Epistasis between cultural traits causes paradigm shifts in cultural evolution

Ignacio Pascual, Jacobo Aguirre, Susanna Manrubia and José A. Cuesta

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Note: This manuscript was transferred from another Royal Society journal with peer review.

Review History
RSOS-191813.R0 (Original submission)

Review form: Reviewer 1

Is the manuscript scientifically sound in its present form?
Yes

Are the interpretations and conclusions justified by the results?
Yes

Is the language acceptable?
Yes

Do you have any ethical concerns with this paper?
No

Have you any concerns about statistical analyses in this paper?
No

Recommendation?
Major revision is needed (please make suggestions in comments)
Comments to the Author(s)

In this work the authors present a model for paradigms shift along cultural evolution, based on Axelrod’ s original proposal for cultural evolution. The main conclusion in this work is that epistasis, properly defined in the context of the present model, is responsible for these shifts.

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4) The nodes are numbered and ordered accordingly. If we locate the nodes in the ring, the epistasis, when present, links each node with its neighbours in only one direction and always in order. Is this restriction something that could affect the results? It is hard to accept that there is no reciprocity in the epistasis unless the value of k is close to the value of N.

5) The fitness, that is governing the evolution of the cultural profile of the population, is not affected by homophily so why should homophily be important? Is not that a trivial results?

Review form: Reviewer 2

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Yes

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Is the language acceptable?
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Do you have any ethical concerns with this paper?
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Have you any concerns about statistical analyses in this paper?
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Recommendation?
Accept with minor revision (please list in comments)

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Decision letter (RSOS-191813.R0)

14-Jan-2020

Dear Dr Cuesta

On behalf of the Editors, I am pleased to inform you that your Manuscript RSOS-191813 entitled “Epistasis between cultural traits causes paradigm shifts in cultural evolution” has been accepted for publication in Royal Society Open Science subject to minor revision in accordance with the referee suggestions. Please find the referees' comments at the end of this email.
The reviewers and handling editors have recommended publication, but also suggest some minor revisions to your manuscript. Therefore, I invite you to respond to the comments and revise your manuscript.

• Ethics statement
If your study uses humans or animals please include details of the ethical approval received, including the name of the committee that granted approval. For human studies please also detail whether informed consent was obtained. For field studies on animals please include details of all permissions, licences and/or approvals granted to carry out the fieldwork.

• Data accessibility
It is a condition of publication that all supporting data are made available either as supplementary information or preferably in a suitable permanent repository. The data accessibility section should state where the article's supporting data can be accessed. This section should also include details, where possible of where to access other relevant research materials such as statistical tools, protocols, software etc can be accessed. If the data has been deposited in an external repository this section should list the database, accession number and link to the DOI for all data from the article that has been made publicly available. Data sets that have been deposited in an external repository and have a DOI should also be appropriately cited in the manuscript and included in the reference list.

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http://datadryad.org/submit?journalID=RSOS&manu=RSOS-191813

• Competing interests
Please declare any financial or non-financial competing interests, or state that you have no competing interests.

• Authors’ contributions
All submissions, other than those with a single author, must include an Authors’ Contributions section which individually lists the specific contribution of each author. The list of Authors should meet all of the following criteria; 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

All contributors who do not meet all of these criteria should be included in the acknowledgements.

We suggest the following format:
AB carried out the molecular lab work, participated in data analysis, carried out sequence alignments, participated in the design of the study and drafted the manuscript; CD carried out the statistical analyses; EF collected field data; GH conceived of the study, designed the study, coordinated the study and helped draft the manuscript. All authors gave final approval for publication.

• Acknowledgements
Please acknowledge anyone who contributed to the study but did not meet the authorship criteria.

• Funding statement
Please list the source of funding for each author.

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publish your manuscript without the end statements. We have included a screenshot example of the end statements for reference. If you feel that a given heading is not relevant to your paper, please nevertheless include the heading and explicitly state that it is not relevant to your work.

Because the schedule for publication is very tight, it is a condition of publication that you submit the revised version of your manuscript before 23-Jan-2020. Please note that the revision deadline will expire at 00.00am on this date. If you do not think you will be able to meet this date please let me know immediately.

