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Idiosyncratic perception: a link between acuity, perceived position and apparent size

Zixuan Wang, Yuki Murai and David Whitney

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Original submission: 12 April 2020
Revised submission: 4 June 2020
Final acceptance: 15 June 2020

Note: Reports are unedited and appear as submitted by the referee. The review history appears in chronological order.

Review History

RSPB-2020-0825.R0 (Original submission)

Review form: Reviewer 1

Recommendation
Accept with minor revision (please list in comments)

Scientific importance: Is the manuscript an original and important contribution to its field?
Excellent

General interest: Is the paper of sufficient general interest?
Good

Quality of the paper: Is the overall quality of the paper suitable?
Excellent

Is the length of the paper justified?
Yes

Should the paper be seen by a specialist statistical reviewer?
No

Do you have any concerns about statistical analyses in this paper? If so, please specify them explicitly in your report.
No

It is a condition of publication that authors make their supporting data, code and materials available - either as supplementary material or hosted in an external repository. Please rate, if applicable, the supporting data on the following criteria.

Is it accessible?
Yes

Is it clear?
No

Is it adequate?
No

Do you have any ethical concerns with this paper?
No

Comments to the Author
This study builds on this lab's previous work on idiosyncrasies in stimulus localisation biases across the visual field. They report that areas of the visual field (which broadly appear to be whole wedge-shaped regions) where position biases are pronounced (Exp 1) are asssociated with poorer Vernier acuity (Exp 2) and also with more reduction in perceived size (Exp 3). These findings are interesting in that they link previously reported idiosyncratic perceptual fingerprints and suggest a common neural substrate for them. This is a high quality study and I only have a few minor comments.

1. Page 15, Line 283-287: The behavioural responses in the Vernier task may have been confusing to participants. When the stimuli were near the upper-right quadrant the stimulus-response mapping is intuitive: A counter-clockwise displacement of the outer line is to the left of the inner line, and this requires subjects to respond with the Left key. However, when the stimuli are in the polar opposite location this mapping is reversed: Here a counter-clockwise replacement is to the right of the inner line, but the require response is still the Left key. In my experience, the intuitiveness of stimulus-response mappings can be problematic. Such an asymmetry would be reflected in differences in performance that in turn could skew the results. However, I don't think this is likely to have been a major problem here because the observers were all trained in psychophysics and these things can certainly be learned. It should be easy to rule this out by inspecting the lapse rates, that is, how much variability there was in performance at the easiest Vernier displacements. Moreover, this effect should really occur mostly in the lower-left quadrant.

2. Line 309: What exactly do you mean by collapsing data into a super-subject? Does this mean a long pooled vector where each entry is a position from one given observer? An alternative approach would be to establish the correlation between measures for each observer first, and then establish the ground average correlation is different from zero. There are advantages and disadvantages to either approach and I am not suggestion which one the authors should use as the results are typically fairly consistent. But please clarify.

3. Sample sizes: Why were there only 3 observers in Exp 3? I don't think this is a problem as the results are pretty clear and you can treat each observer as an independent replication. But it is at odds with the other experiments so could probably use some explanation.

4. Terminology: You refer to low spatial distortion as contraction and high distortion as expansion. This makes sense to me but I think that terminology may be confusing, especially later

when you discuss the relationship to perceived size where *expansion* results in *smaller* perceived size. To avoid confusion it would help to signpost this more and explicitly define this again at this point.

5. Figure 1: Panel label C is missing from the figure itself.

Sam Schwarzkopf
University of Auckland

Review form: Reviewer 2

Recommendation
Major revision is needed (please make suggestions in comments)

Scientific importance: Is the manuscript an original and important contribution to its field?
Excellent

General interest: Is the paper of sufficient general interest?
Good

Quality of the paper: Is the overall quality of the paper suitable?
Good

Is the length of the paper justified?
Yes

Should the paper be seen by a specialist statistical reviewer?
No

Do you have any concerns about statistical analyses in this paper? If so, please specify them explicitly in your report.
No

It is a condition of publication that authors make their supporting data, code and materials available - either as supplementary material or hosted in an external repository. Please rate, if applicable, the supporting data on the following criteria.

