Psikometrik Ağ Analizi

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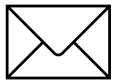 bulut@ualberta.ca

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Sunum İçeriği

- Psikometride geleneksel ve ağ analizi yaklaşımları
- Gaussian grafik modeli (GGM)
- Ağ modellerinin kestirimi
- Psikometride ağ analizi uygulamaları

Psikometride Geleneksel Yaklaşımlar

Eğitimsel ve psikolojik ölçmede:

1. **Yansıtıcı modelleme** (ör., faktör analitik modeller) Ölçülen özellik, gözlemlenen değişkenlere bağlı olarak olarak kavramsallaştırılır.

2. **Biçimlendirici modelleme** (ör., temel bileşen analizi) Ölçülen özellik, gözlemlenen değişkenlerin ortak etkisi olarak görülür.

3. **Üçüncü bir modelleme yaklaşımı???**

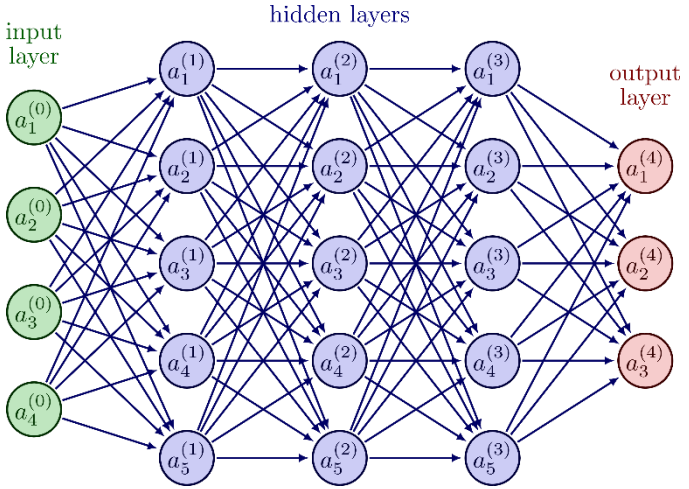
Psikometride Ağ Analizi Yaklaşımı

- Ağ analizinde ölçülen özellikler, “gözlemlenen değişkenler arasındaki nedensel ilişkiler sistemi” olarak tanımlanır (Schmittmann et al., 2013).

- Örneğin,
  - Uyku eksikliği, yorgunluk ve konsantrasyon sorunlarına odaklanan bir depresyon envanterine sahip olduğumuzu varsayalım.

  - Geleneksel psikometrik bakış açısında, bu maddelerden elde edilen sonuçları birleştirir ve bir kişinin depresyon düzeyini temsil eden tek bir puan oluştururuz.

  - Ağ analizi perspektifinde ise öncelikli olarak belirtiler arasındaki olası doğrudan ilişkileri dikkate alırız.
    - Ör. uyku eksikliği → yorgunluk → konsantrasyon sorunları

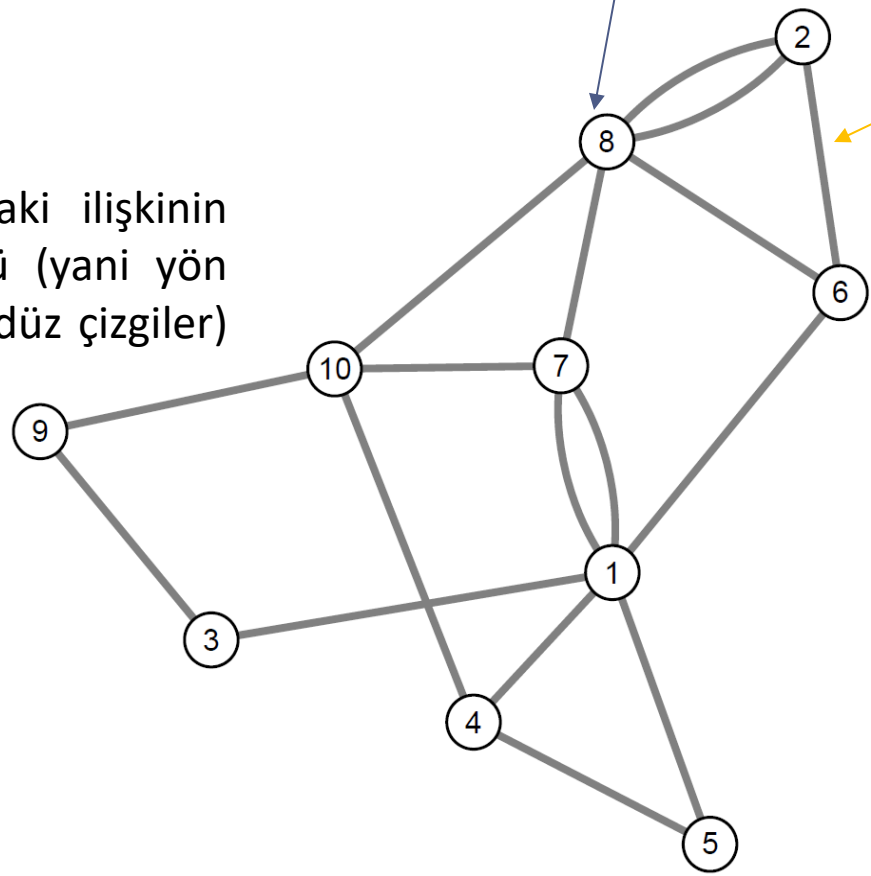


Psikometrik Ağlar ≠ Sosyal Ağ ya da Yapay Sinir Ağları

Gaussian Grafik Modelleri (GGM)

- GGM (Costantini et al., 2015 *n* sayıda düğüm (node) ve *m* sayıda ayrıt (edge) içeren bir ağ modelidir

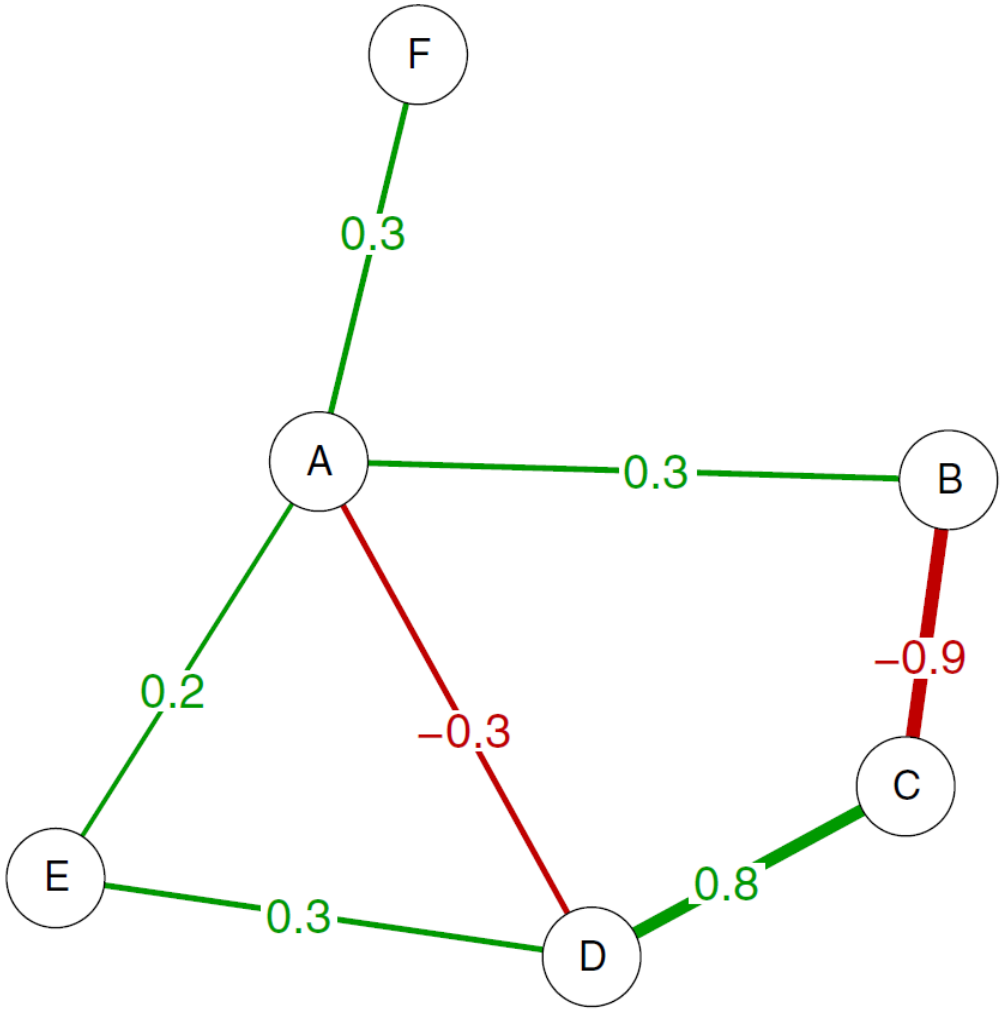
Her bir ayrıt değişkenler arasındaki ilişkinin gücünü temsil eder. Ayrıtlar yönlü (yani yön gösteren oklar) ya da yönsüz (yani düz çizgiler) olabilir.



Gaussian Grafik Modelleri (GGM)

- GGM modelleri genellikle kısmi korelasyon değerleri üzerinden kestirilir.
- Ağ grafikleri oluşturulurken araştırmacılar genellikle negatif kısmi korelasyonlar için "**kırmızı**" çizgiler, pozitif kısmi korelasyonlar için ise "**yeşil**" çizgiler kullanır.
- **Ağırlıklı ayrıtlar**: Daha geniş (yani daha kalın) ve daha doygun çizgiler (yani bağlantılar), daha güçlü kısmi korelasyonları (yani sıfırdan uzak korelasyonları) gösterir.
- **Ağırlıksız ayrıtlar**: Ayrıt, yalnızca bir ilişkinin varlığını veya yokluğunu temsil eder.
- Eğer iki değişken arasında kısmi korelasyon = 0 ise, değişkeninlerin birbirinden bağımsız olduğunu göstermek için iki düğüm arasında bağlantı çizilmez.

