Peer Review Information

Journal: Nature Human Behaviour
Manuscript Title: Fresh teams are associated with original and multi-disciplinary research
Corresponding author name(s): Shlomo Havlin

Editorial Notes:

Reviewer Comments & Decisions:

Decision Letter, initial version:

25th September 2020

Dear Dr. Havlin,

Thank you once again for your manuscript, entitled "The critical role of fresh teams in creating original and multi-disciplinary research", and for your patience during the peer review process.

Your Article has now been evaluated by 3 referees. You will see from their comments copied below that, although they find your work of potential interest, they have raised quite substantial concerns. In light of these comments, we cannot accept the manuscript for publication, but would be interested in considering a revised version if you are willing and able to fully address reviewer and editorial concerns.

We hope you will find the referees' comments useful as you decide how to proceed. If you wish to submit a substantially revised manuscript, please bear in mind that we will be reluctant to approach the referees again in the absence of major revisions. We are committed to providing a fair and constructive peer-review process. Do not hesitate to contact us if there are specific requests from the reviewers that you believe are technically impossible or unlikely to yield a meaningful outcome.

To guide the scope of the revisions, the editors discuss the referee reports in detail within the team, including with the chief editor, with a view to (1) identifying key priorities that should be addressed in revision and (2) overruling referee requests that are deemed beyond the scope of the current study. We hope that you will find the prioritised set of referee points to be useful when revising your study. Please do not hesitate to get in touch if you would like to discuss these issues further.

In particular, Reviewer 3 highlights the fact that the current datasets all cover only one discipline each, and results could differ for multi-disciplinary research teams. Although the reviewer does not

insist on a new analysis, from an editorial standpoint, we feel that the reviewer's suggestion to include an additional multidisciplinary dataset is important, and we ask that your revision include a replication of the findings in an independent dataset.

Additionally, Reviewer 2 highlights the important concern that your manuscript interprets your results causally and makes directional claims, though your analyses are correlational. You revision must thoroughly address this point by ensuring that no causal claims are made or implied based on correlational evidence.

Related to this point, the reviewers highlight a number of alternative mechanisms and considerations, including the possible roles of scientist age, distance between scientists, low-citation papers, one-shot authors, and the strength of collaboration ties. Your revision must address these concerns, including the additional analyses and robustness checks suggested by the reviewers to address these points.

Finally, your revised manuscript must comply fully with our editorial policies and formatting requirements. Failure to do so will result in your manuscript being returned to you, which will delay its consideration. To assist you in this process, I have attached a checklist that lists all of our requirements. I have also attached a template manuscript file that exemplifies our policies and formatting requirements. If you have any questions about any of our policies or formatting, please don't hesitate to contact me.

If you wish to submit a suitably revised manuscript we would hope to receive it within 6 months. We understand that the COVID-19 pandemic is causing significant disruptions which may prevent you from carrying out the additional work required for resubmission of your manuscript within this timeframe. If you are unable to submit your revised manuscript within 6 months, please let us know. We will be happy to extend the submission date to enable you to complete your work on the revision.

With your revision, please:

• Include a "Response to the editors and reviewers" document detailing, point-by-point, how you addressed each editor and referee comment. If no action was taken to address a point, you must provide a compelling argument. This response will be used by the editors to evaluate your revision and sent back to the reviewers along with the revised manuscript.

• Highlight all changes made to your manuscript or provide us with a version that tracks changes.

Please use the link below to submit your revised manuscript and related files:

[REDACTED]

Note: This URL links to your confidential home page and associated information about manuscripts you may have submitted, or that you are reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage.

Thank you for the opportunity to review your work. Please do not hesitate to contact me if you have any questions or would like to discuss the required revisions further.

Sincerely,

Reviewer expertise:

Reviewer #1: network science, statistical physics

Reviewer #2: science of science, economics

Reviewer #3: network science, science of science

REVIEWER COMMENTS:

Reviewer #1:
Remarks to the Author:
The paper gives an interesting new perspective on the point of the study of collaboration networks. In particular, thanks to the definitions given in this paper it is possible to compute the freshness of teams in the writing of a paper.
One point that I did not understand for the specific example of the data base used is if the authors have been able to detect previous collaboration also outside from the database considered. If not I would like to ask to the authors if they can comment on this point and if they believe to take into account this possibility at least in a statistical sense.
The paper is clear, well written and add a new feature to measure quantitatively such aspect of human behaviour, I am therefore in favour of publication on this journal

Reviewer #2:
Remarks to the Author:
Referee report on "The critical role of fresh teams in creating original and multi-disciplinary research"

This paper studies the relationship between the freshness of a team (defined in terms of previous coauthorship between team members), a measure of originality and a measure of multi-disciplinary impact. The paper is based primarily on a large dataset of scientific articles published in the American Physical Society. The authors find freshness is positively correlated with originality and multi-disciplinary impact. The freshness concept (and associated results) is an interesting addition to the literature on scientific teams. The results also have relevant policy implications – policy makers should encourage the formation of new teams. However, I have some concerns about the presentation of results and their interpretation (see below).

Major comments

1) The paper is full of causal language and claims (Here are two examples [page 3]: "Our results suggest that having new team members is more powerful than new collaboration relations in increasing the originality and impact diversity of the resultant papers."; [page 4] "The first question we ask here is whether and how team freshness affects the originality and impact diversity of the produced work."). Yet, there is absolutely no basis for claiming causality here – to claim causality one would need a randomized controlled trials (say assigning the same problem to different teams) or a natural experiment of some kind. What the authors find and document are correlations, which can be interesting, but they should not be described as causal relationships. I am aware that some prior papers in this literature have made similarly misleading causal claims but that is not a reason to make misleading claims here.

2) Freshness is going to be mechanically correlated with a number of other things: prior productivity of team members, age of team members and prior scientific distance between team members; and distinguishing these really matter for the interpretation.

2a) The authors discuss career freshness (close to age of team members) and present a number of results. Do they check whether relationship between team freshness and disruption/multidisciplinary impact remains when controlling for career age of team members (similar to figure S4 for team member productivity)? What I have in mind here is fixing career freshness and see if the effect of team freshness remain. If the relationship between team freshness and disruption/multidisciplinary impact just reflect a scientist age effect, that changes the overall interpretation a lot.
Relatedly, the paper fails to cite less alone engage any paper in the literature on age and scientific production (for a review see Jones, Reedy & Weinberg "Age and Scientific Genius" in the Handbook of Genius).

2b) Individuals who are further in scientific space will tend to collaborate less together. When they do, they will from fresher teams. Is the team freshness essentially capturing prior scientific distance between team members? I would like to see some exploration and discussion of this.

Reviewer #3:
Remarks to the Author:
The paper explores the relationship of the freshness teams in publications against novelty, and multidisciplinarity. For that, the authors employed a disambiguated dataset from APS Journals and measured these three characteristics. Freshness is drawn in terms of how new a team is by looking at the team members' past collaborations. Dispersion is used to measure the novelty of papers. While these two characteristics are already present in the literature, the paper also introduces a new multidisciplinarity measurement that does not rely on disciplines. To my knowledge, measurements like that were not well explored in the Science of Science literature, so I believe this may also be a huge contribution from this paper.

The authors found that fresh teams are more likely to publish novel and multi-disciplinary papers; among other interesting findings.
While the results are all based on correlations, the authors explored many facets of their findings by repeating the experiments with controlled properties, such as academic age and productivity of authors.

The paper is very interesting, scientifically sound, to my knowledge, novel, and reveals important behavior of researcher teams in science, a topic that I find very suitable for this journal. The findings of this paper shed a light on the topic and may allow future development of models and predictive pipelines. In addition, the paper is well organized, well written, and clear.

