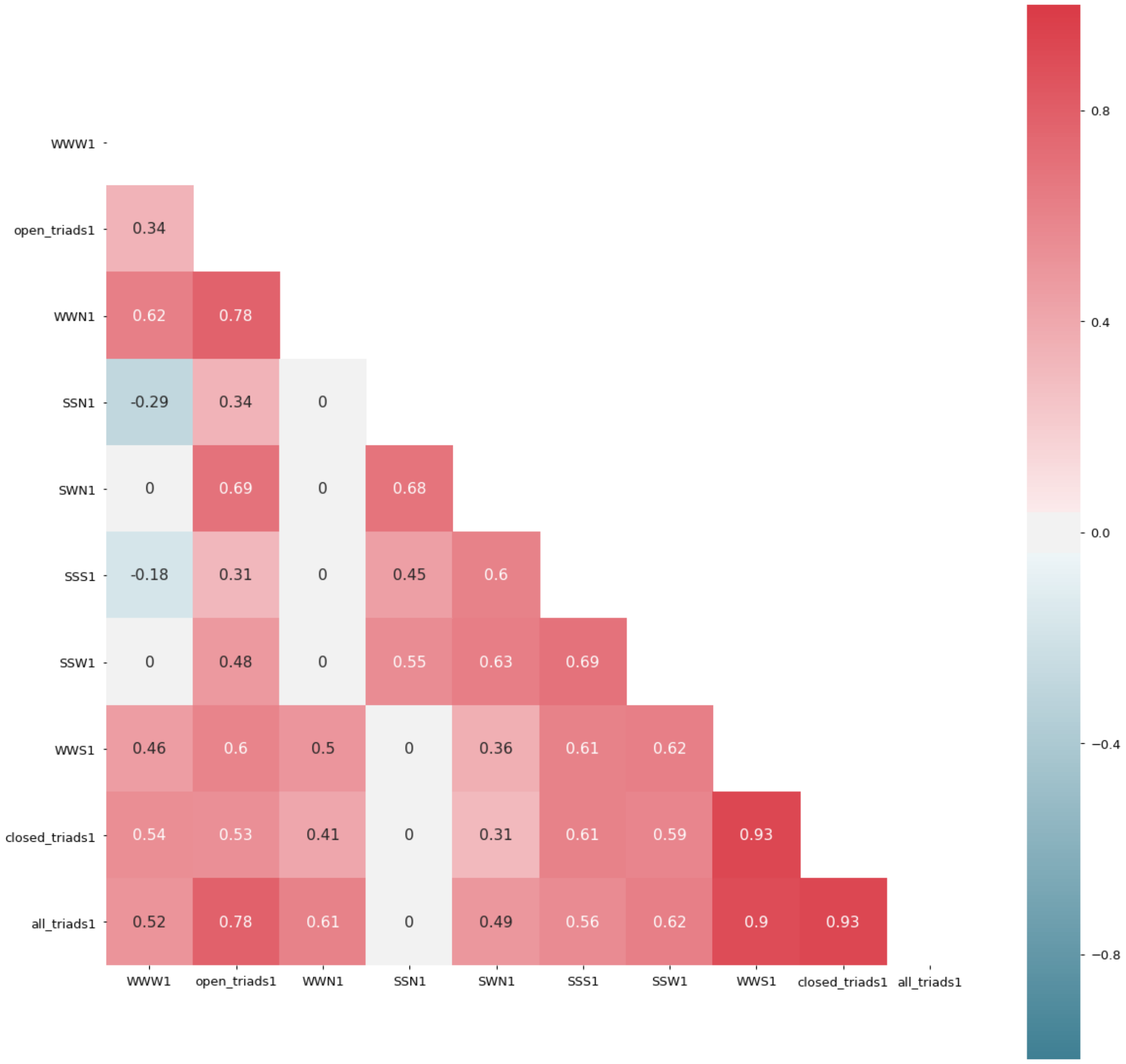

Figure 4. Significant Spearman's correlation coefficients between KR variant I measures

