Reply / round 1: Structure and drivers of social networks and their links with health in older adults (by Sueur, Fancello, Naud, Kestens, Chaix)

Dear authors,

Thank you for submitting your paper to PCI Network Science. The reviewers have provided detailed feedback on your manuscript. Two reviewers express positive sentiments, while one reviewer finds the core questions promising but is critical of the paper's execution. I encourage you to address these comments in a thorough revision. Please resubmit a revised manuscript along with a comprehensive list of changes. Below I summarize the key points from the reviewers' feedback.

Reviewer 1 ("The paper is well-written..."):
1. Suggests checking robustness by verifying results using original variables instead of regression residuals.
2. Recommends conducting rigorous tests for normality.
3. Proposes replacing long tables with figures for better clarity.

We answered positively the comments of the reviewer 1, please see the details below.

Reviewer 2 ("This paper analyzes the link between social network features..."):
1. Recommends that you explore nonlinear or threshold effects.
2. Suggests analyzing subgroups, particularly individuals with high depression levels.

We answered positively the comments of the reviewer 2, please see the details below.

Reviewer 3 ("This paper addresses two important methodological issues..."):
1. Raises significant concerns about the focus of the work and recommends separating the topics into distinct papers.
2. Emphasizes the need for thorough comparison with the existing literature, if the focus is the statistical independence of network measures.
3. Calls for stronger empirical results and clearer interpretation, if the focus is the relationship between healthy ageing and network structure.

We answered positively the comments of the reviewer 3, please see the details below.

Key additional feedback includes:
1. Consider revising the title of the paper to better reflect the main results.

Done. The new title is: The Complexity of Social Networks in Healthy Aging: Novel Metrics and Their Associations with Psychological Well-Being

2. Pay meticulous attention to spelling and grammar.

Done

3. Enhance the presentation of all figures.

We have enhanced the resolution of the figures, with the hope that the Word document or the submission system will not diminish their quality.

4. Provide more context and intuition (e.g., interpretation of eigenvalues, PCA dimensions, specifics of the data sample).

We added several paragraphs in the introduction to answer these comments of the reviewers. We also work on the PCA explanations.

5. Improve the paper's structure to highlight the main contributions and to make the results clearer for the reader.

Done.

6. Place the paper firmly within the context of the recent literature.

Done. Several references were added in the introduction.

I wish you success with your revision.

Thank you very much!

Best regards,

Steve Lawford, ENAC (University of Toulouse)

*by **Steve Lawford**, 23 Aug 2023 10:18*
Manuscript: ***https://doi.org/10.31219/osf.io/j9uz8***
version: 1

Review by Christophe Prieur, 10 Jul 2023 21:13

This paper addresses two important methodological issues, one about the statistical interdependence of usual (or unusual) network measures, one about the dependence of these measures with healthy aging. Both these issues are relevant in network science, and in aging / health studies. However each of these would benefit from being treated separately and more in depth.

I will discuss these two issues one after the other, but first express some concern about the overall structure of the paper and of the demonstration. Ideas are mixed linearly with very few separations between steps, smaller or bigger arguments, which is especially true in the 5-page discussion section, but also in the setting of the network method, as i will detail below.

Thank you very much for your comments. We addressed all of them positively.

1/ On the statistical dependence of network measures.
Very few state of the art is provided on this half-century-long issue. Some recent development in the particular case of personal networks might be a good start: Vacca, 2020 ; Bidart et al, 2018 ; Charbey & Prieur, 2019.