Before fully recommending it for publication I have a few main concerns and comments that I list below:

- While disruption itself does not correlate with citations, the range of possible values (maybe in terms of std. dev.) seems to correlate with it, or at least present two behaviors, as observed in Figure S2(a). Maybe this is due to papers with a small number of citations also having a small number of samples to calculate disruption. Besides, given the power-law nature of citation distribution among papers, those with a low number of citations dominate the dataset. It would be interesting to see if the findings of the relationship between freshness and disruption still hold when controlling the number of citations (maybe repeat the analysis considering two groups of papers: a set of highly and another for lowly cited).

- The paper focused the analysis on the APS dataset, which incorporates mainly Physics research, but also provides similar findings for two other datasets: computer science and Chemistry. Still, in all three cases, the citations and authors are limited to a single discipline. For instance, papers and authors researching transdisciplinary topics may be under-represented on these datasets. Is it possible to extend the findings for this case? I suggest the authors to briefly discuss this limitation and ways to overcome it, or maybe justify why the results should still be valid even by incorporating authors and papers outside of these research topics. Maybe the relationship between career freshness is due to the existence of researchers appearing rarely in that discipline but that may be respectable in another.
- What are the difficulties of repeating the analysis on a more comprehensive dataset, such as WoS?

- A quick look at the disambiguated dataset used by the authors shows that there are many one-shot authors (about 43%), i.e., authors with just one publication in APS journals. Do you think this type of collaboration could artificially inflate freshness? How did you handle these authors? Also, one-shot authors are usually complicated to disambiguate. Thus, are the results robust enough to account for one-shot authors and possible errors in the disambiguation?

- Have you tried to incorporate the frequency of collaborations to the freshness calculation? Currently, any publication can change the landscape of the authors, which can be problematic for authors that also publish in big science (like astronomy or high energy physics). Also, I'm not sure if this is the case of APS, but sometimes top researchers may work on editorial, reviews, or recommendations papers that artificially bring them together in a publication even them never effectively collaborating among themselves. So maybe the authors could discuss a little bit about this or tell why this may not have a significant impact on their findings. An easy way to account for the frequency of previous collaborations would be repeating the analysis only considering strong ties between authors that frequently happened in the past. Another way to account for that would be introducing a memory effect, so only the most recent collaborations are counted to calculate freshness. But this is just a suggestion.

Author Rebuttal to Initial comments

Dear Dr. Aisha Bradshaw
Nature Human Behavior
Editor

Thank you very much for considering our manuscript for *Nature Human Behaviour* and we thank you and the reviewers for the efforts and time in reviewing our work. We are grateful that all three reviewers appreciate our study and raised a number of insightful and constructive comments that could improve our paper. We have revised the manuscript to fully address all the comments of editors and reviewers. In particular, their comments motivated us to conduct further analysis to strengthen our claims, to make more accurate statements, and to clarify better the details of our results. A detailed, point-to-point response to the editor and the referees is given below. Important revisions in the manuscript are shown in red fonts. We believe that the revised manuscript meets the high standard of *Nature Human Behaviour.*

Best regards
Shlomo Havlin (on behalf of all authors of NATHUMBEHAV-200711654)

Response to the Editor

In particular, Reviewer 3 highlights the fact that the current datasets all cover only one discipline each, and results could differ for multi-disciplinary research teams. Although the reviewer does not insist on a new analysis, from an editorial standpoint, we feel that the reviewer's suggestion to include an additional multidisciplinary dataset is important, and we ask that your revision include a replication of the findings in an independent dataset.

Reply: We thank Reviewer 3 and the Editor for this comment. According to this suggestion, we analyzed an independent dataset which contains all papers in five representative multi-disciplinary journals including *Nature, Science, Proceedings of the National Academy of Sciences (PNAS), Nature Communications and Science Advances.* The dataset consists of 633808 papers and 1077399 authors, ranging from year 1869 to year 2020 (Nature: 1869-2020, Science: 1880-2020, PNAS: 1915-2020, Nat. Commun.: 2010-2020, Sci. Adv.: 2015-2020). **The author names in this data are already disambiguated. The data was downloaded freely from Microsoft Academic Graph** (https://docs.microsoft.com/en-us/academic-services/graph/).

We performed the same framework and analysis developed in the original manuscript and find similar effect of team freshness in this dataset of multi-disciplinary journals. Please see the results in Fig. R6 and Fig. R7 (in our reply to the second comment of reviewer 3). In particular, the results in Fig. R6 show a clear positive correlation between team freshness and disruption/multi-disciplinary impact. In Figs. R7(a,d), we find that fresh teams of different sizes have higher disruption and multi-disciplinary impact than old teams. We also observe in Figs. R7(b,e) that incorporating link freshness to node freshness does not bring significantly higher correlation with disruption and multi-disciplinary impact. Finally, we find in Figs. R7(c,f) that disruption and multi-disciplinary impact is negatively correlated with mean career age of the teams in this dataset.

Additionally, Reviewer 2 highlights the important concern that your manuscript interprets your results causally and makes directional claims, though your analyses are correlational. You revision must thoroughly address this point by ensuring that no causal claims are made or implied based on correlational evidence.

Reply: We thank reviewer 2 for this important comment. We have carefully rephrased all the corresponding text in the manuscript to ensure that no casual claims are made based on our correlation analyses. Major modifications are marked in red in the revised manuscript.

Related to this point, the reviewers highlight a number of alternative mechanisms and considerations, including the possible roles of scientist age, distance between scientists, low-citation papers, one-shot authors, and the strength of collaboration ties. Your revision must address these concerns, including the additional analyses and robustness checks suggested by the reviewers to address these points.

Reply: Thanks. To address this issue, we have conducted a number of further control analyses. Figs. R2, R4, R5, R8 and R9 analyze these issues as detailed below.

In Fig. R2, we consider teams with similar mean career age, and study the relation between team freshness and disruption/multi-disciplinarity (see our reply to the second comment of reviewer 2).

In Fig. R4, we control the mean distance between team members. We quantify the distance d_{ij} between scientist i and scientist j in the scientific space by their dis-similarity in research interests. For each scientist i, we construct a set Γ_i recording all the references in his/her papers, representing the research literature he/she is interested in. The distance d_{ij} between scientist i and scientist j can thus be calculated as their Jaccard dis-similarity $d_{ij} = 1 - |\Gamma_i \cap \Gamma_j|/|\Gamma_i \cup \Gamma_j|$ where $|.|$ is the size of the set. For each paper, we calculate the mean distance d_{ij} between team members by using the data before they coauthor this paper. We then take teams with similar mean distance between the team members, and study the relation between team freshness and disruption/multi-disciplinarity (see our reply to the third comment of reviewer 2).

In Fig. R5, we further control the citation of papers by repeating our analyses in papers with similar citations. We compare two groups of papers: highly cited papers $c \geq 30$ and lowly cited papers $3 \leq c \leq 5$ (see our reply to the first comment of reviewer 3).

We also agree with the reviewer 3 that one-shot authors might inflate the team freshness. Despite that there are 43% one-shot authors in the APS data, we find interestingly that these one-shot authors are in only 15.7% papers in APS. This is because multiple one-shot authors often cluster in the same paper. Therefore, 84.3% APS papers do not contain any one-shot authors. We further support our findings in Fig. R8 by carrying out the same analyses in papers without any one-shot authors (see our reply to the third comment of reviewer 3).

In addition, we consider a generalization of our definition of computing team freshness by taking into account the strength of collaboration ties. The freshness of a team of a paper is defined as the fraction of team members who have collaborated fewer than m papers with any of other team

members before they coauthor this paper. When $m=1$, it returns to the original definition of team freshness. The case $m>1$ corresponds to a looser definition of team freshness where scientists having coauthored fewer than m papers with each other are still regarded as a fresh team when they work together next time. In Fig. R9, we study the relation between the weighted definition of team freshness and disruption/multi-disciplinarity. Different settings of the parameter m are tested (see our reply to the fourth comment of reviewer 3).