Table 3. *Descriptives of KR variant II*

	Mean	*S.D.*	*Mdn*	*Min.*	*Max.*	*Skew.*	*Kurt.*
Open triads 2	0,49	0,151	0,519	0,000	0,753	-0,991	1,028
SSS2	0,09	0,097	0,071	0,004	0,675	2,917	13,06
WWW2	0,16	0,134	0,131	0,000	0,622	1,521	2,346
SSW2	0,05	0,036	0,040	0,000	0,194	1,155	1,878
WWS2	0,21	0,083	0,196	0,043	0,522	1,222	2,52
WWN2	0,28	0,131	0,276	0,000	0,611	0,213	-0,146
SSN2	0,02	0,028	0,009	0,000	0,114	1,837	2,806
SWN2	0,19	0,099	0,180	0,000	0,434	0,146	-0,811

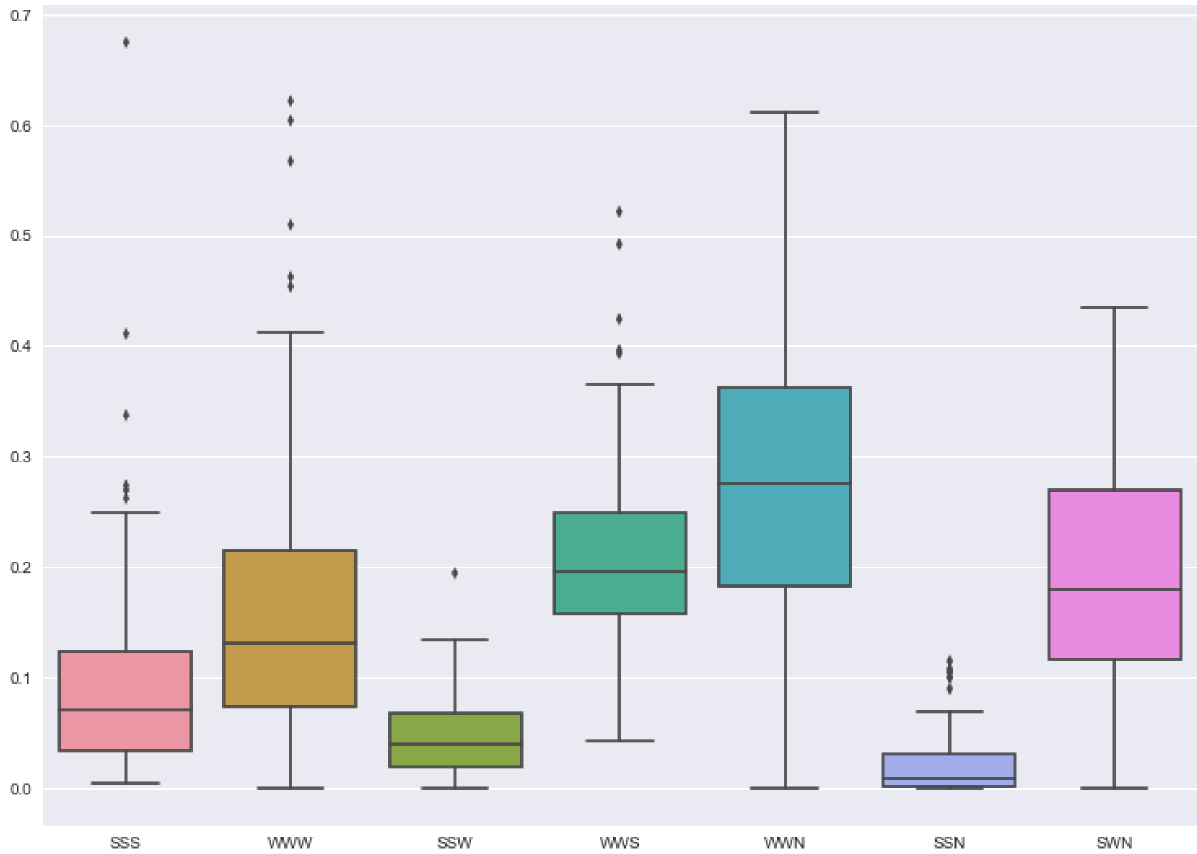

Figure 5. Box plots of KR variant II as proportions of all existing (open and closed) triads in each ego-net