Ağırlıklı ayrıtların olduğu bir ağ modeli örneği

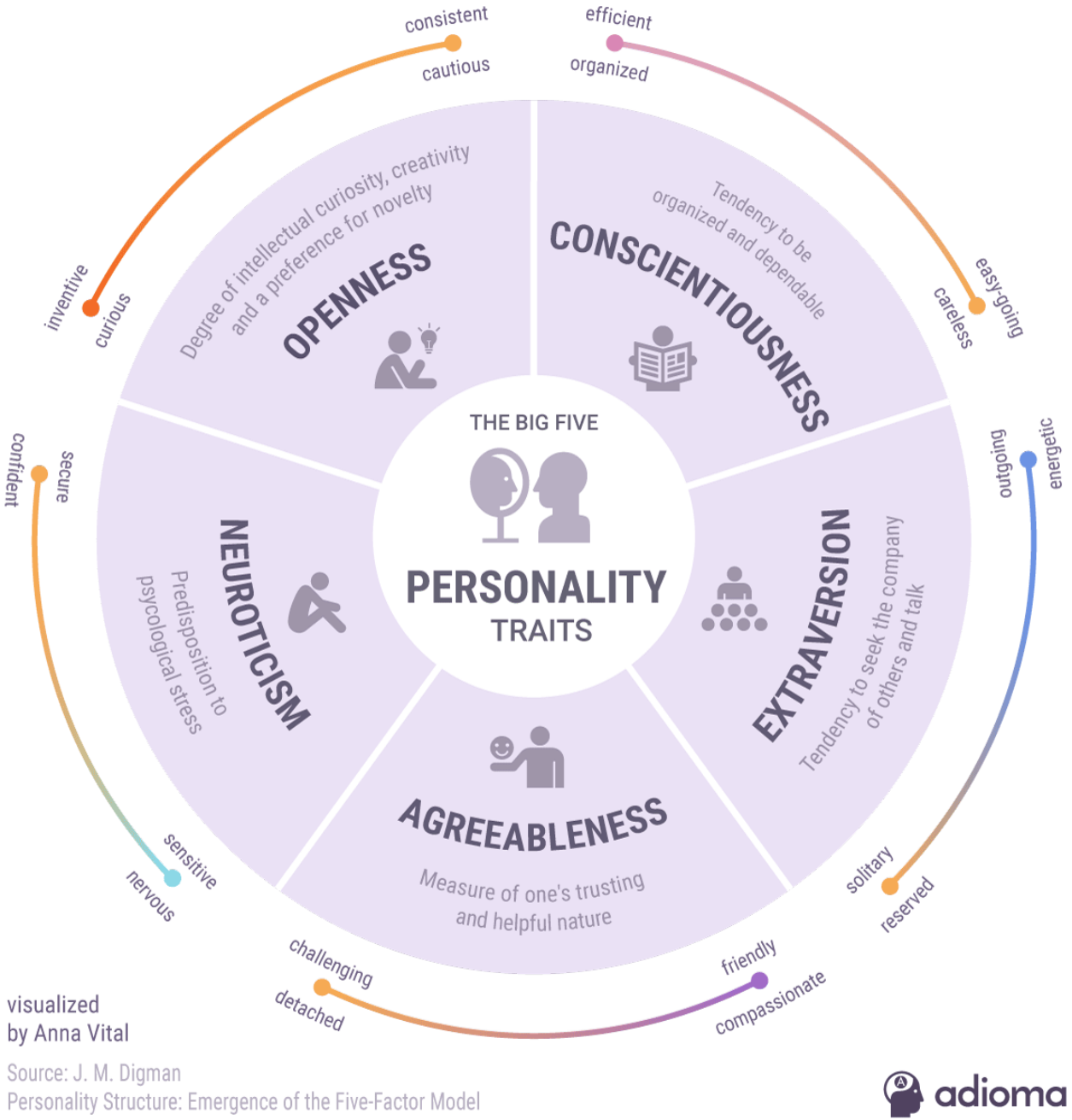


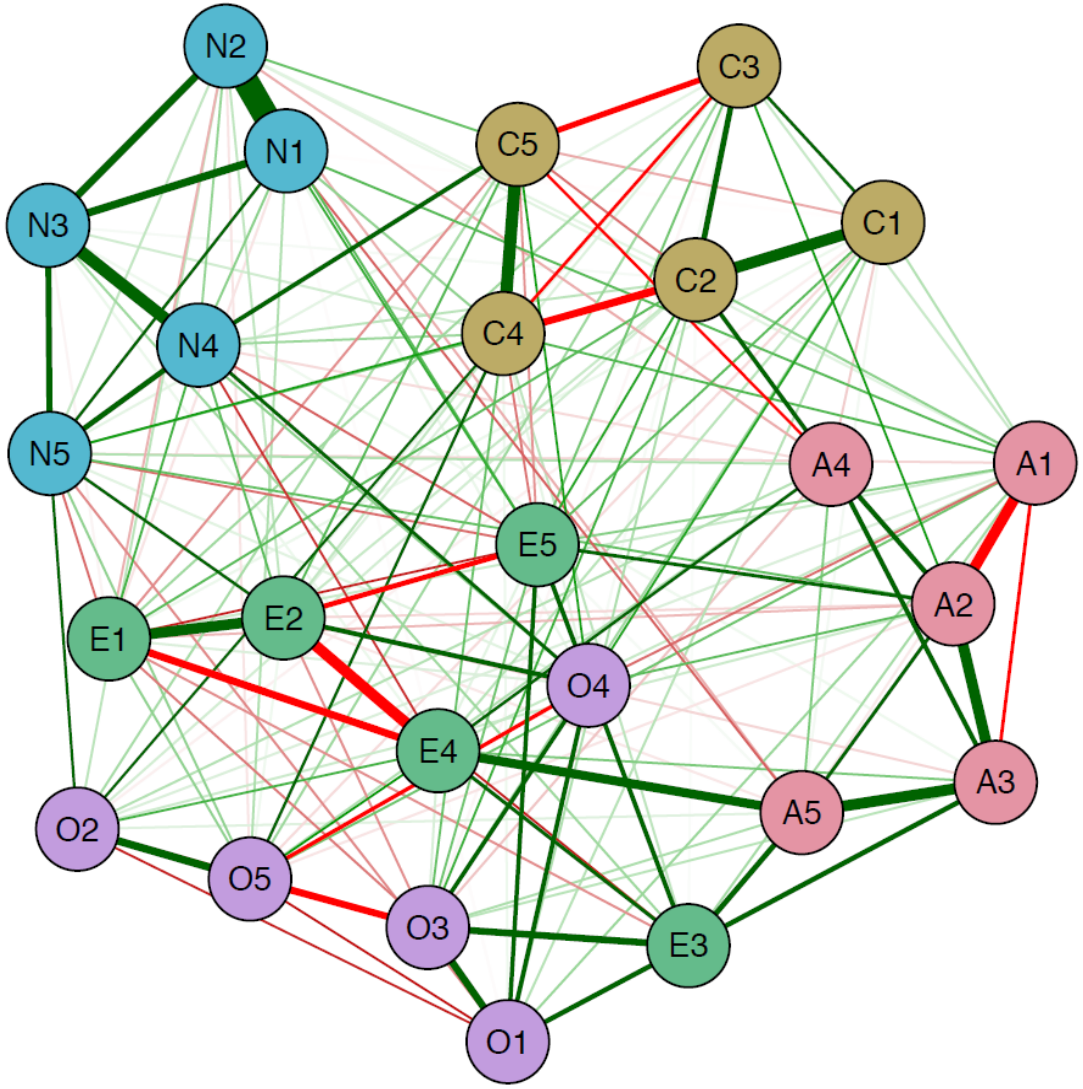
Altı düğümden (yani değişkenden) ve yedi ayrıttan oluşan bir ağ.

Pozitif ayrıtlar yeşil, negatif ayrıtlar kırmızı renk ile gösterilmektedir.

Harfler farklı düğümleri tanımlar, sayılar ise ayrıtlarla ilişkilendirilen ağırlıkları temsil etmektedir.

Kaynak: Costantini et al. (2015)


THE BIG FIVE
PERSONALITY
TRAITS
OPENNESS
Degree of intellectual curiosity, creativity and a preference for novelty
inventive
curious
CONSCIENTIOUSNESS
Tendency to be organized and dependable
consistent
cautious
efficient
organized
careless
easy-going
EXTRAVERSION
Tendency to seek the company of others and talk
outgoing
energetic
solitary
reserved
AGREEABLENESS
Measure of one's trusting and helpful nature
challenging
detached
friendly
compassionate
NEUROTICISM
Predisposition to psycological stress
confident
secure
sensitive
nervous
visualized
by Anna Vital
Source: J. M. Digman
Personality Structure: Emergence of the Five-Factor Model
adioma



Big Five Personality Test

Agreeableness
- A1: Am indifferent to the feelings of others.
- A2: Inquire about others' well–being.
- A3: Know how to comfort others.
- A4: Love children.
- A5: Make people feel at ease.