In all control analyses designed above, we observe the consistent and systematic effect of team freshness as found in the original manuscript, i.e. fresher teams are associated with higher disruption and higher multi-disciplinarity in their published works. These results have been added to the revised supplementary materials and shortly discussed in the revised manuscript.

Finally, your revised manuscript must comply fully with our editorial policies and formatting requirements.

Reply: Thanks. We have carefully checked point-by-point the checklist attached in the decision letter. We have made sure that all editorial policies and formatting requirements are fully complied in the revised manuscript.

Response to Reviewer #1

The paper gives an interesting new perspective on the point of the study of collaboration networks. In particular, thanks to the definitions given in this paper it is possible to compute the freshness of teams in the writing of a paper.

One point that I did not understand for the specific example of the data base used is if the authors have been able to detect previous collaboration also outside from the database considered. If not I would like to ask to the authors if they can comment on this point and if they believe to take into account this possibility at least in a statistical sense.

The paper is clear, well written and add a new feature to measure quantitatively such aspect of human behaviour, I am therefore in favour of publication on this journal

Reply: Thanks a lot for the comment, for finding the paper clear and for being in favor of publication. In the manuscript, we analyze the scientific publications data of the American Physical Society (APS) journals. We are not able to detect scientists' collaboration outside from the APS dataset. Ideally, one could detect all of a scientist's previous collaboration relations via the Web of Science (WoS) data. However, as we do not have access to the WoS data (the access fee is very expensive), we carry out our analysis in the freely available APS data. Since the APS dataset is a large dataset recording the advances in physics since 1893, it covers a large part of individual physicists' publications and their collaboration relations [Nature Physics 11, 791 (2015)]. Also a recent work has pointed out the equivalence of APS and WoS data to study physicists [Science 354, aaf5239 (2016), see its supplementary materials S1.5]. We thus believe that the team freshness calculated via the APS data set can well approximate the team freshness calculated via the WoS data.

The suggestion to take into account the possibility of capturing collaboration outside our dataset in a statistical sense is very interesting, and we thank the referee for pointing out this. One possibility is to use the link prediction algorithm to predict the missing links in the collaboration networks. To this end, we use the APS data set as the training set and use the *Resource Allocation* link prediction algorithm [Eur. Phys. J. B 71, 623 (2009)] to predict and add missing collaboration relations to the data. According to the literature [PNAS 112, 2325 (2019)], the accuracy of the *Resource Allocation* method is one of the top best for scientific collaboration networks (AUC=0.933, precision=0.541). After adding the predicted links to the collaboration networks, we recalculate the team freshness of each paper. We then study the relation between the new team freshness and disruption/multi-disciplinarity of the published papers in Fig. R1 below. We find that the curves of data with predicted links overlap well with those of the original data, confirming the positive correlations between team freshness and disruption/multi-disciplinarity. These results have been added to the supplementary materials and are briefly discussed in the revised manuscript.
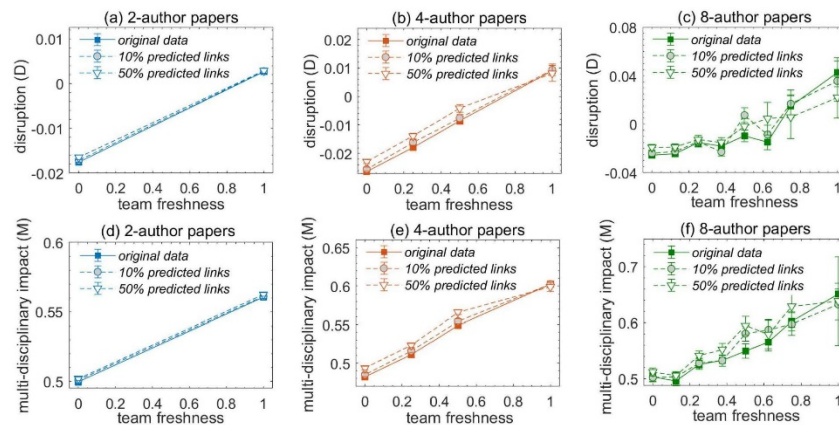

Fig. R1. The dependence of the disruption *D* and multi-disciplinarity *M* of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. The team freshness is respectively calculated in both the original APS data and the data with predicted links. Denoting *E* as the number of links in the original APS collaboration network, we add *10%*E* or *50%*E* most likely missing links to the collaboration network, with the likelihood estimated via the Resource Allocation method. In these cases, a team is fully fresh only if the team members have no prior collaboration in the APS data and no added missing links connecting them.

Response to Reviewer #2

This paper studies the relationship between the freshness of a team (defined in terms of previous coauthorship between team members), a measure of originality and a measure of multi-disciplinary impact. The paper is based primarily on a large dataset of scientific articles published in the American Physical Society. The authors find freshness is positively correlated with originality and multi-disciplinary impact. The freshness concept (and associated results) is an interesting addition

to the literature on scientific teams. The results also have relevant policy implications – policy makers should encourage the formation of new teams. However, I have some concerns about the presentation of results and their interpretation (see below).

Major comments

1) The paper is full of causal language and claims (Here are two examples [page 3]: "Our results suggest that having new team members is more powerful than new collaboration relations in increasing the originality and impact diversity of the resultant papers."; [page 4] "The first question we ask here is whether and how team freshness affects the originality and impact diversity of the produced work."). Yet, there is absolutely no basis for claiming causality here – to claim causality one would need a randomized controlled trials (say assigning the same problem to different teams) or a natural experiment of some kind. What the authors find and document are correlations, which can be interesting, but they should not be described as causal relationships. I am aware that some prior papers in this literature have made similarly misleading causal claims but that is not a reason to make misleading claims here.

Reply: Thanks for this comment and for finding our novel freshness concept interesting. We fully agree with the referee and have carefully revised all the corresponding texts in the manuscript to ensure that no casual claims are made based on our correlation analyses. In the discussion section, we have added a part in the second paragraph to further emphasize that our findings are correlational and not causal. Major modifications are marked in red in the revised manuscript.

The two examples mentioned above have been rephrased as "Our results suggest that freshness defined by new team members is more correlated with the originality and impact diversity of the resultant papers than freshness defined by new collaboration relations among team members" and "The first question we ask here is whether and how team freshness is correlated with the originality and impact diversity of the produced work".

2) Freshness is going to be mechanically correlated with a number of other things: prior productivity of team members, age of team members and prior scientific distance between team members; and distinguishing these really matter for the interpretation.

2a) The authors discuss career freshness (close to age of team members) and present a number of results. Do they check whether relationship between team freshness and disruption/multidisciplinary impact remains when controlling for career age of team members (similar to figure S4 for team member productivity)? What I have in mind here is fixing career freshness and see if the effect of team freshness remain. If the relationship between team freshness and disruption/multidisciplinary impact just reflect a scientist age effect, that changes the overall interpretation a lot.

Reply: Thanks for these good ideas. We fully agree with the reviewer that there is a correlation between career age of team members and team freshness. In Fig. 5 of the manuscript, we study the relation between career freshness and disruption/multidisciplinary impact when controlling team freshness. According to the excellent suggestion of the referee, below we fix the career freshness and check whether the effect of team freshness remains.