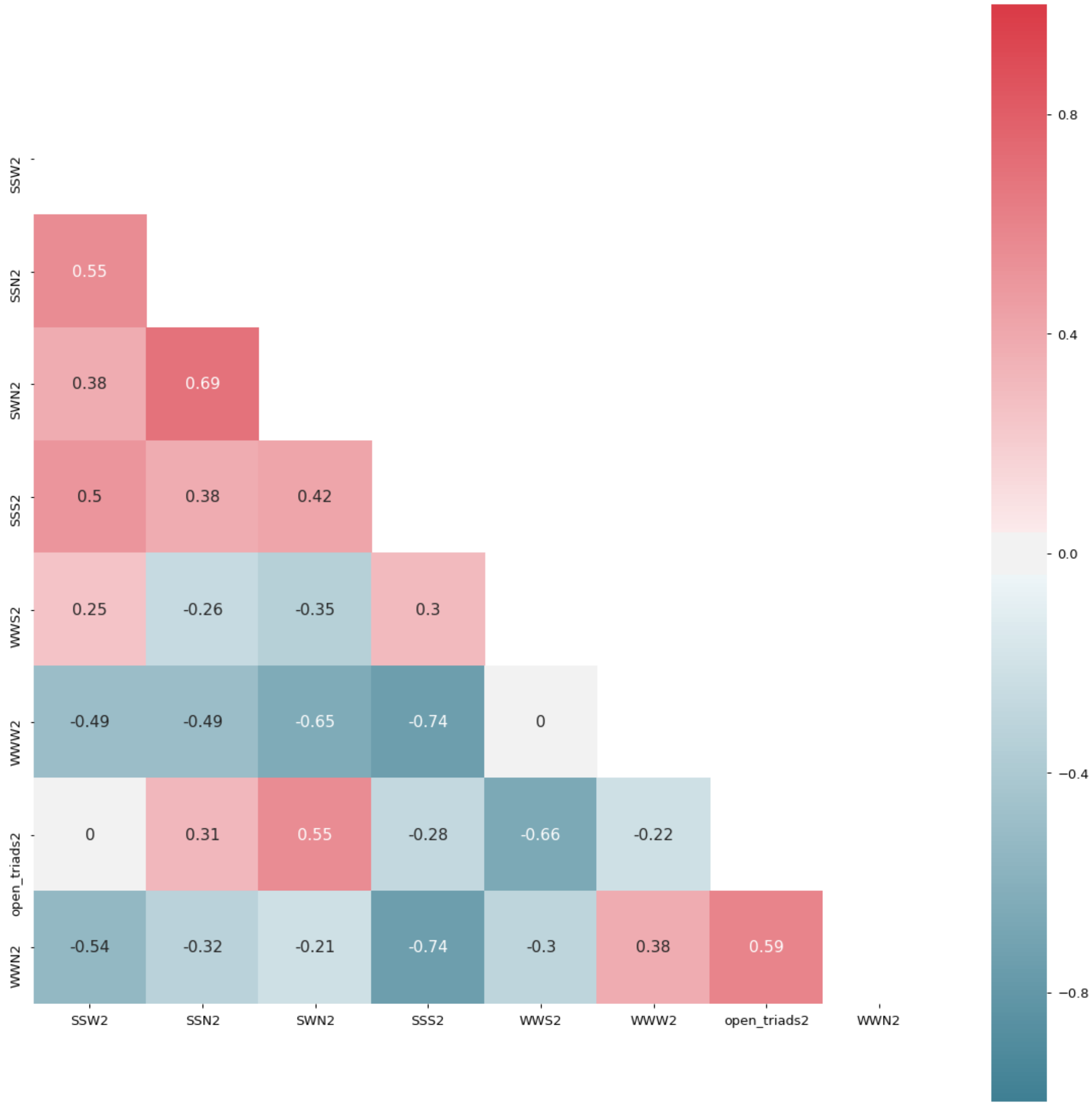

Figure 6. Significant Spearman's correlation coefficients between KR variant II measures