We added these references and extended the introduction: “In this paper, we adopted a new way to test data in order to avoid this data interdependence and potentially false positives and false negatives. Some studies already address this dependence of network measures. (Vacca (, 2020) introduced a new method for identifying structural typologies in personal networks, emphasizing that personal network structure, or how individuals' contacts are connected to each other, has a significant impact on social outcomes, and the new method is compared to another recently introduced approach, finding that both methods effectively capture variation in network structures but also exhibit substantial disagreement and cross-classification, with potential applications in researching personal communities, social support, and social capital. (Bidart et al., (2018) introduced a typology of personal networks, constructed from detailed data on young French individuals in a longitudinal study, which relies on a limited set of indicators related to the structure of relationships between individuals, with the goal of creating a generalizable approach applicable to different surveys. Finally, (Charbey & Prieur, (2019) applied a network science approach, drawing from methods in various disciplines, to analyze around 10,000 non-overlapping Facebook ego networks collected through a survey application, utilizing a concept called "graphlet representativity" to classify these networks more effectively, resulting in two clusterings: one of graphlets (paths, star-like, holes, light triangles, and dense) and one of the networks, revealing distinct structural characteristics of the Facebook ego networks, and

discussing differences between results obtained using 4-node and 5-node graphlets, with potential follow-up directions in sociology and network science."

Taking as central this issue in a paper would imply properly defining and discussing the measures, maybe not as meticulously as in Sosa et al, 2020, but not the way it is elusively done here (in a table put as an appendix). This would bring the authors to argue about using the so-called Simmelian brokerage instead of well-established Burt's measures of structural holes. Simmelian brokerage, defined in Latora et al, 2013 (Journal of statistical physics), is far from having brought a large consensus in network analysis: according to Google Scholar, Latora et al, 2013 is reportedly cited 71 times, among which few works in sociology, if any. If one absolutely had to get rid of Ronald Burt (but why, really?), at least one might refer to him anyway, and why not consider for instance using Vedres & Stark's structural folds instead? Or other measures that have been more thoroughly studied in the field.

In this study, we selected Simmelian brokerage as one of our network measures for several reasons, and we acknowledge the importance of discussing this choice in greater depth. Simmelian brokerage, defined by Latora et al. in 2013, has been employed to assess the role of the ego as a broker in a social network. It measures the extent to which the social network components become disconnected from each other when removing the participant from the network. While Simmelian brokerage may not have achieved the same level of consensus or recognition in the field of sociology as some other established measures, such as Ronald Burt's structural holes, there were specific considerations that led us to choose this measure.

Firstly, Simmelian brokerage offers a unique perspective on the structural characteristics of social networks. It not only considers the potential isolation of network components when the ego is removed but also combines elements of both betweenness and clustering coefficients, thus providing a more holistic view of the participant's bridging role within the network. This combination of measures can offer insights into the formation of strong ties and the potential for creating group cohesion, which can be particularly relevant in studying the social networks of older adults. Additionally, our choice to use Simmelian brokerage in this study does not preclude the importance of more established measures, such as Burt's structural holes or Vedres & Stark's structural folds. We recognize that these measures have been extensively studied in network analysis and have a well-established place in the literature. However, for the specific research questions we aimed to address, we found Simmelian brokerage to be a suitable choice. We encourage future research to explore the applicability of these more traditional measures in similar contexts. Furthermore, our choice of Simmelian brokerage aligns with our objective of exploring innovative methodologies in the study of social networks, particularly within the context of older adults. While Latora et al.'s work may not have garnered the same citation count in sociology as in other disciplines, we believe that embracing diverse perspectives from other fields can enrich the understanding of social network dynamics in gerontology.

We added a new paragraph: "In our study, we employed a range of network indices to investigate the complex dynamics of social networks among older adults, with each index serving a distinct purpose. Simmelian brokerage, as one of our chosen measures, provided unique insights into the role of participants (egos) as brokers in the network, shedding light on the potential fragmentation of network components when egos are removed. This index, while less commonly employed in sociology, was selected due to its ability to combine elements of both betweenness and clustering coefficients, offering a more comprehensive view of network structure. Additionally, our study incorporated other well-established indices, such as degree centrality, which measured the number of connections participants had with other network members, and network density, assessing the overall interconnectedness of the network. The global clustering coefficient was used to gauge the extent to which cohesive structures formed within the network. Furthermore, the diversity index allowed us to examine the diversity of connections across different categories of people. Together, these indices provided a multi-faceted approach to comprehensively explore the structure, diversity, and dynamics of social networks among older adults, offering a more nuanced understanding of the factors influencing their social interactions and potential impacts on well-being. While Simmelian brokerage may not have enjoyed the same recognition as some traditional measures, our study aimed to broaden the scope of methodologies in the field, opening avenues for future research to delve deeper into these intricate network dynamics."