In Fig. R2 (see below), we consider teams with similar mean career age (i.e. controlling career freshness of the teams), and study the relation between their team freshness and disruption/multidisciplinary impact. We observe very similar findings as found in the manuscript, i.e. fresher teams are associated with higher disruption and higher multi-disciplinarity in their published works. The results suggest that the positive correlation between team freshness and disruption/multi-disciplinary impact is not an artifact of career freshness. Fig. R2 below has been added to the supplementary materials and is briefly discussed in the revised manuscript.
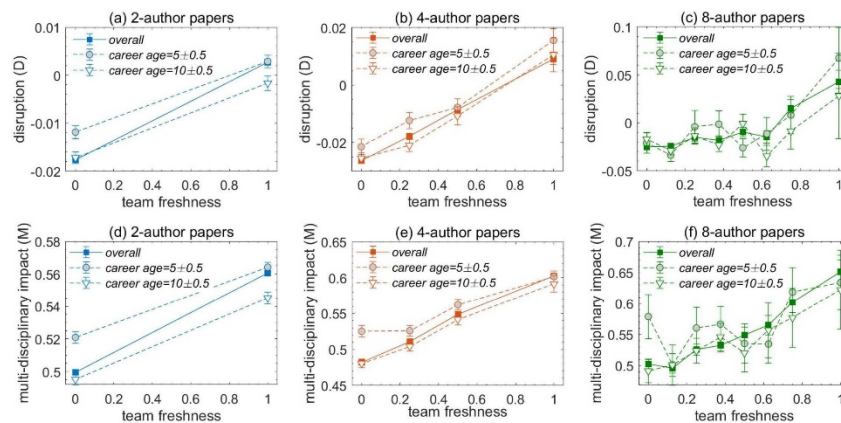

Fig. R2, The dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. We fix the career freshness by taking the teams of mean career age of team members in [4.5, 5.5] and [9.5, 10.5] years, respectively. After controlling the career freshness, one can still observe a clear positive correlation between team freshness and disruption/multidisciplinary impact.

Relatedly, the paper fails to cite less alone engage any paper in the literature on age and scientific production (for a review see Jones, Reedy & Weinberg "Age and Scientific Genius" in the Handbook of Genius).

Reply: Thanks for pointing out the missing references on age and scientific production. In the revised manuscript, we have cited the review mentioned above, together with several representative research articles on age and scientific production. The corresponding discussion on these references have been added in the introduction section of the revised version.

2b) Individuals who are further in scientific space will tend to collaborate less together. When they do, they will from fresher teams. Is the team freshness essentially capturing prior scientific distance between team members? I would like to see some exploration and discussion of this.

Reply: Thanks. This is an important comment. To consider this, we quantify the distance d_{ij} between scientist i and scientist j in the scientific space by the dis-similarity between them in their research interests. For each scientist i, we construct a set Γ_i recording all the references in his/her papers, representing the research literature he/she is interested in. The distance d_{ij} between scientist i and scientist j can thus be calculated as their Jaccard dis-similarity $d_{ij} = 1 - |\Gamma_i \cap \Gamma_j|/|\Gamma_i \cup \Gamma_j|$ where $|.|$ is the size of the set. For each paper, we calculate the mean distance d_{ij}

12

between team members by using the data before they coauthor this paper. We find that the mean distance d_{ij} is indeed positively correlated with team freshness (the Pearson correlation is 0.429 for 2-author papers, 0.401 for 4-author papers, 0.380 for 8-author papers). This finding is supported by Fig. R3 below where we show the mean distance d_{ij} for teams with different freshness. These results suggest that individuals who are further in scientific space indeed tend to form fresher teams.
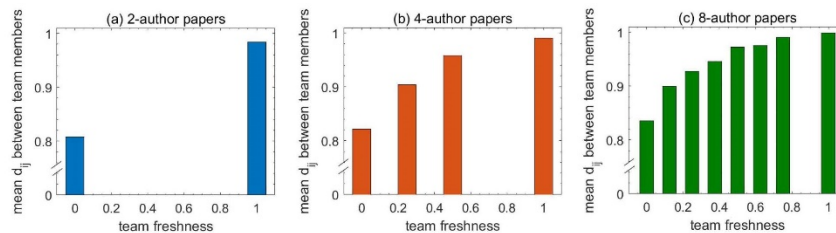

Fig. R3, The mean distance d_{ij} between team members in teams with different freshness for (a) 2-author papers, (b) 4-author papers, and (c) 8-author papers. As seen, teams with higher freshness tend to have higher mean scientific distance between team members.

We further analyze whether the team freshness captures additional information beyond scientific distance between team members. To this end, we control the mean distance between team members and study again the relation between team freshness and disruption/multi-disciplinarity. In Fig. R4, one can still detect a positive correlation between team freshness and disruption/multi-disciplinarity even when the mean distance between team members is fixed in a small range. Although less often, the scientists who are close in scientific space are forming fresh teams. Our results in Fig. R4 below suggest that those fresh teams are associated with higher disruption/multi-disciplinarity. Figs. R3 and R4 have been added to the supplementary materials and briefly discussed in the revised manuscript.
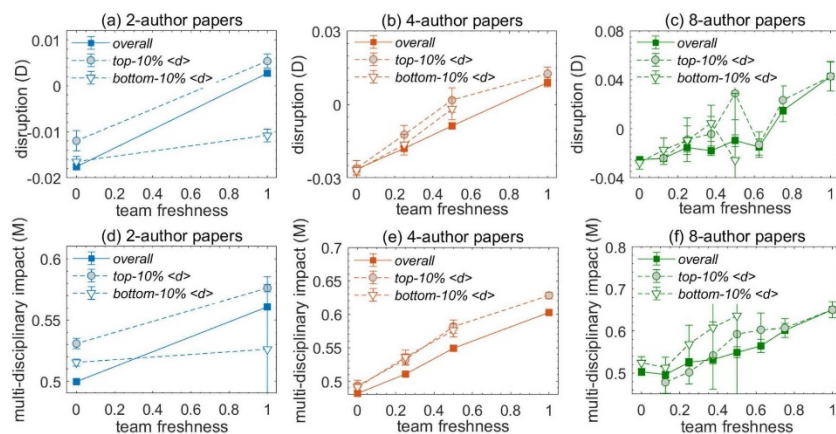

Fig. R4, The dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. We control here the scientific distance of team members. Specifically, we analyze the 10% teams with the largest mean distance <d> between team members and the 10% teams with the smallest mean distance <d> between team members.

13

We find that in both cases higher team freshness is associated with larger disruption and multi-disciplinary impact. In 4-author papers and 8-author papers, there are no results for large team freshness when fixing bottom 10% distance. This is because scientists who are very close in scientific space have high probability to collaborate with each other before, and thus cannot form a fully fresh team when they collaborate again.

Response to Reviewer #3

The paper explores the relationship of the freshness teams in publications against novelty, and multidisciplinarity. For that, the authors employed a disambiguated dataset from APS Journals and measured these three characteristics. Freshness is drawn in terms of how new a team is by looking at the team members' past collaborations. Dispersion is used to measure the novelty of papers. While these two characteristics are already present in the literature, the paper also introduces a new multidisciplinarity measurement that does not rely on disciplines. To my knowledge, measurements like that were not well explored in the Science of Science literature, so I believe this may also be a huge contribution from this paper.

The authors found that fresh teams are more likely to publish novel and multi-disciplinary papers; among other interesting findings. While the results are all based on correlations, the authors explored many facets of their findings by repeating the experiments with controlled properties, such as academic age and productivity of authors.

The paper is very interesting, scientifically sound, to my knowledge, novel, and reveals important behavior of researcher teams in science, a topic that I find very suitable for this journal. The findings of this paper shed a light on the topic and may allow future development of models and predictive pipelines. In addition, the paper is well organized, well written, and clear.

Before fully recommending it for publication I have a few main concerns and comments that I list below:

- While disruption itself does not correlate with citations, the range of possible values (maybe in terms of std. dev.) seems to correlate with it, or at least present two behaviors, as observed in Figure S2(a). Maybe this is due to papers with a small number of citations also having a small number of samples to calculate disruption. Besides, given the power-law nature of citation distribution among papers, those with a low number of citations dominate the dataset. It would be interesting to see if the findings of the relationship between freshness and disruption still hold when controlling the number of citations (maybe repeat the analysis considering two groups of papers: a set of highly and another for lowly cited).