Table 4. *Descriptives of KR variant III*

	Mean	*S.D.*	*Mdn*	*Min.*	*Max.*	*Skew.*	*Kurt.*
SSS3	0,06	0,151	0,02	0	1	5,108	27,047
WWW3	0,04	0,102	0,02	0	1	8,764	81,548
SSW3	0,34	0,210	0,27	0	1	1,443	1,703
WWS3	0,29	0,213	0,24	0	1	1,334	1,543
WWN3	0,48	0,183	0,45	0	1	0,396	0,27
SSN3	0,36	0,118	0,33	0	1	2,334	10,835
SWN3	0,26	0,190	0,20	0	1	1,797	3,726
Non-randomness	0,26	0,106	0,23	0,09	0,71	1,714	4,462

Table 5. *Z scores of seven triadic configurations before and after transformation and Non-randomness values (KR variant III)*

Before transformation	*Mean*	*S.D.*	*Min.*	*Median*	*Max.*	*Skew.*	*Kurt.*
zSSS	395,454	1126,337	-31,997	86,763	7277,48	4,999	25,849
zWWW	97,249	307,204	-8,992	54,201	2988,146	8,764	81,548
zSSW	34,324	45,206	-39,471	18,574	175,841	1,443	1,703
zWWS	102,354	75,895	0,569	84,71	356,607	1,334	1,543
zWWN	16,138	21,24	-38,981	13,269	76,788	0,396	0,27
zSSN	-3,189	26,777	-83,976	-8,35	143,458	2,334	10,835
zSWN	14,648	44,482	-45,182	1,093	189,19	1,797	3,726
After Min-Max Transformation							
zSSS	0,057	0,151	0	0,016	1	5,108	27,047
zWWW	0,035	0,102	0	0,021	1	8,764	81,548
zSSW	0,343	0,21	0	0,27	1	1,443	1,703
zWWS	0,286	0,213	0	0,236	1	1,334	1,543
zWWN	0,476	0,183	0	0,451	1	0,396	0,27
zSSN	0,355	0,118	0	0,333	1	2,334	10,835
zSWN	0,255	0,19	0	0,197	1	1,797	3,726
Non-randomness	0,258	0,106	0,091	0,23	0,712	1,714	4,462