Now once the measures are properly defined and discussed, if the main goal of the study were to assess their statistical interdependence, dealing with a much larger sample would be mandatory. Quoting the article: "we need more formal social network analyses (more quantitative and less subjective) [than Cornwell (2009)]". But the present study relies on 72 networks, while Cornwell relies on a sample of 3 *thousand* networks.

We know that our sample size is limited. However, our study illustrates a new method to analyze social network metrics and better identify the different concepts of social capital (e.g. social support, social integration, Sueur et al., 2021a). Our methodology should be extended to other datasets to better understand the structure, drivers, and consequences of social networks of older adults and of people in general. We howver added a paragraph: “We acknowledge the limitation of a small sample size, which can impact the generalizability and statistical power of the findings. A small sample size can lead to limited representativeness of the broader population, making it challenging to draw definitive conclusions that apply to a larger group of people. It can also affect the ability to detect statistically significant relationships or associations between variables. In this context, we recognize that the findings may not fully capture the complexity and nuances of social network dynamics and their impact on health, and that the results should be interpreted with caution. They emphasize the need for further research with larger and more diverse datasets to validate and extend their methodology, allowing for a more comprehensive understanding of social network structures, their determinants, and their consequences for various population groups.”

Arguably Cornwell's networks are limited in size by design, but in the present study, the maximum size is 19, which is very limited to draw solid conclusions. In comparison, Vacca relies on six datasets between 119 and 385 egos having up to 45 alters, Bidart et al on 287 egos with up to 134 alters, Charbey & Prieur on two datasets of 3k and 10k egos with up to 350 alters.

Indeed, the purpose and methodologies of our study differ significantly from those of the studies you cited, primarily because the studies you mentioned also incorporate online and social media friends. This discrepancy is particularly relevant to the issue of defining social support, a concept we highlighted. In our research, we concentrate on tangible, physical, and psychological support, which naturally leads to a smaller number of network connections, or 'alters.' While studies with larger network sizes often offer greater applicability and generalizability, it's important to recognize that smaller networks can still yield valuable insights into specific social dynamics and phenomena. Researchers should be diligent in designing their studies and carefully consider the network size that best aligns with their research objectives and constraints. We added this in the paper.

Moreover, the distributions of the variables on the 72 egos are hard to infer from what is shown in the paper. The correlation table in Figure 1 is difficult if not impossible to read (even zooming-in shows highly pixelated text, with many numbers missing). I could not even read the network sizes ("degree") to check to what extent the sample is limited (the highest bar in the degree barchart is on a very low degree, which suggests networks not much bigger than Cornwell's).

I apologize for the inconvenience. This issue appears to be related to the Word document format and should not occur with the original document. Furthermore, it's worth noting that the dataset is comprehensively summarized in the tables and is accessible online for readers who wish to analyze specific variables.

2/ On the ties between network measures and healthy aging.
Here again, taking this issue as central would bring the authors to discuss more in depth the interpretations of their statistical results. Despite the limitation of the sample, both in size (72) and in network sizes (19), there might be relevant insights from other non-netowk variables, or better, from qualitative material (whether the survey contains open questions for instance).
The way they are stated here however, the interpretations are mostly hypothetical, with very few empirical clues.

It is crucial to verify, and this verification has been conducted in other studies as well. For this dataset, please refer to (Fernandes et al. 2021; Fancello et al. 2023), and for a similar dataset in Canada, consult (Kestens et al. 2016; Naud et al. 2020). In our paper, the primary objective was to introduce a novel approach to data analysis by examining the interdependence between network indices and assessing how this interdependence impacts well-being measures. We added this explanation in the introduction

Some fruitful references on the matter: Daatland & Lowenstein, 2005, relying on a survey of 6k respondents, provides insightful considerations on relationships (while not using network data) ; Wyngaerden et al, 2019, use personal network measures (ego-betweenness, etc) on 380 egos, with whom they have conducted face-to-face interviews, which provides rich empirical material.