Reply: Thanks to the referee for finding our paper "very interesting" and our novel measurements to be a "huge contribution", and for this important suggestion. In Fig. R5 below we followed the referee's excellent suggestion and control the citation of papers by repeating our analyses in papers with similar citations c. As suggested by the referee, we compare two groups of papers: highly cited papers ($c \geq 30$) and lowly cited papers ($3 \leq c \leq 5$). We find indeed that team freshness is positively

14

correlated with disruption/multi-disciplinarity in both highly and lowly cited papers. In addition, we observe a stronger correlation between team freshness and disruption for highly cited papers than for lowly cited papers. Fig. R5 has been added to the revised supplementary materials and is briefly discussed in the revised manuscript.
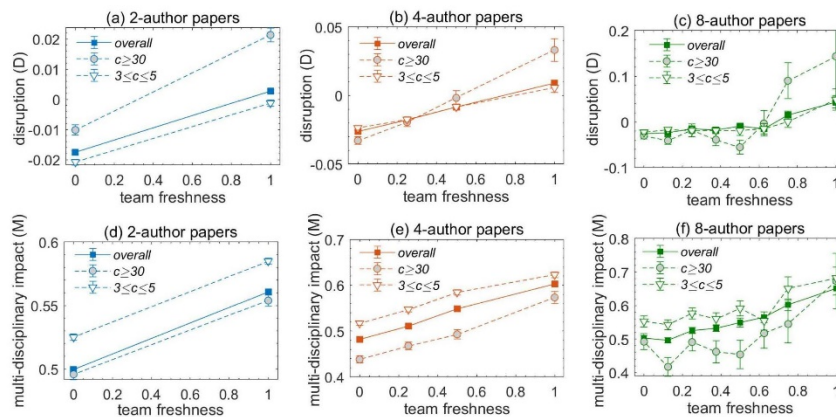

Fig. R5, The dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. Here, we compare the behavior of papers when controlling low and high numbers of citations. We consider a group of highly cited papers (with at least 30 citations) and another group of less cited papers (citations between 3 and 5). The results suggest that team freshness is positively correlated with disruption/multi-disciplinarity in both highly and lowly cited papers.

- The paper focused the analysis on the APS dataset, which incorporates mainly Physics research, but also provides similar findings for two other datasets: computer science and Chemistry. Still, in all three cases, the citations and authors are limited to a single discipline. For instance, papers and authors researching transdisciplinary topics may be under-represented on these datasets. Is it possible to extend the findings for this case? I suggest the authors to briefly discuss this limitation and ways to overcome it, or maybe justify why the results should still be valid even by incorporating authors and papers outside of these research topics. Maybe the relationship between career freshness is due to the existence of researchers appearing rarely in that discipline but that may be respectable in another.
- What are the difficulties of repeating the analysis on a more comprehensive dataset, such as WoS?
Reply: Thanks for this outstanding advice. Actually, one has to pay to access the full Web of Science (WoS) data, and the access fee is very expensive. Since we do not have access to WoS, we can carry out our analysis in freely available datasets, including the APS data in the original manuscript and two large-scale datasets about Computer Science and Chemistry in the supplementary materials.

According to the very good suggestion by the referee, we analyzed in the revised mansucript an additional large dataset which contains all papers in five representative multi-disciplinary journals including *Nature, Science, Proceedings of the National Academy of Sciences (PNAS), Nature Communications and Science Advance*s. Papers and authors researching transdisciplinary topics are

15

well captured in this dataset. The dataset consists of 633808 papers and 1077399 authors, ranging from year 1869 to year 2020 (Nature: 1869-2020, Science: 1880-2020, PNAS: 1915-2020, Nat. Commun.: 2010-2020, Sci. Adv.: 2015-2020). The author names in this data are already disambiguated. The data was downloaded freely from Microsoft Academic Graph (https://docs.microsoft.com/en-us/academic-services/graph/).

We performed the same analysis as in the original manuscript and the results are presented in Fig. R6 and Fig. R7 below. The first observation is that both disruption and multi-disciplinary impact of the papers in this dataset are generally higher than those in the APS dataset. In addition, we find similar effect of team freshness in this dataset of multi-disciplinary journals. Specifically, the results in Fig. R6 show a clear positive correlation between team freshness and disruption/multi-disciplinary impact. In Figs. R7(a,d), we find that fresh teams have higher disruption and multi-disciplinary impact than old teams for teams of different size. We also observe in Figs. R7(b,e) that incorporating link freshness to node freshness does not bring significantly higher correlation with disruption and multi-disciplinary impact, which is similar to the original manuscript. Finally, we find in Figs. R7(c,f) that disruption and multi-disciplinary impact is negatively correlated with mean career age of the teams in this dataset. We discuss these new results in the revised manuscript and added Figs. R6 and R7 to the revised SM.
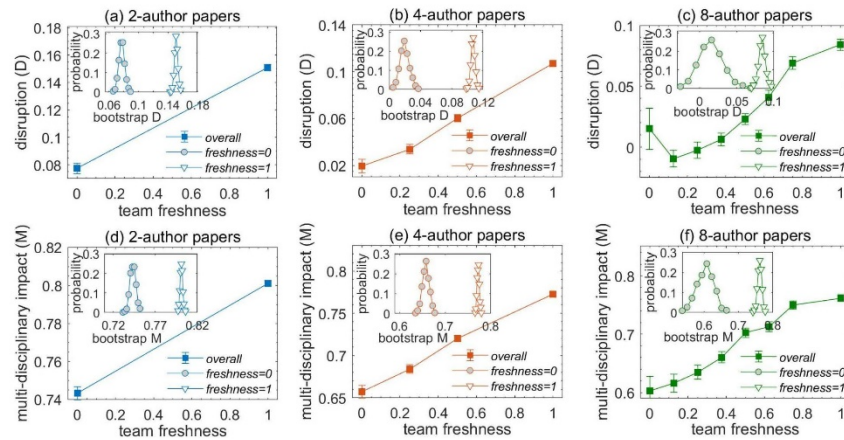

Fig. R6, Dependence of disruption (originality) and multi-disciplinarity on team freshness for the multi-disciplinary data set. Shown are the dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. The results suggest that both originality and multi-disciplinarity significantly increase with team freshness. The insets show the distributions of bootstrap disruption or bootstrap multi-disciplinarity. A remarkable difference, i.e., high significance, can be observed between the distributions of D of papers with team freshness 0 and 1.
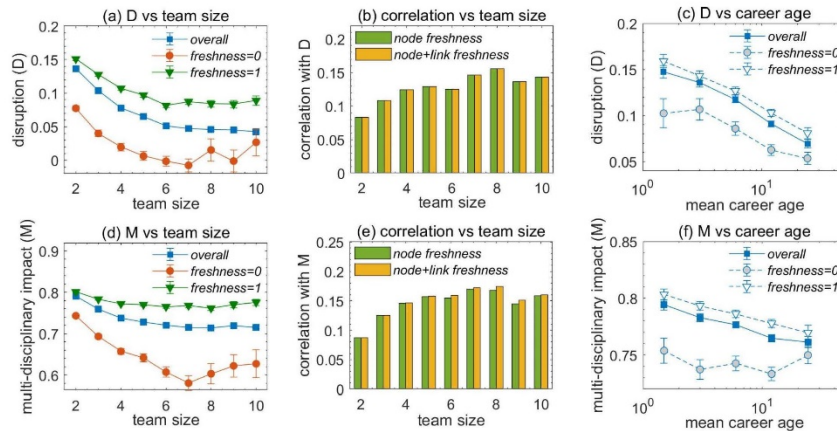
Fig. R7, Other effects of freshness in the multi-disciplinary data. Plot of (a) the mean disruption D and (d) the mean multi-disciplinary impact M of papers versus different team sizes. For each team size, we also study the mean disruption D and the mean multi-disciplinary impact M of papers published by old teams (freshness=0) and fresh teams (freshness=1). (b) The Pearson correlation of node freshness and disruption for papers of different team sizes. (e) The Pearson correlation of node freshness and multi-disciplinary impact for papers of different team sizes. For comparison, we calculate the maximum Pearson correlation when we consider team freshness as a weighted linear combination of node and link freshness. We show also the dependence of (c) the mean disruption D and (f) multi-disciplinarity M on team members' mean career age in 2-author papers.