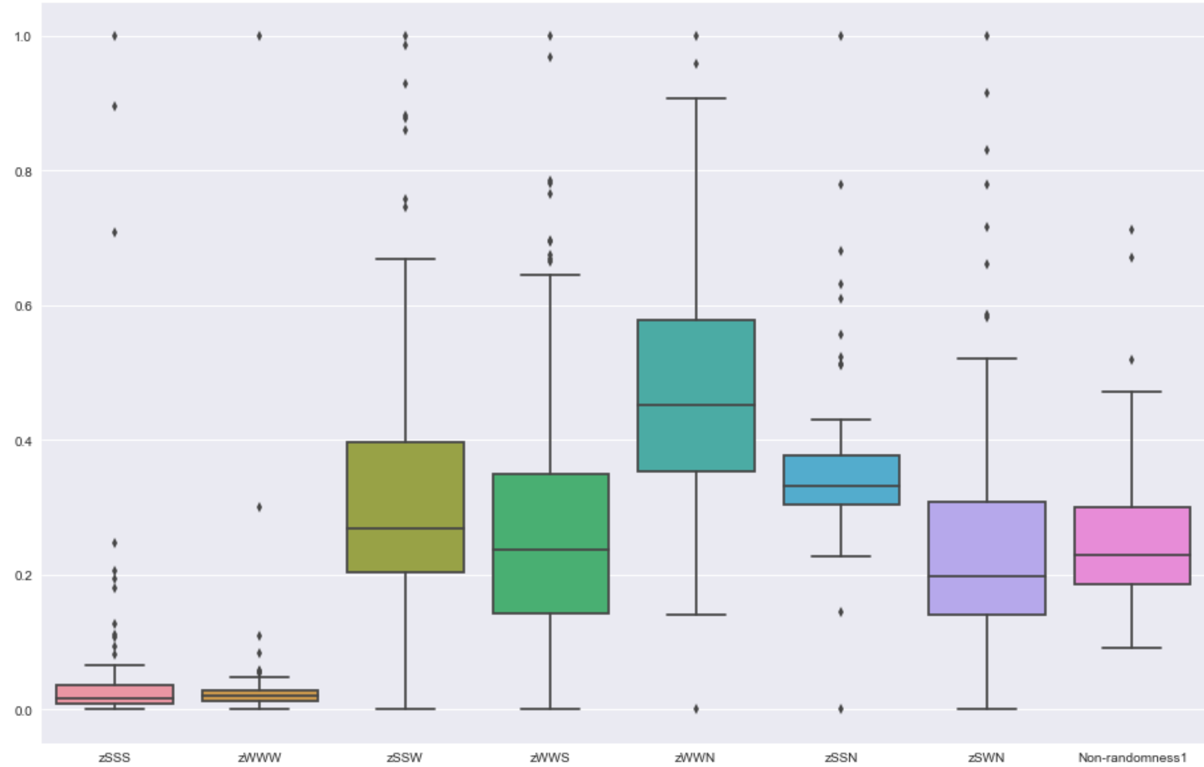

Figure 7. Boxplots of transformed Z scores and Non-randomness measure

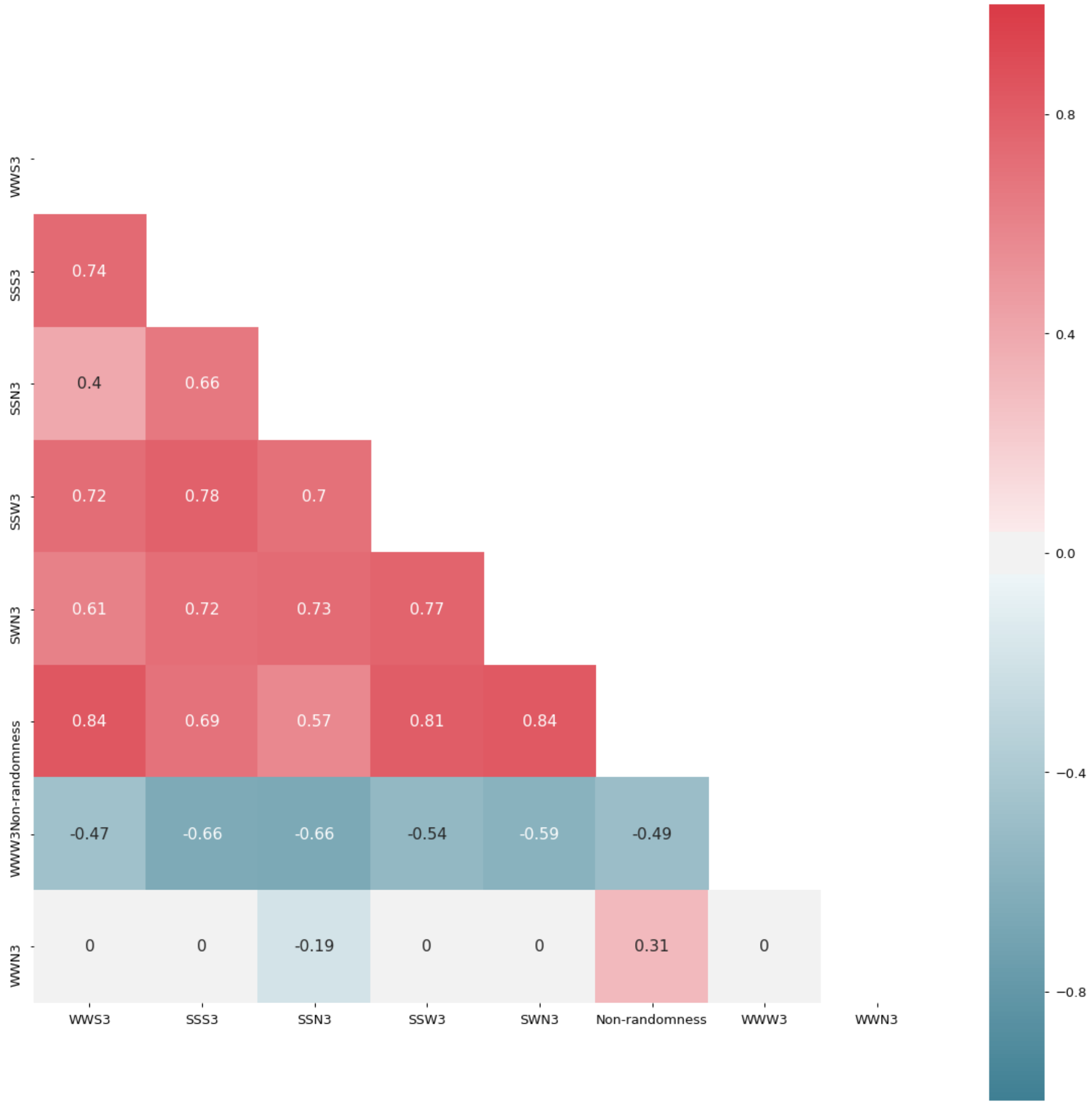

Figure 8. Significant Spearman's correlation coefficients between KR variant III measures