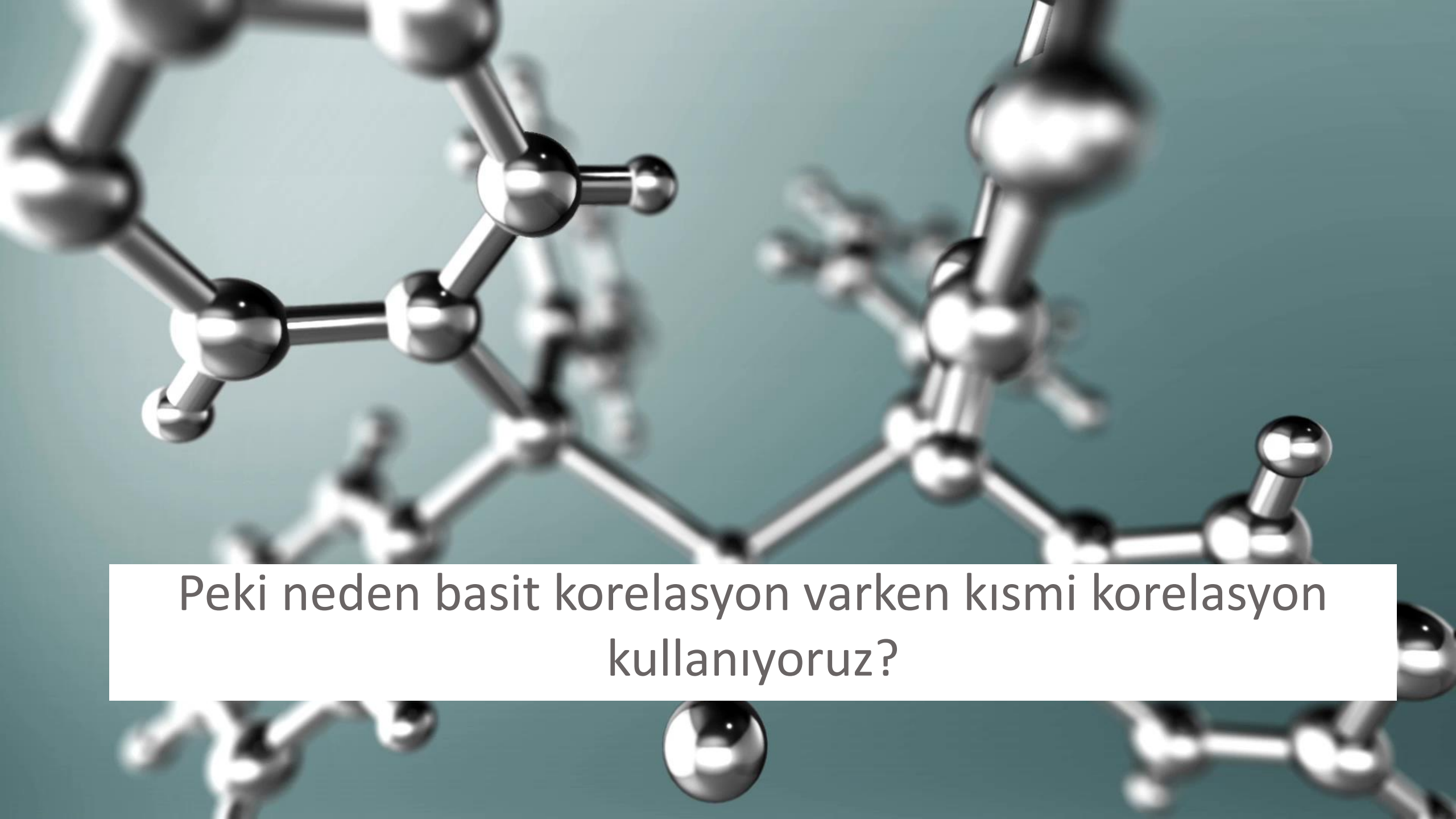
Conscientiousness
- C1: Am exacting in my work.
- C2: Continue until everything is perfect.
- C3: Do things according to a plan.
- C4: Do things in a half–way manner.
- C5: Waste my time.

Extraversion
- E1: Don't talk a lot.
- E2: Find it difficult to approach others.
- E3: Know how to captivate people.
- E4: Make friends easily.
- E5: Take charge.

Neuroticism
- N1: Get angry easily.
- N2: Get irritated easily.
- N3: Have frequent mood swings.
- N4: Often feel blue.
- N5: Panic easily.

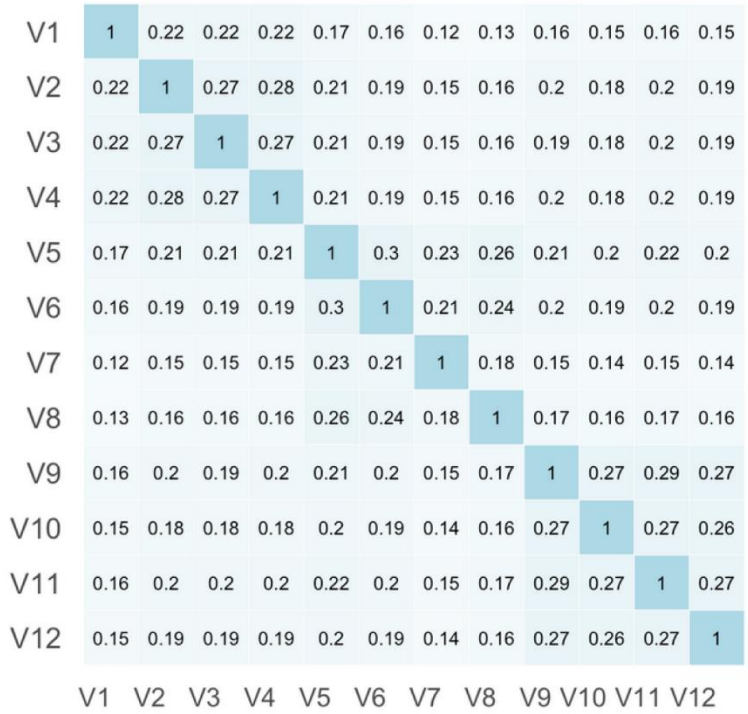
Openness
- O1: Am full of ideas.
- O2: Avoid difficult reading material.
- O3: Carry the conversation to a higher level.
- O4: Spend time reflecting on things.
- O5: Will not probe deeply into a subject.

Kaynak: Epskamp, S. (2017). Network psychometrics (Doctoral dissertation). *Amsterdam: University of Amsterdam*.

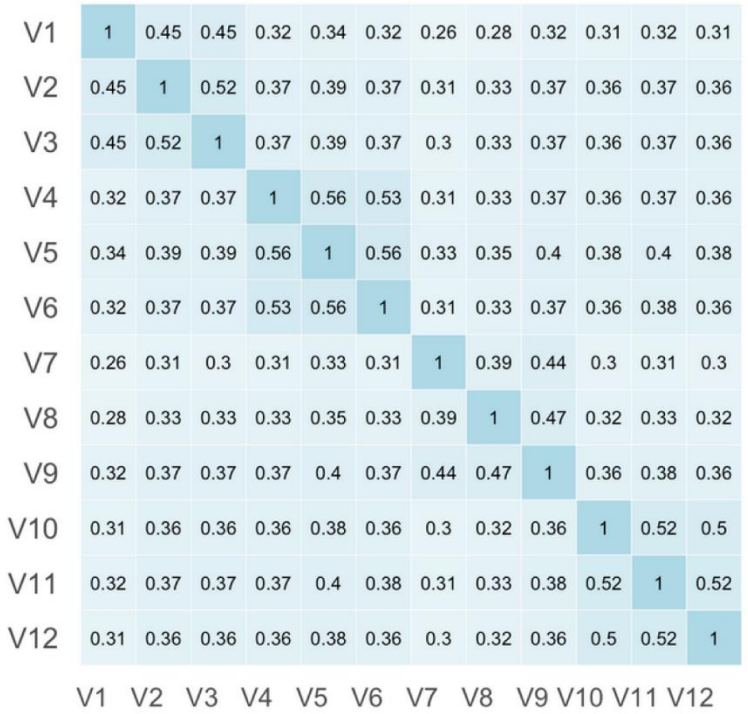


Peki neden basit korelasyon varken kısmi korelasyon kullanıyoruz?

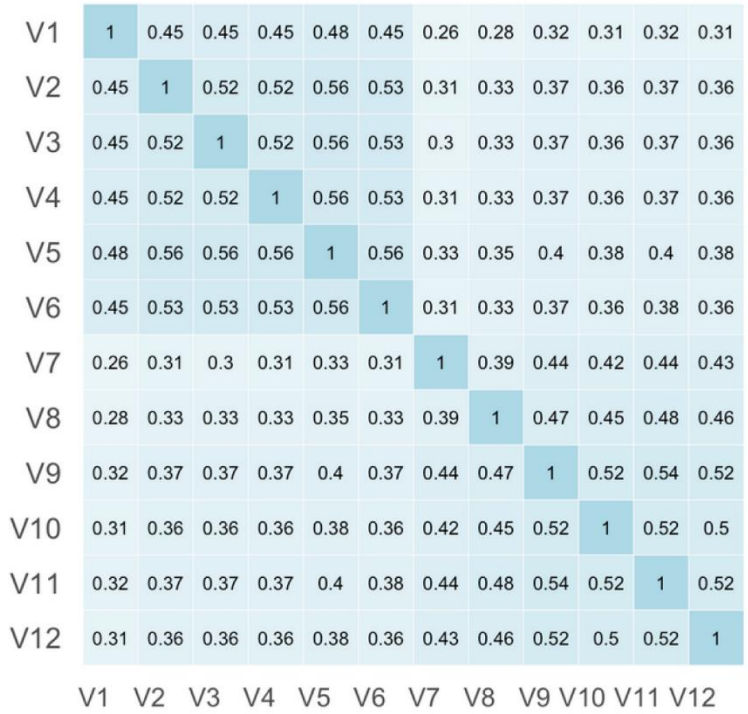
Aşağıdaki basit korelasyon matrislerine bakarak kaç faktörlü bir yapı olduğunu tahmin edelim…



	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	1	0.22	0.22	0.22	0.17	0.16	0.12	0.13	0.16	0.15	0.16	0.15
V2	0.22	1	0.27	0.28	0.21	0.19	0.15	0.16	0.2	0.18	0.2	0.19
V3	0.22	0.27	1	0.27	0.21	0.19	0.15	0.16	0.19	0.18	0.2	0.19
V4	0.22	0.28	0.27	1	0.21	0.19	0.15	0.16	0.2	0.18	0.2	0.19
V5	0.17	0.21	0.21	0.21	1	0.3	0.23	0.26	0.21	0.2	0.22	0.2
V6	0.16	0.19	0.19	0.19	0.3	1	0.21	0.24	0.2	0.19	0.2	0.19
V7	0.12	0.15	0.15	0.15	0.23	0.21	1	0.18	0.15	0.14	0.15	0.14
V8	0.13	0.16	0.16	0.16	0.26	0.24	0.18	1	0.17	0.16	0.17	0.16
V9	0.16	0.2	0.19	0.2	0.21	0.2	0.15	0.17	1	0.27	0.29	0.27
V10	0.15	0.18	0.18	0.18	0.2	0.19	0.14	0.16	0.27	1	0.27	0.26
V11	0.16	0.2	0.2	0.2	0.22	0.2	0.15	0.17	0.29	0.27	1	0.27
V12	0.15	0.19	0.19	0.19	0.2	0.19	0.14	0.16	0.27	0.26	0.27	1