We cited these papers in the introduction.

To conclude, i find the two ideas of this paper promising, but i don't agree any of the two claims have been sufficiently proved. Once again, the two deserve a paper per se (and keeping them both together blurs the argument), a better account of the state of the art should be taken, and the reduced size of the sample might be turned into a benefit by switching to more empirically-backed interpretative insights.

Thank you for your feedback. We hope that this revised version of the paper will meet your publication criteria.

Review by Paul Rochet, 04 Jul 2023 15:14

The paper is well-written and worthy of publication in my opinion, under minor revisions.

Thank you very much for your positive comments!

The author use various statistical tools to identify how various social network metrics linked to well-being (or absence thereof) of elderly are correlated. Some of the results of the analysis are statistically significant.

Specific remarks:

- I don't understand the sentence "... collinearity occurs when the correlations were approximately 0.9 or above". since the value 0.9 is purely arbitrary.

We added a reference and changed the sentence to: “The highest correlation (R^2) was 0.63, while collinearity is typically considered to be present when correlations are approximately 0.9 or higher (Franke, 2010).”

- As a non-expert in health related issues or social relationships, I did not understand what the sentence "people living with ego" (line 25) meant until later on in the paper (line 169).

Sorry about this. We added details: “was only linked to the number of people living (being in the same residence) with ego (i.e. the interviewed participant).”

- The approach that consists in replacing the Simmelian brokerage and clustering coefficients by their residuals from a linear regression of the network density seems a little questionable to me. I would suggest to measure instead of the significance of the unaltered variables in addition to the network density in the multivariate linear model.

Statistically speaking, it is not logical to separately test the effects of two independent variables on one different dependent variable in distinct tests, as we cannot determine whether these two dependent variables exhibit collinearity, which may result in false positives. Similarly, it is inadvisable to test the effects of two collinear independent variables on a dependent variable in a same model, as this could lead to false negatives by nullifying the genuine impact of one factor. This is why in this paper we initially examined variable correlations and employed a principal

component analysis (PCA) to identify which dependent variables contribute to the dimensions revealed by PCA and to elucidate their implications. If this was not clear, we detailed it now in the introduction.

- line 227, it would be better to use test for normality (ex: shapiro-wilk) and homoscedasticity (ex: Breusch-Pagan) than to "verify" it graphically. Or at least change the term "verify".

Sorry, we changed the sentence to: “We checked statistically several model assumptions (normality and homogeneity of residuals, variance inflation factors) and no obvious violations or influential cases were detected.”

- line 269, what does eigenvalue < 1 mean?

Sorry, we added details and references: eigenvalue < > 1 which is commonly accepted as significantly explaining the variance (Budaev, 2010; Holland, 2008; Smith, 2002).

- the information of tables 1 and 2 should be displayed graphically instead of in a table in my opinion.

Thank you. We are comfortable with representing these tables graphically. However, to be honest, we are unsure about how to condense all these variables, indicators, and values into figures. Do you have any suggestions in mind?

Review by anonymous reviewer 1, 25 Jul 2023 15:57

This paper analyzes the link between social network features and mental health outcomes in a cohort of older adults in Paris. This study contributes to a developing branch of the literature that tries to identify the influence of social behaviors on mental health, which has been recognized as a crucial public health issue over the last years. While the results do not conform with previous studies, since the authors do not find any evidence for a link between social network features (including the number of relationships) and mental health outcomes (i.e., depression, life satisfaction, and well-being), it may provide valuable insights. It is a good example of a study that should be published because it contributes to an important debate, even though it presents null results. Overall, the manuscript is clear, the survey methodology is interesting, and the text is straight to the point. I do not have many comments, but recommend some minor editing.

Thank you very much for your positive comments!