- A quick look at the disambiguated dataset used by the authors shows that there are many one-shot authors (about 43%), i.e., authors with just one publication in APS journals. Do you think this type of collaboration could artificially inflate freshness? How did you handle these authors? Also, one-shot authors are usually complicated to disambiguate. Thus, are the results robust enough to account for one-shot authors and possible errors in the disambiguation?

Reply: Thanks. This is also an important comment. We agree with the reviewer that the team freshness might be inflated by the one-shot authors. We therefore checked carefully the data and confirm that there are indeed around 43% authors in APS are one-shot authors (102357 such authors out of 236884 total authors). However, we also find interestingly that these one-shot authors represent only 15.7% papers in APS (75989 such papers out of 482566 total papers). This is because multiple one-shot authors often cluster in the same paper. Therefore, 84.3% APS papers do not contain any one-shot authors. Nevertheless, to test the bias raised by the referee, we tested and confirmed our findings in Fig. R8 below by carrying out the same analyses in papers without any one-shot authors. In Fig. R8, one can observe that the curves after removing one-shot authors overlap well with those obtained from the original data, indicating that our findings are robust and not caused by the one-shot authors. Fig. R8 has been added to the supplementary materials and the results of Fig. R8 are briefly discussed in the revised manuscript.

For the sake of author name disambiguation, we use the author name dataset provided by Sinatra et al. which is obtained with a comprehensive disambiguation process in the APS data [Science 354, aaf5239 (2016)]. Specifically, authors are first disambiguated according to their first and last names.

When two authors have the same full name, or the same initials and same last name, one of the following three conditions must be fulfilled for them to be considered as the same individual: (1) The two authors cited each other at least once; (2) The two authors share at least one co-author; (3) The two authors share at least one similar affiliations. We agree with the reviewer that one-shot authors are usually complicated to disambiguate as they have fewer papers to check condition (1) and (2). However, condition (3) can effectively disambiguate one-shot authors, as their affiliations can be extracted from their single papers. In general, the false positive rate and the false negative rate of this disambiguation method are 2% and 12%, respectively. The same name disambiguation process as in ref. [Science 354, aaf5239 (2016)] is made to the Computer Science and Chemistry datasets.
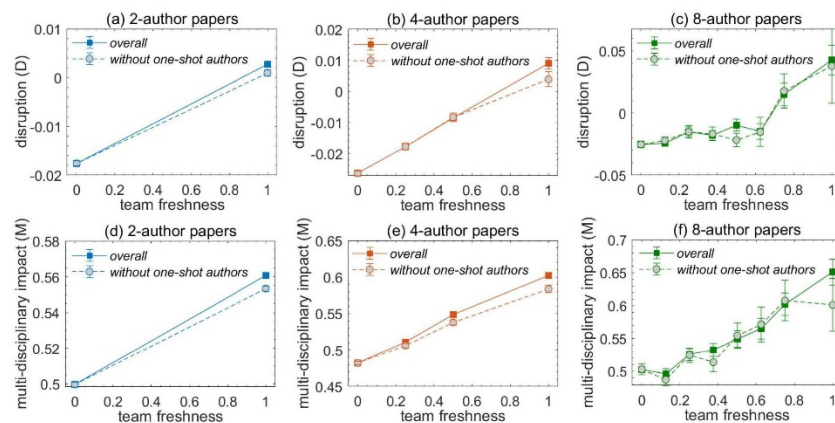

Fig. R8, The dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. We study here the relation between team freshness and disruption/multi-disciplinarity in the APS data where all one-shot authors are removed.

- Have you tried to incorporate the frequency of collaborations to the freshness calculation? Currently, any publication can change the landscape of the authors, which can be problematic for authors that also publish in big science (like astronomy or high energy physics). Also, I'm not sure if this is the case of APS, but sometimes top researchers may work on editorial, reviews, or recommendations papers that artificially bring them together in a publication even them never effectively collaborating among themselves. So maybe the authors could discuss a little bit about this or tell why this may not have a significant impact on their findings. An easy way to account for the frequency of previous collaborations would be repeating the analysis only considering strong ties between authors that frequently happened in the past. Another way to account for that would be introducing a memory effect, so only the most recent collaborations are counted to calculate freshness. But this is just a suggestion.

Reply: Thanks a lot for this good suggestion. Accordingly, we consider in the revised manuscript a more general definition of team freshness by taking into account the strength of prior collaboration ties. The freshness of a team of a paper is defined as the fraction of team members who have collaborated fewer than m papers with any of other team members before they coauthor this paper.

18

When $m=1$, it returns to the original definition of team freshness. The case $m>1$ corresponds to a looser definition of team freshness where scientists having coauthored fewer than m papers with each other are still regarded as a fresh team when they work together next time. In this case, the team freshness is mainly determined by strong ties. In Fig. R9 below, we study the relation between the weighted definition of team freshness and disruption/multi-disciplinarity. Different settings of the parameter m are tested. One can observe positive correlations between team freshness and disruption/multi-disciplinarity when $m>1$. However, the correlation under $m>1$ is weaker than that under $m=1$. This is because the looser definition of the team freshness will classify some teams with lower freshness in the original definition to the fully fresh teams, which decreases the average disruption/multi-disciplinarity of the fully fresh teams. For the sake of simplicity, we preserve the original definition ($m=1$) in the manuscript and present the results of $m>1$ in the revised supplementary materials.
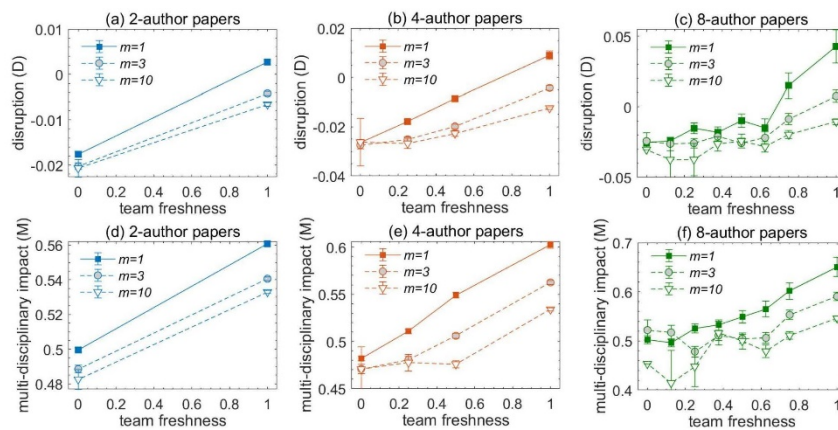

Fig. R9, The dependence of the disruption D and multi-disciplinarity M of papers on the team freshness, for (a)(d) 2-author papers, (b)(e) 4-author papers, (c)(f) 8-author papers, respectively. We consider here a more general definition of team freshness in which team freshness mainly determined by strong ties. In this new definition, scientists having published fewer than m coauthored papers with each other will still be regarded as a fresh team when they work together next time. We study the relation between the new team freshness and disruption/multi-disciplinarity under $m=3$ and $m=10$. In these settings, positive correlations can still be observed.

Decision Letter, first revision:

5th November 2020

Dear Professor Havlin,

RE: "The critical role of fresh teams in creating original and multi-disciplinary research"

Thank you for submitting your revised manuscript and for all your work on the revision.

Although your manuscript has been revised in response to reviewer comments, it does not fully comply with our editorial policies and formatting requirements. In particular, your manuscript still contains causal language and suggests that the project can answer a question that is directional (i.e. the impact of team freshness on science). For instance, page 8 includes the statement "These results suggest that larger fresh teams play a more important role than small fresh teams in advancing science with new and original ideas and opportunities," and page 3 reads "we also study the effect of the career freshness of team members." Our policy is that authors must not use causal language to describe research questions and results addressed through associational evidence and methods. We therefore ask that you further revise your manuscript to address this remaining concern.