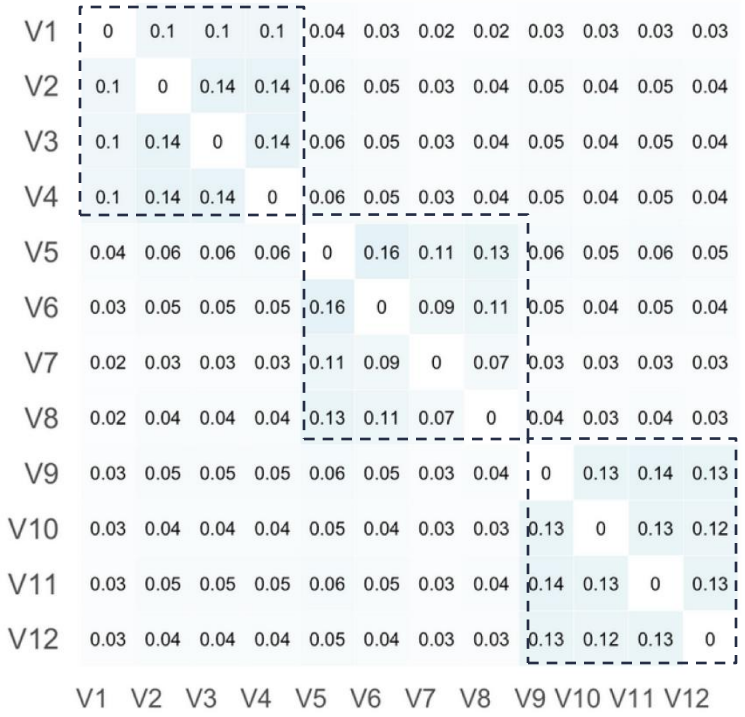


	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	1	0.45	0.45	0.32	0.34	0.32	0.26	0.28	0.32	0.31	0.32	0.31
V2	0.45	1	0.52	0.37	0.39	0.37	0.31	0.33	0.37	0.36	0.37	0.36
V3	0.45	0.52	1	0.37	0.39	0.37	0.3	0.33	0.37	0.36	0.37	0.36
V4	0.32	0.37	0.37	1	0.56	0.53	0.31	0.33	0.37	0.36	0.37	0.36
V5	0.34	0.39	0.39	0.56	1	0.56	0.33	0.35	0.4	0.38	0.4	0.38
V6	0.32	0.37	0.37	0.53	0.56	1	0.31	0.33	0.37	0.36	0.38	0.36
V7	0.26	0.31	0.3	0.31	0.33	0.31	1	0.39	0.44	0.3	0.31	0.3
V8	0.28	0.33	0.33	0.33	0.35	0.33	0.39	1	0.47	0.32	0.33	0.32
V9	0.32	0.37	0.37	0.37	0.4	0.37	0.44	0.47	1	0.36	0.38	0.36
V10	0.31	0.36	0.36	0.36	0.38	0.36	0.3	0.32	0.36	1	0.52	0.5
V11	0.32	0.37	0.37	0.37	0.4	0.38	0.31	0.33	0.38	0.52	1	0.52
V12	0.31	0.36	0.36	0.36	0.38	0.36	0.3	0.32	0.36	0.5	0.52	1

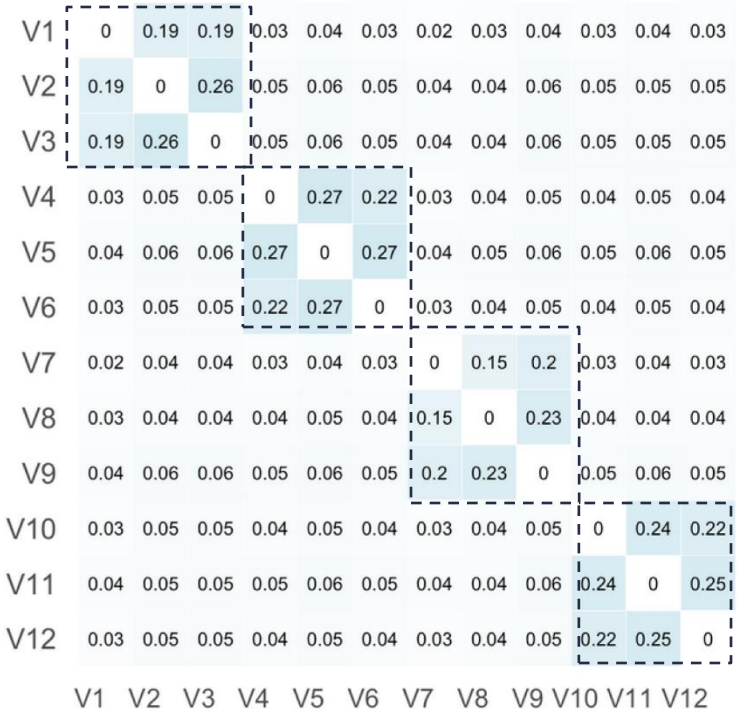


	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	1	0.45	0.45	0.45	0.48	0.45	0.26	0.28	0.32	0.31	0.32	0.31
V2	0.45	1	0.52	0.52	0.56	0.53	0.31	0.33	0.37	0.36	0.37	0.36
V3	0.45	0.52	1	0.52	0.56	0.53	0.3	0.33	0.37	0.36	0.37	0.36
V4	0.45	0.52	0.52	1	0.56	0.53	0.31	0.33	0.37	0.36	0.37	0.36
V5	0.48	0.56	0.56	0.56	1	0.56	0.33	0.35	0.4	0.38	0.4	0.38
V6	0.45	0.53	0.53	0.53	0.56	1	0.31	0.33	0.37	0.36	0.38	0.36
V7	0.26	0.31	0.3	0.31	0.33	0.31	1	0.39	0.44	0.42	0.44	0.43
V8	0.28	0.33	0.33	0.33	0.35	0.33	0.39	1	0.47	0.45	0.48	0.46
V9	0.32	0.37	0.37	0.37	0.4	0.37	0.44	0.47	1	0.52	0.54	0.52
V10	0.31	0.36	0.36	0.36	0.38	0.36	0.42	0.45	0.52	1	0.52	0.5
V11	0.32	0.37	0.37	0.37	0.4	0.38	0.44	0.48	0.54	0.52	1	0.52
V12	0.31	0.36	0.36	0.36	0.38	0.36	0.43	0.46	0.52	0.5	0.52	1

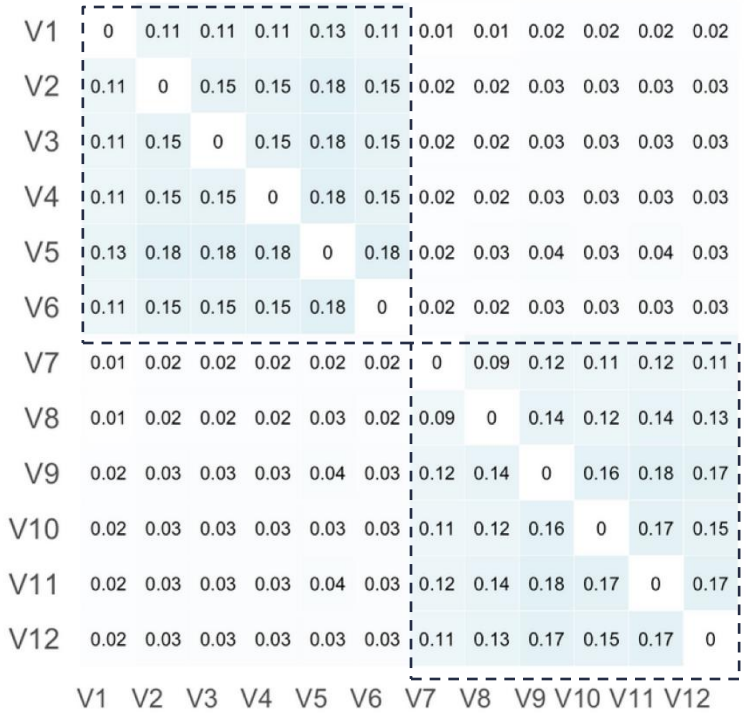
Şimdi de aynı verilerden elde edilen "kısmi" korelasyon matrislerine bakarak tahmin yapalım…



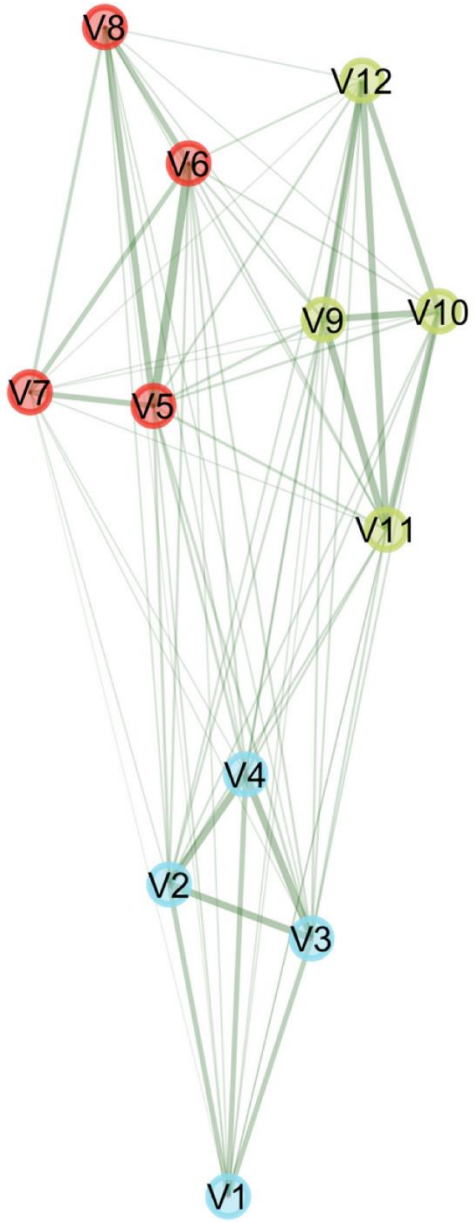
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	0	0.1	0.1	0.1	0.04	0.03	0.02	0.02	0.03	0.03	0.03	0.03
V2	0.1	0	0.14	0.14	0.06	0.05	0.03	0.04	0.05	0.04	0.05	0.04
V3	0.1	0.14	0	0.14	0.06	0.05	0.03	0.04	0.05	0.04	0.05	0.04
V4	0.1	0.14	0.14	0	0.06	0.05	0.03	0.04	0.05	0.04	0.05	0.04
V5	0.04	0.06	0.06	0.06	0	0.16	0.11	0.13	0.06	0.05	0.06	0.05
V6	0.03	0.05	0.05	0.05	0.16	0	0.09	0.11	0.05	0.04	0.05	0.04
V7	0.02	0.03	0.03	0.03	0.11	0.09	0	0.07	0.03	0.03	0.03	0.03
V8	0.02	0.04	0.04	0.04	0.13	0.11	0.07	0	0.04	0.03	0.04	0.03
V9	0.03	0.05	0.05	0.05	0.06	0.05	0.03	0.04	0	0.13	0.14	0.13
V10	0.03	0.04	0.04	0.04	0.05	0.04	0.03	0.03	0.13	0	0.13	0.12
V11	0.03	0.05	0.05	0.05	0.06	0.05	0.03	0.04	0.14	0.13	0	0.13
V12	0.03	0.04	0.04	0.04	0.05	0.04	0.03	0.03	0.13	0.12	0.13	0