To revise your manuscript, log into https://mc.manuscriptcentral.com/rsos and enter your Author Centre, where you will find your manuscript title listed under "Manuscripts with Decisions". Under "Actions," click on "Create a Revision." You will be unable to make your revisions on the originally submitted version of the manuscript. Instead, revise your manuscript and upload a new version through your Author Centre.

When submitting your revised manuscript, you will be able to respond to the comments made by the referees and upload a file "Response to Referees" in "Section 6 - File Upload". You can use this to document any changes you make to the original manuscript. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response to the referees. We strongly recommend uploading two versions of your revised manuscript:

1) Identifying all the changes that have been made (for instance, in coloured highlight, in bold text, or tracked changes);
2) A 'clean' version of the new manuscript that incorporates the changes made, but does not highlight them.

When uploading your revised files please make sure that you have:

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3) Included a 100 word media summary of your paper when requested at submission. Please ensure you have entered correct contact details (email, institution and telephone) in your user account;
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If your manuscript is newly submitted and subsequently accepted for publication, you will be asked to pay the article processing charge, unless you request a waiver and this is approved by Royal Society Publishing. You can find out more about the charges at https://royalsocietypublishing.org/rsos/charges. Should you have any queries, please contact openscience@royalsociety.org.

Once again, thank you for submitting your manuscript to Royal Society Open Science and I look forward to receiving your revision. If you have any questions at all, please do not hesitate to get in touch.

Kind regards,
Andrew Dunn
Royal Society Open Science Editorial Office
Royal Society Open Science
openscience@royalsociety.org

on behalf of Professor Matjaz Perc (Associate Editor) and Miles Padgett (Subject Editor)
openscience@royalsociety.org

Reviewer comments to Author:
Reviewer: 1

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Author’s Response to Decision Letter for (RSOS-191813.R0)

See Appendix A.
Dear Dr Cuesta,

It is a pleasure to accept your manuscript entitled "Epistasis between cultural traits causes paradigm shifts in cultural evolution" in its current form for publication in Royal Society Open Science. The comments of the reviewer(s) who reviewed your manuscript are included at the foot of this letter.

Please ensure that you send to the editorial office an editable version of your accepted manuscript, and individual files for each figure and table included in your manuscript. You can send these in a zip folder if more convenient. Failure to provide these files may delay the processing of your proof. You may disregard this request if you have already provided these files to the editorial office.

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Thank you for your fine contribution. On behalf of the Editors of Royal Society Open Science, we look forward to your continued contributions to the Journal.

Kind regards,
Royal Society Open Science Editorial Office
Royal Society Open Science
openscience@royalsociety.org

on behalf of Professor Matjaz Perc (Associate Editor) and Miles Padgett (Subject Editor)
openscience@royalsociety.org

Associate Editor Comments to Author (Professor Matjaz Perc):
Associate Editor
Comments to the Author:
Thank you for the comprehensive revision of your manuscript, which we are happy to accept for publication in Royal Society Open Science.

Reviewer comments to Author:

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Follow Royal Society Publishing on Facebook:
https://www.facebook.com/RoyalSocietyPublishing.FanPage/
Read Royal Society Publishing's blog: https://blogs.royalsociety.org/publishing/
Dear Editor of Royal Society Open Science,

Thank you very much for your accepting our manuscript for publication in Royal Society Open Science. We have gone through all minor comments that the referees made and either fixed them or provided a response to them all. In what follows you will find the detailed responses.

Best wishes,

J. A. Cuesta, on behalf of all authors

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There y axis in b and d was incorrectly labeled, thank you for spotting the error: it has to be population density. All simulations have 64 nodes ($2^6$). The figure has been substituted by its raw, unedited version for clarity. Here, any impression of a different number of nodes is due to the 2D projection.

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Appendix A

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We have moved previous subsections introducing the definition of fitness landscapes and Kauffman’s NK model; they precede now the definition of the system dynamics. The last paragraph in the latter section has been also moved for consistency and an introductory sentence (highlighted in red) has been added.