We also require that all inferential statistical results be fully reported, including coefficients/effect sizes, p-values, and confidence intervals. For results presented in tables or only mentioned in the main text, you should indicate the location in the Supplementary Information where the relevant full set of statistical information can be found.

Before we can send the manuscript back to our reviewers, we ask that you revise it to ensure that it does not contain causal claims and complies fully with our policies on reporting statistical results. I have attached another copy of our checklist, as well as the template document that exemplifies our formatting and policy requirements. If you are uncertain as to how to address any of the points in the checklist, please don't hesitate to contact me.

Please use the link below to submit your revised manuscript and related files:

[REDACTED]

Note: This URL links to your confidential home page and associated information about manuscripts you may have submitted, or that you are reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage.

Thank you in advance for attending to these requests and I look forward to receiving your revised manuscript.

Sincerely,
Aisha

Aisha Bradshaw

![natureresearch]

Editor
Nature Human Behaviour

| Author Rebuttal, first revision: |

Dr. Aisha Bradshaw
Nature Human Behavior
Editor

Dear Dr. Bradshaw

Thank you very much for sending us the second letter explaining the issues remaining in our revised manuscript. We have made further modifications accordingly and also ensured that all editorial policies and formatting requirements are fully complied in the revised manuscript.

We would like to thank you and the reviewers again for the efforts and time in reviewing our work. We are grateful that all three reviewers appreciated our study and raised a number of insightful and constructive comments for improving our paper. We have revised the manuscript to fully address all the comments of editors and reviewers. In particular, their comments motivated us to conduct further extensive analysis to strengthen our claims, to make more accurate statements, and to clarify better the details of our results.

Please see below our responses to your comments in the first and second letters. A detailed, point-to-point response to the referees is also given below. Important revisions in the manuscript are shown in red fonts. We believe that the revised manuscript meets the high standard of *Nature Human Behaviour.*

Best regards
Shlomo Havlin (on behalf of all authors of NATHUMBEHAV-200711654)

Response to the Editor's second letter

Although your manuscript has been revised in response to reviewer comments, it does not fully comply with our editorial policies and formatting requirements. In particular, your manuscript still contains causal language and suggests that the project can answer a question that is directional (i.e. the impact of team freshness on science). For instance, page 8 includes the statement "These results suggest that larger fresh teams play a more important role than small fresh teams in advancing science with new and original ideas and opportunities," and page 3 reads "we also study the effect of the career freshness of team members." Our policy is that authors must not use causal language to describe research questions and results

addressed through associational evidence and methods. We therefore ask that you further revise your manuscript to address this remaining concern.

Reply: Thanks for noticing these sentences we unfortunately missed in the revision. We have carefully gone through the whole manuscript again and rephrased all the corresponding text to ensure that no casual claims are made. To remove the flavor of causality, we also modified the title of the paper to "The critical association of fresh teams with original and multi-disciplinary research". Major modifications are marked in red in the revised manuscript.

We also require that all inferential statistical results be fully reported, including coefficients/effect sizes, p-values, and confidence intervals. For results presented in tables or only mentioned in the main text, you should indicate the location in the Supplementary Information where the relevant full set of statistical information can be found.

Reply: Thanks for the detailed instructions. We have made sure that we report now in the revised manuscript the Pearson coefficients, p-values, and confidence intervals for all inferential statistical results. For the main paper figures, the Pearson correlation coefficients together with the 95% confidence intervals and p-values are summarized in the tables presented in the supplementary tables and we refer to those tables in the main paper. For the figures in the supplementary materials, we have added the Pearson correlation coefficients together with the 95% confidence intervals and p-values directly in the figure captions.

Decision Letter, second revision:

22nd January 2021

*Please ensure you delete the link to your author homepage in this e-mail if you wish to forward it to your co-authors.

Dear Professor Havlin,

Thank you once again for submitting your revised manuscript, entitled "The critical association of fresh teams with original and multi-disciplinary research," and for your patience during the re-review process.

Your manuscript has now been evaluated by our referees, and in the light of their advice I am delighted to say that we can in principle offer to publish it. First, however, we would like you to revise your paper to address the remaining points made by the reviewers, and to ensure that it complies with our Guide to Authors at http://www.nature.com/nathumbehav/info/gta.

One of the main reasons for delays in formal acceptance is failure to fully comply with editorial policies and formatting requirements. To assist you with finalizing your manuscript for publication, I attach a checklist that lists all of our editorial policies and formatting requirements. I also attach a template document, which exemplifies our policies and formatting requirements.

Please attend to *every item* in the checklist and upload a copy of the completed checklist with your submission. I have highlighted in the checklist items that require your attention, but please carefully

check each point. I also mention here a few points that are frequently missed and can cause delays, as well as some specific points that will need attention:

1) Ensure that all corresponding authors have linked their ORCID to their account on our online manuscript handling system. This is very frequently missed and invariably causes delays in formal acceptance.

2) Ensure that you provide all of the materials requested in the attached checklist and below with your final submission.

3) Ensure that the Results section clearly indicates where full statistical results (coefficients/effect sizes, p-values, and confidence intervals) can be found for each result discussed. That is, this section should include references to the relevant Supplementary Tables, in addition to the existing references to the figures.

4) For Figures 2, 3, and 5, please ensure that graph axes start at (or include) zero. The range of the axes should also be consistent across panels within the same figure.

5) Because your manuscript cannot establish causality or the direction of the relationship between team freshness and originality/multi-disciplinary impact, we ask that you remove the recommendations for what funders and researchers should do (i.e. any policy recommendations) from the Discussion section.

6) In order to avoid qualitative characterizations of your work, we ask that you remove "critical" from the title. We suggest rephrasing as 'Fresh teams are associated with original and multi-disciplinary research', but the choice of title is largely yours.

Nature Human Behaviour offers a transparent peer review option for new original research manuscripts submitted from 1st December 2019. We encourage increased transparency in peer review by publishing the reviewer comments, author rebuttal letters and editorial decision letters if the authors agree. Such peer review material is made available as a supplementary peer review file. Please state in the cover letter 'I wish to participate in transparent peer review' if you want to opt in, or 'I do not wish to participate in transparent peer review' if you don't. Failure to state your preference will result in delays in accepting your manuscript for publication.
Please note: we allow redactions to authors' rebuttal and reviewer comments in the interest of confidentiality. If you are concerned about the release of confidential data, please let us know specifically what information you would like to have removed. Please note that we cannot incorporate redactions for any other reasons. Reviewer names will be published in the peer review files if the reviewer signed the comments to authors, or if reviewers explicitly agree to release their name. For more information, please refer to our FAQ page.

We hope to hear from you within three weeks; please let us know if the revision process is likely to take longer.

To submit your revised manuscript, you will need to provide the following:
• Cover letter
• Point-by-point response to the reviewers (if applicable)

nature research

- Manuscript text (not including the figures) in .docx or .tex format
- Individual figure files (one figure per file)
- Extended Data & Supplementary Information, as instructed
- Reporting summary
- Editorial policy checklist
- Third-party rights table (if applicable)
- Suggestions for cover illustrations (if desired)

Consortia authorship:
For papers containing one or more consortia, all members of the consortium who contributed to the paper must be listed in the paper (i.e., print/online PDF). If necessary, individual authors can be listed in both the main author list and as a member of a consortium listed at the end of the paper. When submitting your revised manuscript via the online submission system, the consortium name should be entered as an author, together with the contact details of a nominated consortium representative. See https://www.nature.com/authors/policies/authorship.html for our authorship policy and https://www.nature.com/documents/nr-consortia-formatting.pdf for further consortia formatting guidelines, which should be adhered to prior to acceptance.