	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	0	0.19	0.19	0.03	0.04	0.03	0.02	0.03	0.04	0.03	0.04	0.03
V2	0.19	0	0.26	0.05	0.06	0.05	0.04	0.04	0.06	0.05	0.05	0.05
V3	0.19	0.26	0	0.05	0.06	0.05	0.04	0.04	0.06	0.05	0.05	0.05
V4	0.03	0.05	0.05	0	0.27	0.22	0.03	0.04	0.05	0.04	0.05	0.04
V5	0.04	0.06	0.06	0.27	0	0.27	0.04	0.05	0.06	0.05	0.06	0.05
V6	0.03	0.05	0.05	0.22	0.27	0	0.03	0.04	0.05	0.04	0.05	0.04
V7	0.02	0.04	0.04	0.03	0.04	0.03	0	0.15	0.2	0.03	0.04	0.03
V8	0.03	0.04	0.04	0.04	0.05	0.04	0.15	0	0.23	0.04	0.04	0.04
V9	0.04	0.06	0.06	0.05	0.06	0.05	0.2	0.23	0	0.05	0.06	0.05
V10	0.03	0.05	0.05	0.04	0.05	0.04	0.03	0.04	0.05	0	0.24	0.22
V11	0.04	0.05	0.05	0.05	0.06	0.05	0.04	0.04	0.06	0.24	0	0.25
V12	0.03	0.05	0.05	0.04	0.05	0.04	0.03	0.04	0.05	0.22	0.25	0



	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	0	0.11	0.11	0.11	0.13	0.11	0.01	0.01	0.02	0.02	0.02	0.02
V2	0.11	0	0.15	0.15	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V3	0.11	0.15	0	0.15	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V4	0.11	0.15	0.15	0	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V5	0.13	0.18	0.18	0.18	0	0.18	0.02	0.03	0.04	0.03	0.04	0.03
V6	0.11	0.15	0.15	0.15	0.18	0	0.02	0.02	0.03	0.03	0.03	0.03
V7	0.01	0.02	0.02	0.02	0.02	0.02	0	0.09	0.12	0.11	0.12	0.11
V8	0.01	0.02	0.02	0.02	0.03	0.02	0.09	0	0.14	0.12	0.14	0.13
V9	0.02	0.03	0.03	0.03	0.04	0.03	0.12	0.14	0	0.16	0.18	0.17
V10	0.02	0.03	0.03	0.03	0.03	0.03	0.11	0.12	0.16	0	0.17	0.15
V11	0.02	0.03	0.03	0.03	0.04	0.03	0.12	0.14	0.18	0.17	0	0.17
V12	0.02	0.03	0.03	0.03	0.03	0.03	0.11	0.13	0.17	0.15	0.17	0


V8
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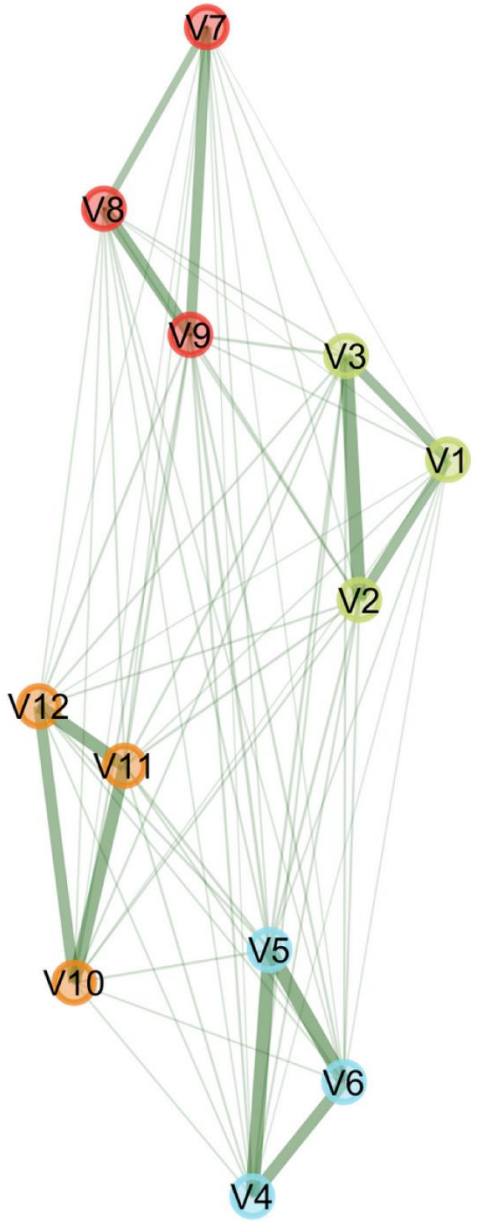
V7
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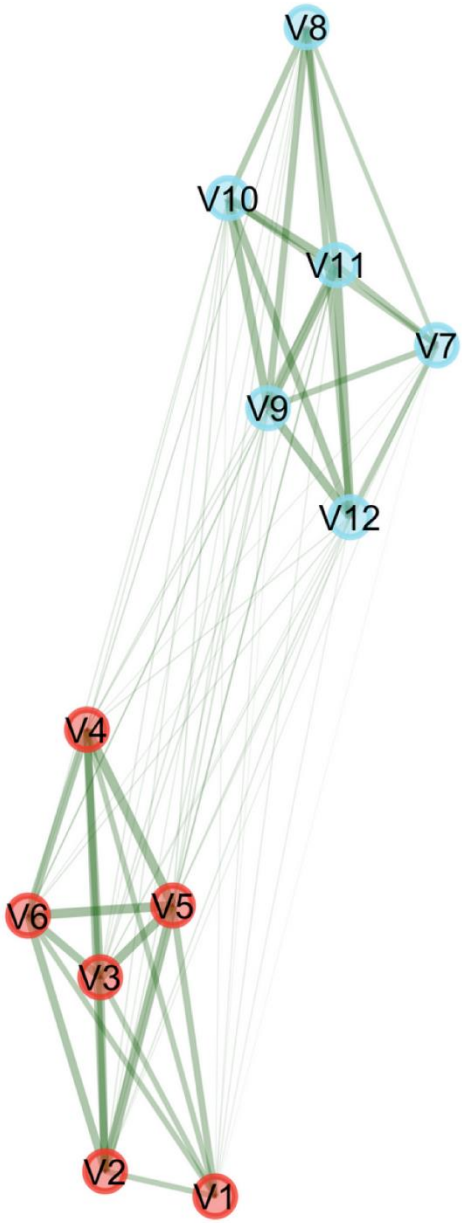
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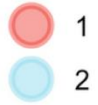
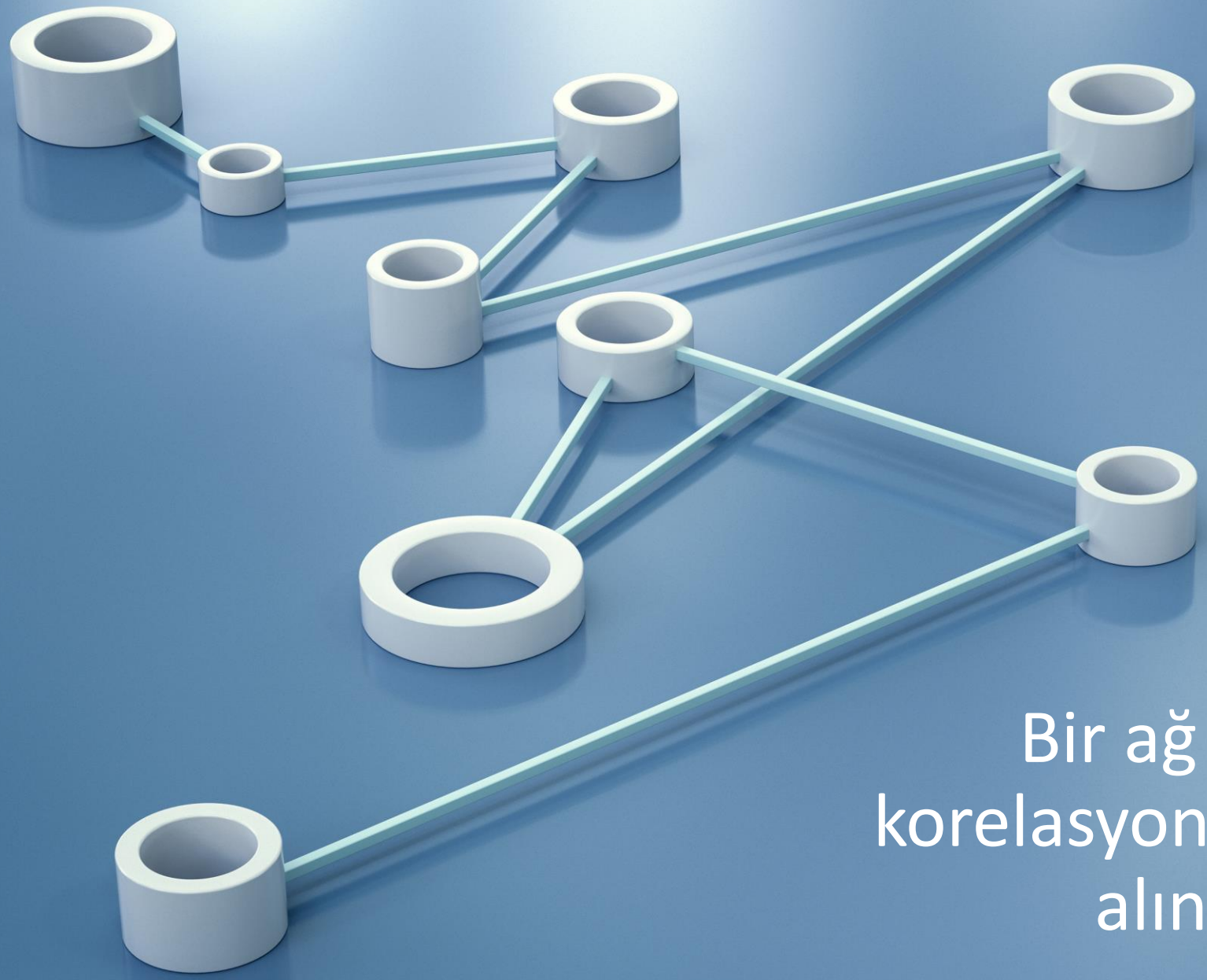
V2
V1


1
2



Bir ağ içindeki kısmi korelasyonların hepsi dikkate alınmalı mıdır?