Major comment:

1. One point that could be further discussed is that mental health may not related to network features in a linear way. It could be that certain features matter only with some threshold effect (for example, having no friend at all has a negative effect on mental health, but once someone has at least one friend, they are “protected” from loneliness). Because the sample is small, this might have gone undetected. Looking at extreme cases or separating the sample between individuals with high levels of depression and the rest might help identifying whether this is the case or not.

You are right. First we checked the different correlations between variables and we did not observe sigmoid function indicating a threshold effect. Moreover, we added a new paragraph in the discussion: One other possible criticism is that the relationship between mental health and network features may not follow a linear pattern. Threshold effects could be at play, where certain network characteristics have a significant impact only once they cross a specific threshold. For example, complete social isolation may indeed have a detrimental effect on mental health, but having at least one friend could provide a protective effect against loneliness. The study's small sample size might not have been sufficient to detect such threshold effects. We checked however for sigmoid functions indicating a threshold effect and did not find such nonlinear data. Further investigation into extreme cases or subgroup analysis could shed light on these nuances. By doing so, researchers could examine whether specific network characteristics have a more

pronounced impact on those who are already experiencing higher levels of depression, potentially identifying critical thresholds or nonlinear relationships that might not be evident in the overall analysis. This approach could provide a deeper understanding of how social networks influence mental health and may help uncover patterns that were not apparent in the primary analysis due to the limitations of the small sample size.

Minor comments:

1. The title is misleading, as the authors do not examine the “drivers of social networks”, and they also do not look at health but specifically at mental health. It would be good to reformulate it to fit more closely the content of the paper.

We changed the title.

2. The manuscript should be proofread. There are quite a few spelling mistakes and grammatical or syntactic errors. Examples: line 13: “Social network is an important factor”, line 60 “social networks is the webs”, line 72 “network size interacts with personal cognitive and physical decline”(this sentence does not make sense to me), line 127 “our study felt during the Covd-19”, etc.

Done.

3. The fourth dimension of the PCA seems difficult to interpret as it is. I would consider either not interpreting at all the results for this dimension or try to understand further what it represents.

We added more details about the dimension 4: “To understand this dimension more deeply, it's important to recognize that the Simmelian brokerage metric is a complex value measure that assesses the strength of Simmelian ties. These ties extend beyond the simple strength of a relationship, taking into account the number of strong reciprocal ties within a group. In other words, Simmelian ties signify that there must be at least three or more mutual strong ties within a specific network group for them to exist. When considering the residuals of the Simmelian brokerage, we are essentially examining what remains after removing the influence of network density. Since these residuals form a distinct dimension, separate from assortativity (dimension 1) and ego centrality (dimension 2), it implies that they capture a specific aspect of connectivity or relationship dynamics that is not fully explained by either network density, the clustering coefficient, or Simmelian brokerage. While the exact interpretation of dimension 4 may require further investigation and analysis, it suggests that it represents a unique feature of participants' social networks, potentially related to their social integration or network structure. Further research could help uncover the specific nature of this dimension and its implications for participants' well-being and social interactions.”

4. Considering the size of the sample, it seems possible to investigate specific cases more closely. In particular, the authors could examine (qualitatively) the cases of the individuals who reported high levels of depression.

5. The specific context (Paris) may explain the counter-intuitive results of this study, as the authors note line 415. For readers who do not know the city, it could be good to explain this point a bit more.

We added a paragraph: “Paris presents a unique setting for epidemiological research due to its densely populated urban environment, socioeconomic and cultural diversity, and access to healthcare services. The city's multicultural population and varying socioeconomic statuses introduce complexities in studying social networks and their associations with health. Factors like lifestyle, access to resources, and the cost of living in Paris can impact social network dynamics and health outcomes. Additionally, the city's public health initiatives and environmental factors, such as air quality and traffic congestion, play a role in the health of its residents. Researchers must consider these specific characteristics of Paris when conducting epidemiological studies to provide meaningful insights into the relationships between social networks and health.”