Reviewer Recognition:
In recognition of the time and expertise our reviewers provide to Nature Human Behaviour's editorial process, we would like to formally acknowledge their contribution to the external peer review of your manuscript entitled "The critical association of fresh teams with original and multi-disciplinary research". For those reviewers who give their assent, we will be publishing their names alongside the published article.

Forms:
Nature Human Behaviour has now transitioned to a unified Rights Collection system which will allow our Author Services team to quickly and easily collect the rights and permissions required to publish your work. Once your paper is accepted, you will receive an email in approximately 10 business days providing you with a link to complete the grant of rights. If you choose to publish Open Access, our Author Services team will also be in touch at that time regarding any additional information that may be required to arrange payment for your article.

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If you have any questions please contact ASJournals@springernature.com.

Please use the following link for uploading these materials:
[REDACTED]

If you have any further questions, please feel free to contact me.

With best regards,
Aisha

Aisha Bradshaw
Editor

Nature Human Behaviour

Reviewer #1:
Remarks to the Author:
I am satisfied by the authors changes to the manuscript, they made extra work and answered all my requests. I am in favour of publication in the present form

Reviewer #2:
Remarks to the Author:
My comments have been adequately addressed. No further comments.

Reviewer #3:
Remarks to the Author:
With the newly revised manuscript, the authors addressed all the issues I raised. In particular, I am convinced that the main results can not be explained by simple/trivial mechanisms given the new experiments with more controlled variables. The authors also provided results for another dataset of interdisciplinary research, which yield a similar outcome. I'm also glad that the authors clarified that their analyses can not be interpreted as causal relationships, something I missed to mention in my original revision (but were raised by the other reviewers). Currently, I have no extra major comments but a minor suggestion:

The new paragraphs starting on pages 6 and 7 are too long and hard to follow (too many concepts). I would recommend the authors to break them down into smaller paragraphs.

Aside from that minor correction, I recommend the paper for publication.

Author Rebuttal, second revision:

Dr. Aisha Bradshaw
Nature Human Behavior
Editor

Dear Dr. Bradshaw

Thank you very much for sending us the positive decision letter. We have made modifications to address the remaining points raised by reviewer 3, and to ensure that the revised manuscript complies with all editorial policies and formatting requirements.

Please see below our responses to your comments, as well as our response to the comments of reviewer 3. Important revisions in the manuscript are shown in red fonts. We hope that the revised manuscript can be formally accepted in Nature Human Behaviour.

Best regards
Shlomo Havlin (on behalf of all authors of NATHUMBEHAV-200711654)

Response to the Editor

Please attend to *every item* in the checklist and upload a copy of the completed checklist with your submission. I have highlighted in the checklist items that require your attention, but please carefully check each point. I also mention here a few points that are frequently missed and can cause delays, as well as some specific points that will need attention:
Reply: Thanks for highlighting the checklist items. We have carefully checked each point and make sure that our revised manuscript complies with these requirements. We have submitted a marked Editorial policy checklist through the online submission system.

1) Ensure that all corresponding authors have linked their ORCID to their account on our online manuscript handling system. This is very frequently missed and invariably causes delays in formal acceptance.
Reply: Thanks. My ORCID is http://orcid.org/0000-0002-9974-5920. I have linked my ORCID to my account in the online manuscript handling system.

2) Ensure that you provide all of the materials requested in the attached checklist and below with your final submission.
Reply: Thanks. We have provided all of the materials requested in the checklist and listed in the decision letter.

3) Ensure that the Results section clearly indicates where full statistical results (coefficients/effect sizes, p-values, and confidence intervals) can be found for each result discussed. That is, this section should include references to the relevant Supplementary Tables, in addition to the existing references to the figures.
Reply: Thanks. We have added references in the Results section to the relevant Supplementary Tables showing the full statistical results.

4) For Figures 2, 3, and 5, please ensure that graph axes start at (or include) zero. The range of the axes should also be consistent across panels within the same figure.
Reply: Thanks. We have modified figures 2, 3 and 5 to ensure that these figures comply with the requirements above. There are several specific points we would like to clarify. In Fig. 2, we have ensured

graph axes start at (or include) zero. However, Fig. 2 a-c and Fig. 2d-f present results of different metrics (i.e. disruption and multi-disciplinary impact, respectively), and the range of these two metrics are very different by definition (i.e., disruption can be negative but multi-disciplinary impact is always positive). So we have ensured that the range of the y-axes are consistent within Fig. 2 a-c and within Fig. 2 d-f. Similar modifications have been made to Figs. 3 and 5. That is, we have ensured that all y-axes start at (or include) zero and the range of the axes are consistent within the panels showing the same metric. Finally, we would like to clarify that since we study teams, we do not take into account one-author papers. There is thus no data point for team size 0 and 1 in the x-axes in Fig. 3. Therefore, the x-axes in Fig. 3 start at 2.

5) Because your manuscript cannot establish causality or the direction of the relationship between team freshness and originality/multi-disciplinary impact, we ask that you remove the recommendations for what funders and researchers should do (i.e. any policy recommendations) from the Discussion section.
Reply: Thanks for this comment. Accordingly, as your suggested, we have removed the recommendations for what funders and researchers should do from the Discussion section.

6) In order to avoid qualitative characterizations of your work, we ask that you remove "critical" from the title. We suggest rephrasing as 'Fresh teams are associated with original and multi-disciplinary research', but the choice of title is largely yours.
Reply: Thanks. Following your suggestion, we have rephrased the title of our paper as 'Fresh teams are associated with original and multi-disciplinary research'.

Nature Human Behaviour offers a transparent peer review option for new original research manuscripts submitted from 1st December 2019. We encourage increased transparency in peer review by publishing the reviewer comments, author rebuttal letters and editorial decision letters if the authors agree. Such peer review material is made available as a supplementary peer review file. Please state in the cover letter 'I wish to participate in transparent peer review' if you want to opt in, or 'I do not wish to participate in transparent peer review' if you don't. Failure to state your preference will result in delays in accepting your manuscript for publication.
Reply: Thanks. I wish to participate in transparent peer review.

Response to Reviewer #3

With the newly revised manuscript, the authors addressed all the issues I raised. In particular, I am convinced that the main results can not be explained by simple/trivial mechanisms given the new experiments with more controlled variables. The authors also provided results for another dataset of interdisciplinary research, which yield a similar outcome. I'm also glad that the authors clarified that their analyses can not be interpreted as causal relationships, something I missed to mention in my original

revision (but were raised by the other reviewers). Currently, I have no extra major comments but a minor suggestion:

The new paragraphs starting on pages 6 and 7 are too long and hard to follow (too many concepts). I would recommend the authors to break them down into smaller paragraphs.

Aside from that minor correction, I recommend the paper for publication.
Reply: Thanks for the comment. In the revised manuscript, we have accordingly broken the new paragraphs on page 6 and 7 into four smaller paragraphs for better readability. Finally, we thank you again for your insightful comments that have significantly improved our manuscript.

Final Decision Letter:

Dear Professor Havlin,

We are pleased to inform you that your Article "Fresh teams are associated with original and multi-disciplinary research", has now been accepted for publication in Nature Human Behaviour.

Before your manuscript is typeset, we will edit the text to ensure it is intelligible to our wide readership and conforms to house style. We look particularly carefully at the titles of all papers to ensure that they are relatively brief and understandable.

Once your manuscript is typeset and you have completed the appropriate grant of rights, you will receive a link to your electronic proof via email with a request to make any corrections within 48 hours. If, when you receive your proof, you cannot meet this deadline, please inform us at rjsproduction@springernature.com immediately. Once your paper has been scheduled for online publication, the Nature press office will be in touch to confirm the details.

Acceptance of your manuscript is conditional on all authors' agreement with our publication policies (see http://www.nature.com/nathumbehav/info/gta). In particular your manuscript must not be published elsewhere and there must be no announcement of the work to any media outlet until the publication date (the day on which it is uploaded onto our web site).

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With best regards,
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