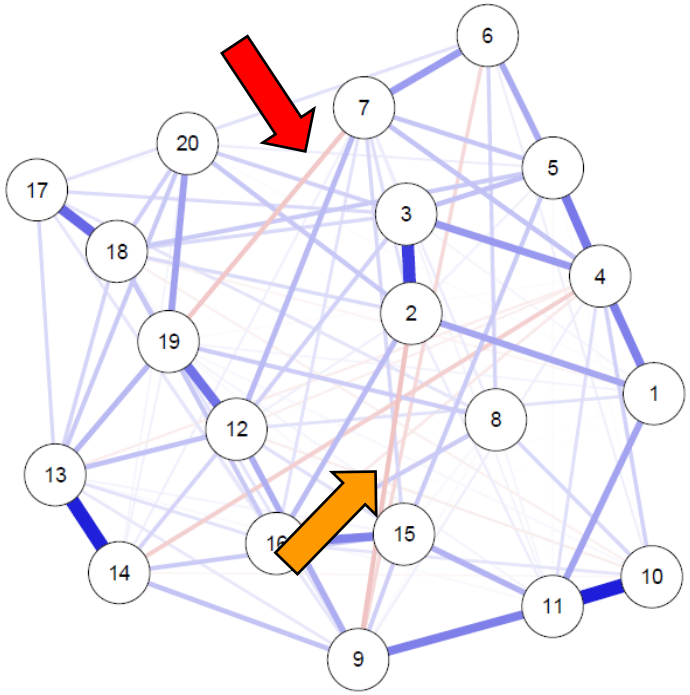
Ağ Modellerinin Kestirimi: Lasso ve Grafiksel Lasso

- Ağ yapılarında kompleks modelleri önlemek için zayıf bağlantıların sayısını sınırlamak gereklidir.

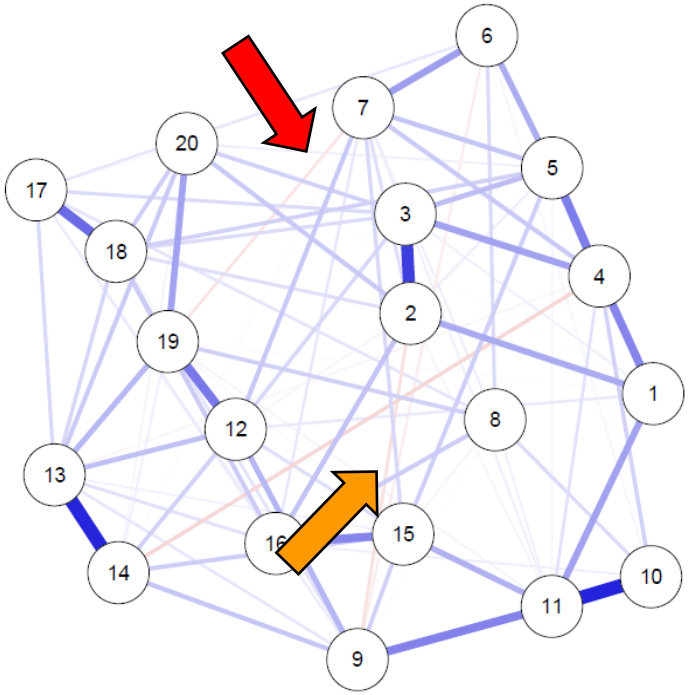
- Least absolute shrinkage and selection operator (Lasso; Tibshirani, 1996) gibi istatistiksel düzenleme tekniklerini kullanarak zayıf bağlantıları ortadan kaldırmak mümkündür.

- Lasso (L1) düzenlemesi, bir ağ modeli tahmin edilirken kısmi korelasyon katsayılarını daraltır, bu da küçük korelasyon katsayıların sıfır olarak tahmin edildiği anlamına gelir.

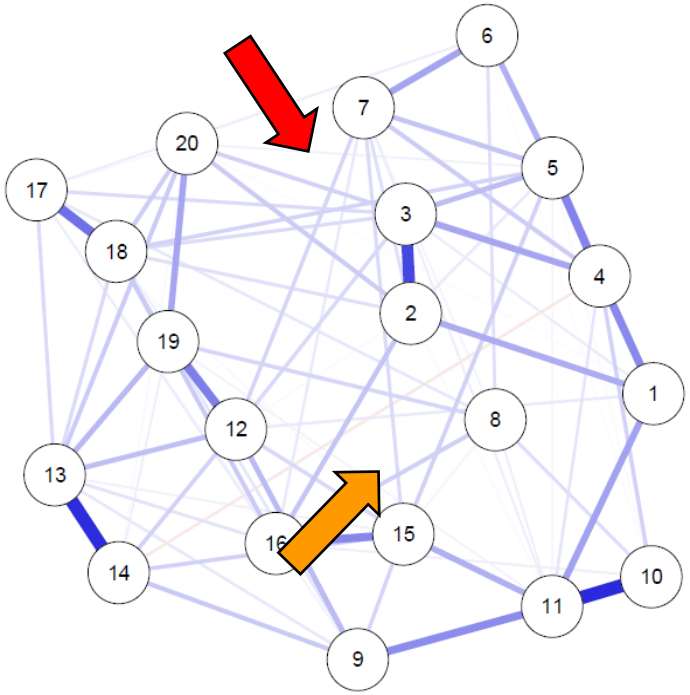
- Lasso GGM modellerinin kestiriminde kullanıldığında grafiksel lasso ya da kısaca Glasso (Friedman et al., 2008) ismini alır.



$\lambda = 0$



$\lambda = 0.25$

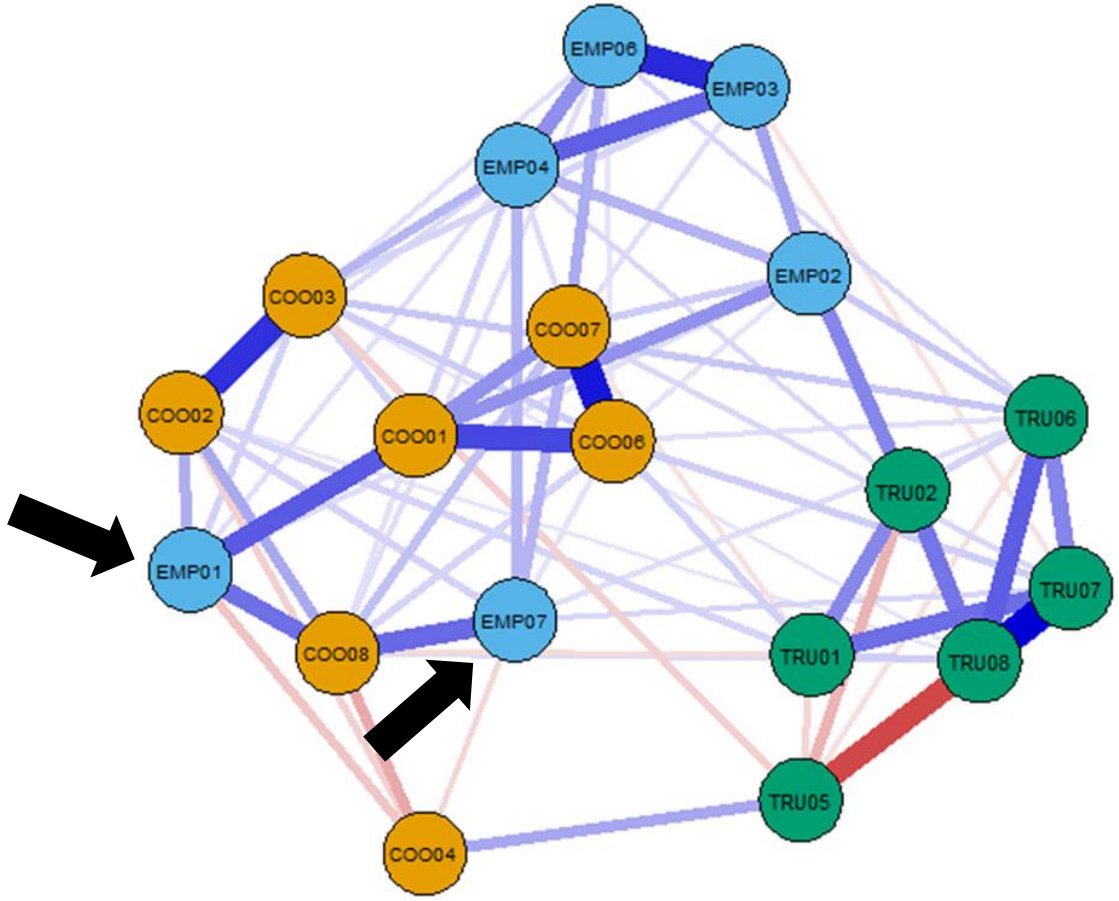


$\lambda = 0.5$

Kaynak: Epskamp and Fried (2017)

Psikometride Ağ Analizi Uygulamaları

Yapı ve Kapsam Geçerliliğini Test Etme



Cooperation
- COO01: Like to help others.
- COO02: Get along well with others.
- COO03: Work well with other people.
- COO04: Starts arguments with others people.
- COO06: Always willing to help my classmates.
- COO07: Ready to help anybody.
- COO08: Polite, courteous to others.

Empathy
- EMP01: Helpful and unselfish with others.
- EMP02: Important to me that my friends are okay.
- EMP03: Can sense how others feel.
- EMP04: Know how to comfort others.
- EMP06: Understand what others want.
- EMP07: Warm towards others.

Trust
- TRU01: Think most of my classmates keep their promises.
- TRU02: Believe that my friends can keep my secrets.
- TRU05: Distrust people.
- TRU06: Believe that other people will help me.
- TRU07: Believe that most people are honest.
- TRU08: Trust others.