3) **There seems to be an inconsistency in the definition of dH. The first definition states that it is the usual Hamming distance, i.e. the number of differences in the values of the cultural traits between two nodes. But later the authors say that the maximum value of dH is reached for a given value of alpha. How is that the Hamming distance depends on alpha if it only measures the number of coincidences? At least this not clear considering the role assigned to alpha**

We are unable to spot the inconsistency stated by the referee. Indeed, dH is the usual Hamming distance. The maximum we talk about corresponds to a complex function of different parameters and variables, among them dH and the degree of homophily. And this function has a maximum when certain combination of dH and alpha occurs. This does not imply that dH depends on alpha since, as the referee states, it just measures the number of coincidences. This nonetheless, we have rephrased the sentence to clarify that it is not the increase in alpha that directly modifies the distance between individuals.

4) **The nodes are numbered and ordered accordingly. If we locate the nodes in the ring, the epistasis, when present, links each node with its neighbours in only one direction and always in order. Is this restriction something that could affect the results? It is hard to accept that there is no reciprocity in the epistasis unless the value of k is close to the value of N.**

Kauffman’s NK model is admittedly a cartoon model for real epistasis. However, we use it because its qualitative properties correctly capture the gross features of epistasis. In a cultural context, data are insufficient to describe even the most generic properties of the landscape. The reciprocity the reviewer mentions holds in general in molecular sequences, but perhaps this is not so in cultural traits. For example, being vegetarian implies that a person does not eat meat, but not eating meat can depend on other personal choices. Despite the lack of reciprocity implicit in the definition of the landscape, the fact that the NK model is able to quantitatively mimic the landscape of RNA secondary structure, for example, strongly supports that this restriction does not affect the results. (Note that nodes are linked to the same number of neighbors in both directions, as explained right after Eq. (2.2) – (2.10) in the previous version. Whether symmetrically linked, as done, or always in one direction and in order, is however irrelevant for the results.)

5) **The fitness, that is governing the evolution of the cultural profile of the population, is not affected by homophily so why should homophily be important? Is not that a trivial results?**

Homophily affects the distribution of the population in the fitness landscape, and it is in this sense that it might be important: it changes the cultural diversity and often clusters the population in separated groups. Still, it does not affect the occurrence of paradigm shifts. In our view, this result is not trivial. On the contrary, since homophily is an important factor in cultural spread, it is important to show that its presence does not condition the occurrence of such shifts.

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We have changed “term” by “factor”, since we meant the last “multiplicative term”.

2 – The description of the Kauffman’s NK landscape is a little bit confusing for me. Could the authors improve this section? Here, in line 27 which describe equation (2.10) they refer to an index |j| which seems to be absent in the mentioned equation.

Though there is some care required in the generations of fitness landscapes through Kauffman’s NK model, there are abundant examples that the reader can easily find. Therefore, we would prefer to keep this section (which is however self-contained) to a minimum, as it is.

The line below (former) equation (2.10) describes the meaning of the notation [j] for any value of j. We refer to an “abstract” index j because in the equation we use [i+1], [i+2], etc., and the definition applies to them all. For instance, if i+3 happens to be no larger than n, then [i+3]=i+3, whereas if i+3>n, then [i+3]=i+3-n. As a matter of fact, [j] is introduced as a shorthand for 1 + (j mod n) – which would definitely be more cumbersome to use in the expressions.

3 – I do not understand figure 1. Four panels refers to fitness as a function of tau for all nodes? Which are the difference between panels (a) and (b) (and between (c) and (d)?). They correspond to initial and final times of evolution? The description either in the text or in the caption are not enough to understand this figure.

We apologize for the mistake in the labels of axis y in panels (b) and (d), as spotted by the first referee and corrected in the new figure: these panels represent populations. Hopefully the representation is now clear. Also, the caption has been extended to better explain what is represented in each panel.

4 – In line 45 of page 8, when comparing figures 2 and 3, the refer to figure 2 (c). Should be Figure 2 (b)?

The reference to figure 2 (c) is correct. Note that figure 3 only represents the transitions in Fig. 2 (a) and (b), while the sudden shift (which is present in Fig. 2 (b), but not in Fig. 2 (a)) is qualitatively analogous to the transition in Fig. 2 (c) (not shown in Fig. 3).