Section III: Three personality profiles detected through cluster analysis

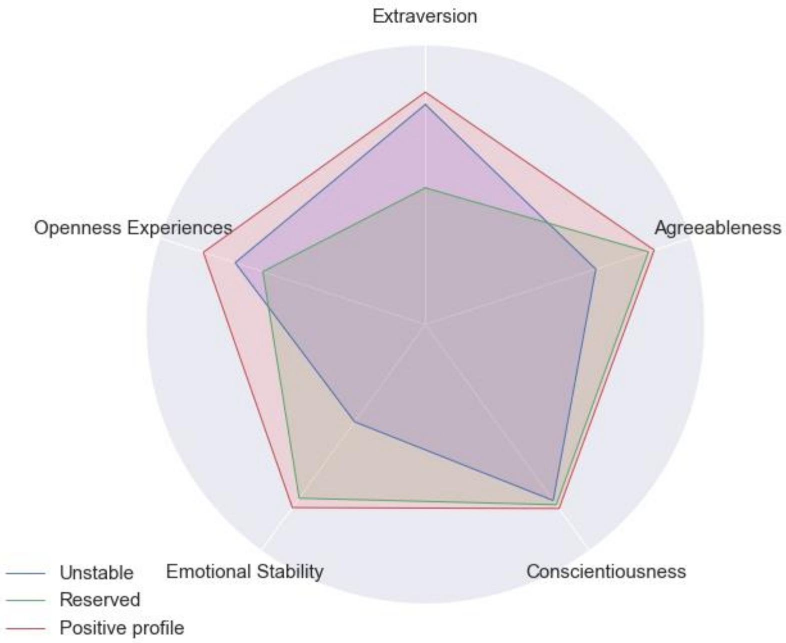

Figure 9. Three personality profiles: Unstable (n=24), Reserved (n=38) and Positive profile (n=38)