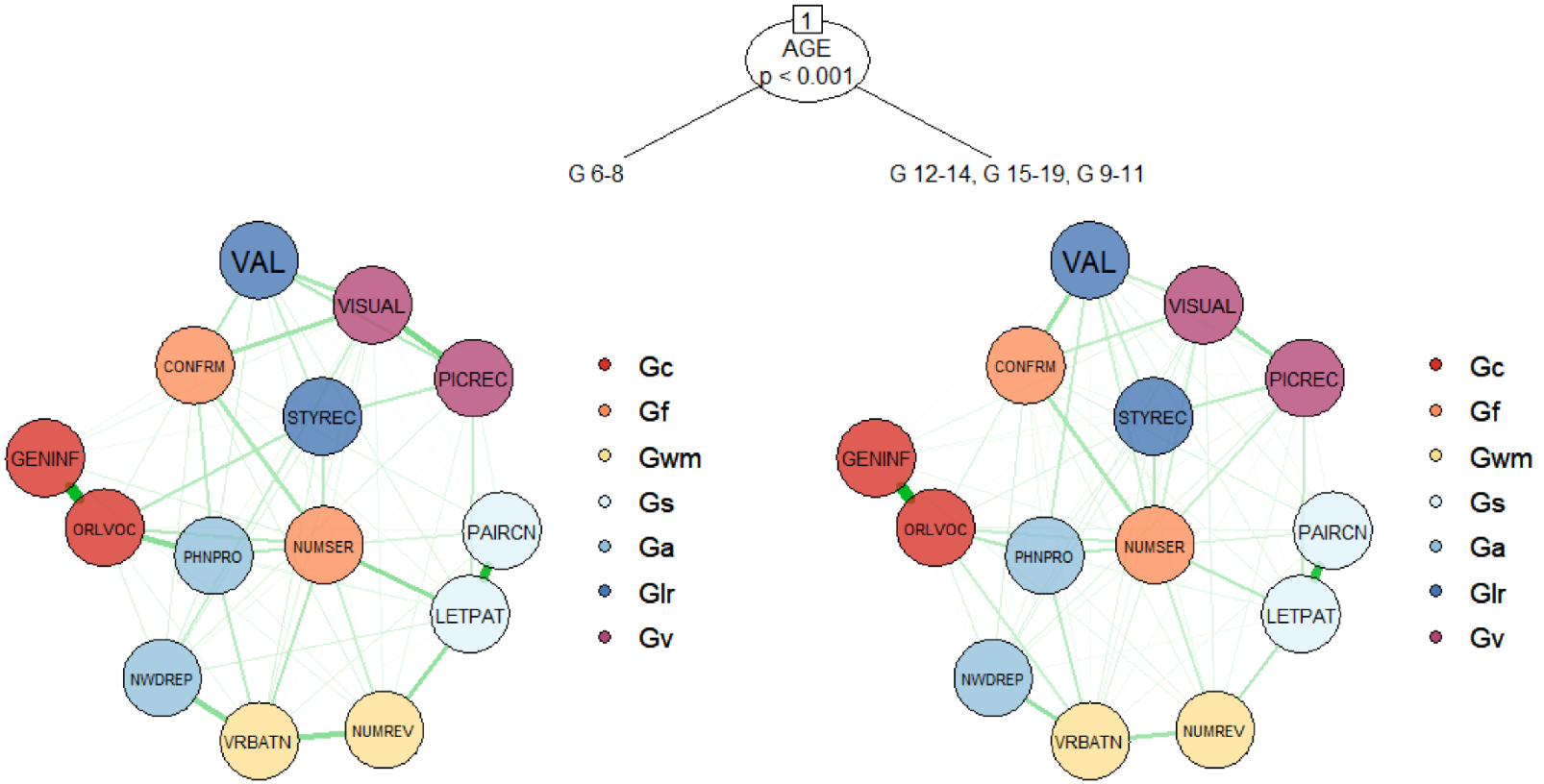
Clelland, A.C., & Bulut, O. (2024, April). *A network psychometrics approach to explore Canadian students' collaborative skills*. Poster presented at the annual meeting of the American Educational Research Association, Philadelphia, PA.

Test Boyutluluğu Analizi

- Exploratory Graph Analysis (EGA; Golino & Epskamp, 2017)

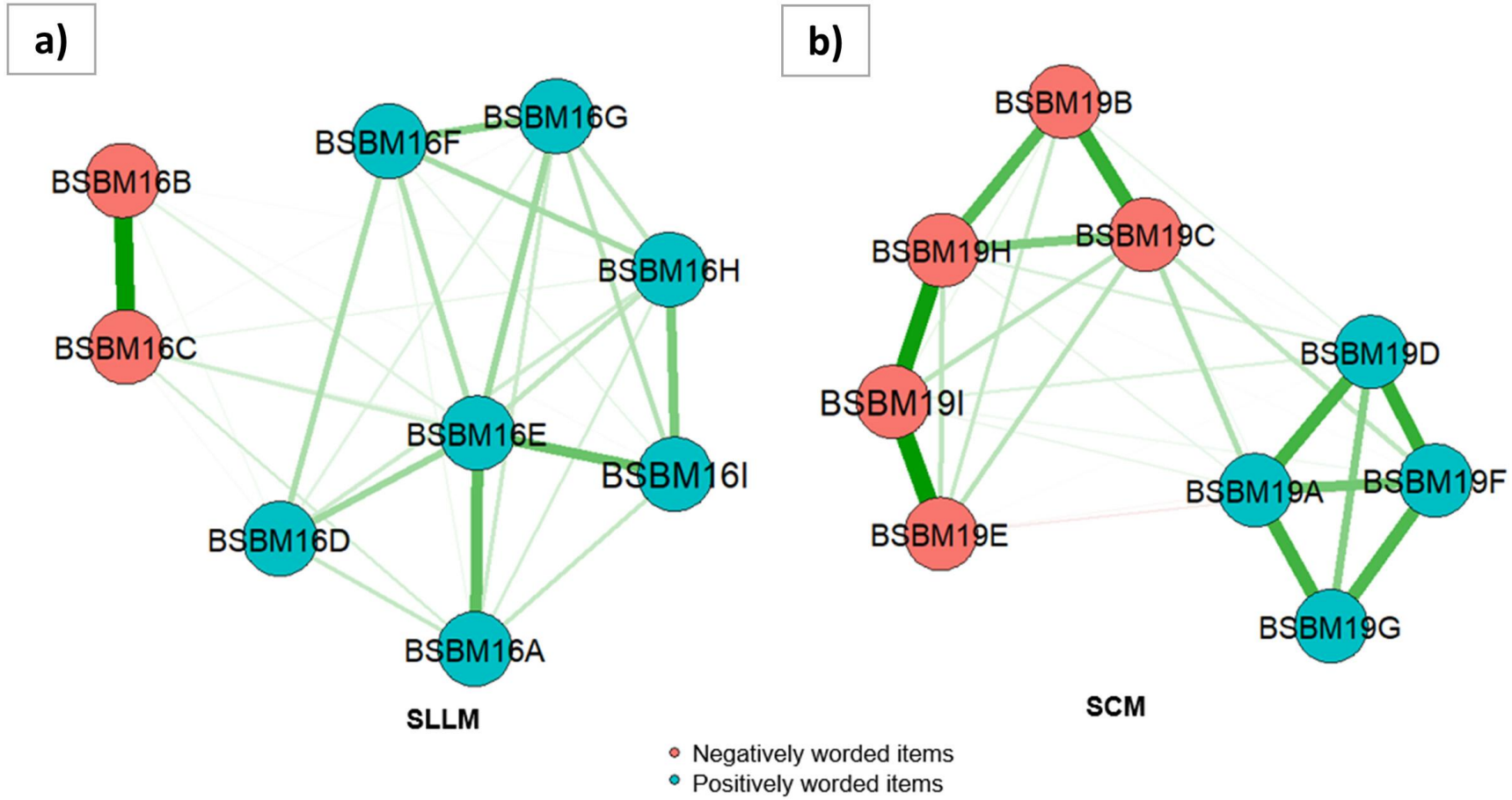
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	0	0.11	0.11	0.11	0.13	0.11	0.01	0.01	0.02	0.02	0.02	0.02
V2	0.11	0	0.15	0.15	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V3	0.11	0.15	0	0.15	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V4	0.11	0.15	0.15	0	0.18	0.15	0.02	0.02	0.03	0.03	0.03	0.03
V5	0.13	0.18	0.18	0.18	0	0.18	0.02	0.03	0.04	0.03	0.04	0.03
V6	0.11	0.15	0.15	0.15	0.18	0	0.02	0.02	0.03	0.03	0.03	0.03
V7	0.01	0.02	0.02	0.02	0.02	0.02	0	0.09	0.12	0.11	0.12	0.11
V8	0.01	0.02	0.02	0.02	0.03	0.02	0.09	0	0.14	0.12	0.14	0.13
V9	0.02	0.03	0.03	0.03	0.04	0.03	0.12	0.14	0	0.16	0.18	0.17
V10	0.02	0.03	0.03	0.03	0.03	0.03	0.11	0.12	0.16	0	0.17	0.15
V11	0.02	0.03	0.03	0.03	0.04	0.03	0.12	0.14	0.18	0.17	0	0.17
V12	0.02	0.03	0.03	0.03	0.03	0.03	0.11	0.13	0.17	0.15	0.17	0

Ölçme Değişmezliği



Kaynak: Bulut, O., Cormier, D. C., Aquilina, A. M., & Bulut, H. C. (2021). Age and sex invariance of the Woodcock-Johnson IV Tests of Cognitive Abilities: Evidence from psychometric network modeling. Journal of Intelligence, 9(3), 1-16. https://doi.org/10.3390/jintelligence9030035

Madde İfade Etkisi



Kaynak: Bulut, H. C., Bulut, O., & Clelland, A. (2024). A psychometric network analysis approach for detecting item wording effects in self-report measures across subgroups. *Field Methods*. https://doi.org/10.1177/1525822X241247444

“Students Like Learning Mathematics” in TIMSS 2019

BSBM16A	I enjoy learning mathematics
BSBM16B_R	I wish I did not have to study mathematics
BSBM16C_R	Mathematics is boring
BSBM16D	I learn many interesting things in mathematics
BSBM16E	I like mathematics
BSBM16F	I like any schoolwork that involves numbers
BSBM16G	I like to solve mathematics problems
BSBM16H	I look forward to mathematics lessons
BSBM16I	Mathematics is one of my favorite subjects.

Olumsuzluk

Olumsuz çağrışım

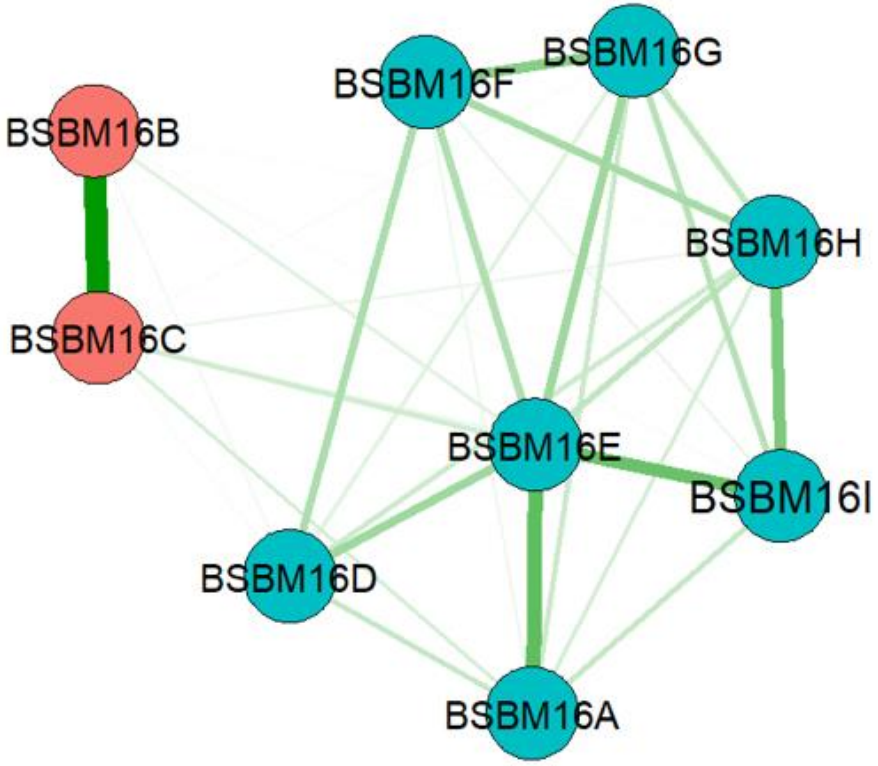
1 = Disagree a lot **2** = Disagree **3** = Agree **4** = Agree a lot

4 = Disagree a lot **3** = Disagree **2** = Agree **1** = Agree a lot

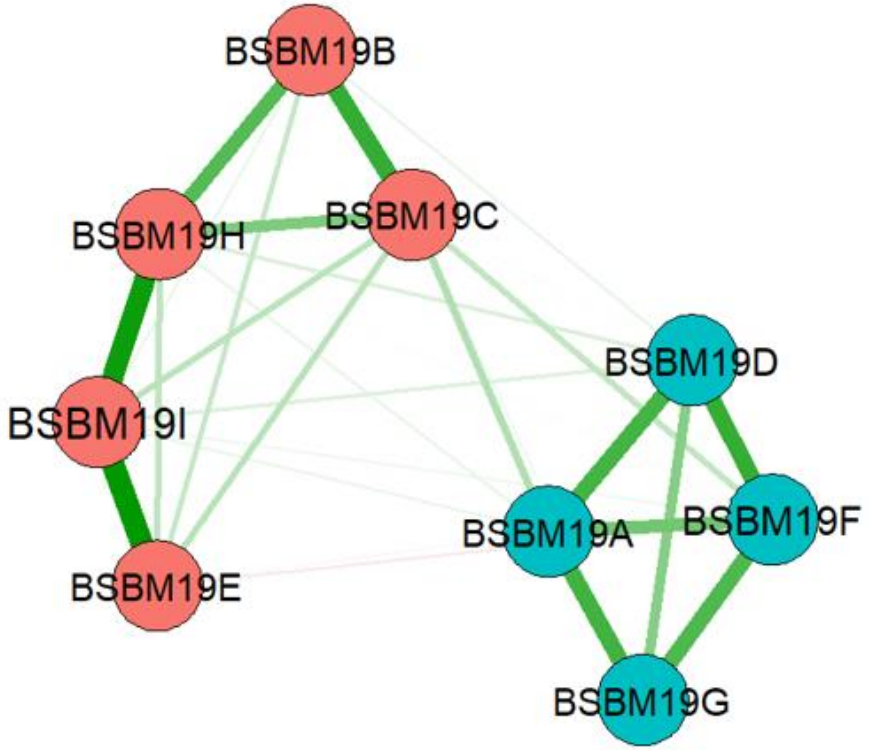
“Students Confident in Mathematics” in TIMSS 2019

BSBM19A	I usually do well in mathematics
BSBM19B_R*	Mathematics is more difficult for me than for many of my classmates
BSBM19C_R**	Mathematics is not one of my strengths
BSBM19D	I learn things quickly in mathematics
BSBM19E_R	Mathematics makes me nervous
BSBM19F	I am good at working out difficult mathematics problems
BSBM19G	My teacher tells me I am good at mathematics
BSBM19H_R	Mathematics is harder for me than any other subject
BSBM19I_R	Mathematics makes me confused

Students Like Learning Mathematics (SLLM)



Students Confident in Mathematics (SCM)



Olumlu maddeler

Olumsuz maddeler

Yapı ve Madde Tutarlılığı

Yapı Tutarlılığı

Tespit edilen ağ yapısının tekrarlı bootstrap örneklemler alındığında yine ortaya çıkıyor mu?

Madde Tutarlılığı

Analiz edilen maddeler tekrarlı bootstrap örneklemler alındığında yine yine aynı madde grubu ya da komünitesine ait çıkıyor mu?

Kaynak: Christensen, A. P., & Golino, H. (2021). Estimating the stability of psychological dimensions via bootstrap exploratory graph analysis: A Monte Carlo simulation and tutorial. *Psych*, *3*(3), 479-500. https://doi.org/10.3390/psych3030032

Yerel Bağımsızlık Varsayımını Test Etme

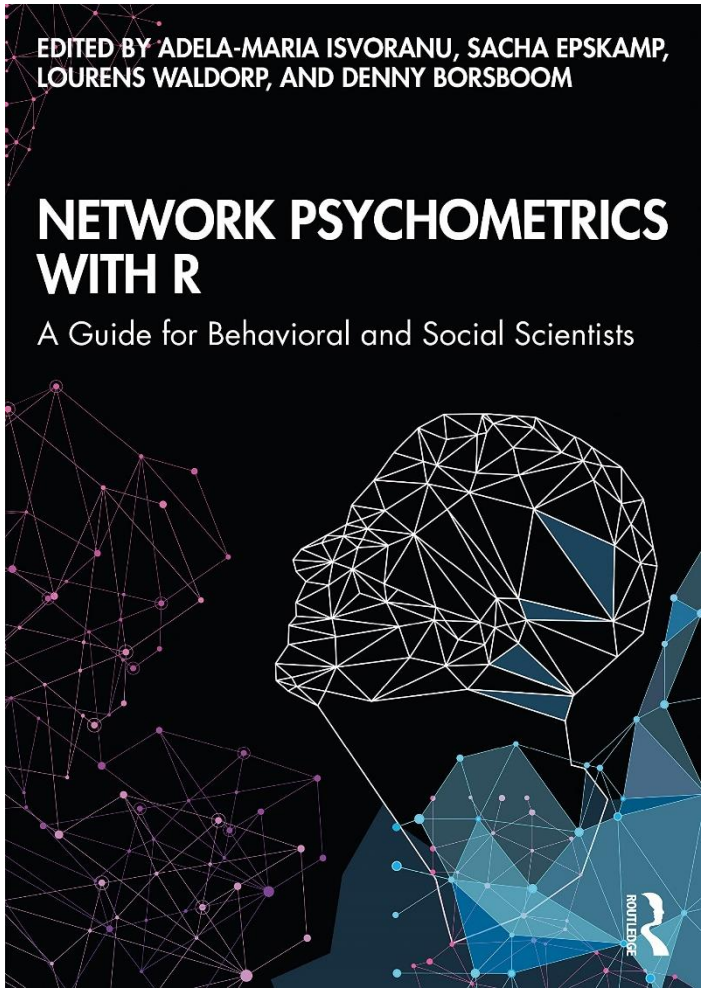
- Ölçülen ortak bir beceri olması dışında maddeleri birbirlerine bağlayan başka etken var mı? (Madde Tepki Kuramı)

- **Unique Variable Analysis** (Christensen et al., 2022) birbirlerine bağlı madde çiftlerini tespit etmekte kullanılır → weighted topological overlap (wTO)

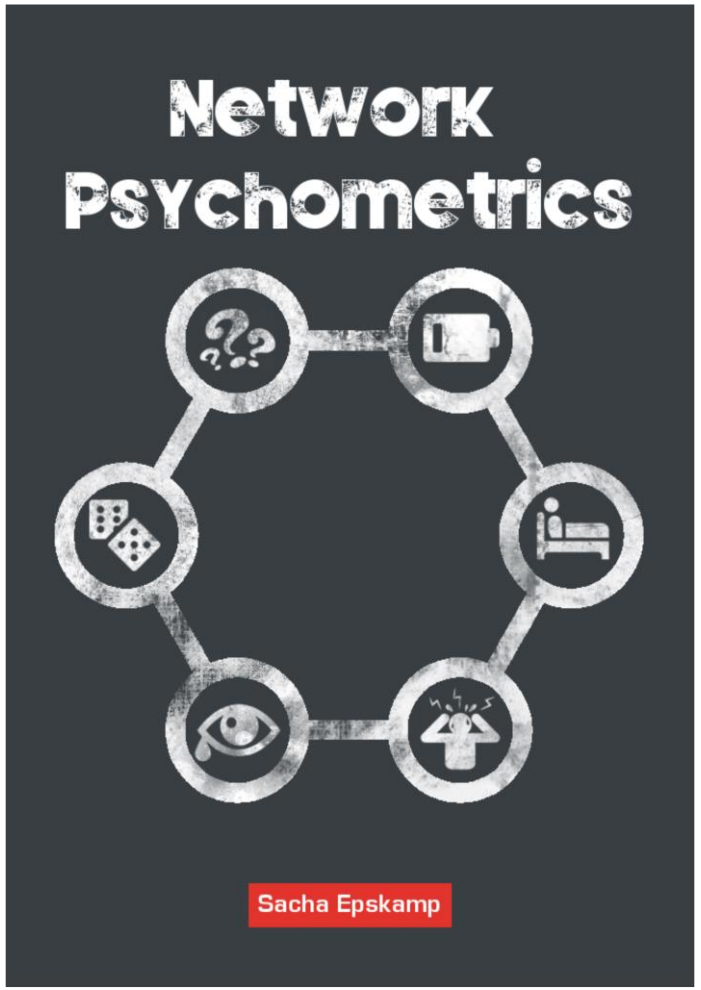
- wTO ağ içindeki düğümlerin ne ölçüde benzer ayrıt ya da kenarlara sahip olduğunu ölçer.

- wTO ≥ 0.25 → maddeler arası gereğinden fazla bağımlılık olduğunu, yani bazı soruların gereksiz olduğunu gösterir.

Ek Kaynaklar



https://doi.org/10.4324/9781003111238



https://www.researchgate.net/publication/313344229_Network_Psychometrics