Is it accessible?
Yes

Is it clear?
Yes

Is it adequate?
Yes

Do you have any ethical concerns with this paper?
No

Comments to the Author
The authors investigated idiosyncratic distortions of spatial vision in three experiments by measuring perceived position, acuity and perceived size at multiple locations in the visual field. The results show idiosyncratic and correlated distortions in all three tasks, which points to a

common origin. The measurements are very extensive and carefully conducted. I have only a few comments for improving the presentation of the results in the manuscript.

Presentation of individual biases: For Vernier acuity and perceived size, only the correlation with the spatial distortions from Experiment 1 is shown in Figures 2 and 3. I think it would be useful to show Vernier acuity and perceived size as a function of location for all observers to get a full picture of the spatial variations in those tasks as well.

Stability of biases: The authors point out that they found stable biases at several places in the manuscript. While I tend to agree with that assessment, I think the time span over which stability was assessed should be stated more clearly.

Minor comments
Stimuli in Experiment 1: The luminance of the background is not stated in the manuscript.

Line 78: The authors state that the monitor frame was covered by black tape to minimize the influence of references. This would make sense if the background of the monitor was black, but Figure 1a suggests that it was actually gray.

Figure 1b: I suggest using a color map with continuously increasing luminance. Positive and negative values are indistinguishable in gray scale print with the current color map.

Line 253: The authors might want to mention that Vernier acuity unlike other acuity measurements exceeds the spatial resolution limits imposed by the maximal cone density on the retina (thus also called hyperacuity, Westheimer, 1975) and therefore tests acuity at a cortical rather than a retinal level.

Line 328: I recommend to provide degrees of freedom of the test statistics and to specify exact p-values whenever they are larger than 0.001. Was that correlation calculated for all locations and for all observers? This might lead to the problem of pseudoreplication, where multiple observations on the same observers are treated as independent samples (Lazic, 2010).

Lines 448 and 452: The caption of Figure 3 refers to left and right with respect to psychometric functions and correlation plots, but the arrangement in the figure is rather top and bottom.

Line 490: With respect to the asymmetry along the vertical meridian, the authors might want to relate to the seminal theory by Previc (1990).

Line 511: There are also idiosyncratic biases in motor decisions (e.g. Schütz, 2014).

References
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Westheimer, G. (1975). Visual acuity and hyperacuity. Investigative Ophthalmology & Visual Science, 14(8), 570-572.

Decision letter (RSPB-2020-0825.R0)

12-May-2020

Dear Miss Wang:

Your manuscript has now been peer reviewed and the reviews have been assessed by an Associate Editor. The reviewers' comments (not including confidential comments to the Editor) and the comments from the Associate Editor are included at the end of this email for your reference. As you will see, the reviewers and the Editors have raised some concerns with your manuscript and we would like to invite you to revise your manuscript to address them.

We do not allow multiple rounds of revision so we urge you to make every effort to fully address all of the comments at this stage. If deemed necessary by the Associate Editor, your manuscript will be sent back to one or more of the original reviewers for assessment. If the original reviewers are not available we may invite new reviewers. Please note that we cannot guarantee eventual acceptance of your manuscript at this stage.

To submit your revision please log into http://mc.manuscriptcentral.com/prsb and enter your Author Centre, where you will find your manuscript title listed under "Manuscripts with Decisions." Under "Actions", click on "Create a Revision". Your manuscript number has been appended to denote a revision.

When submitting your revision please upload a file under "Response to Referees" - in the "File Upload" section. This should document, point by point, how you have responded to the reviewers' and Editors' comments, and the adjustments you have made to the manuscript. We require a copy of the manuscript with revisions made since the previous version marked as 'tracked changes' to be included in the 'response to referees' document.

Your main manuscript should be submitted as a text file (doc, txt, rtf or tex), not a PDF. Your figures should be submitted as separate files and not included within the main manuscript file.

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If your study uses animals please include details in the methods section of any approval and licences given to carry out the study and include full details of how animal welfare standards were ensured. Field studies should be conducted in accordance with local legislation; please include details of the appropriate permission and licences that you obtained to carry out the field work.

Data accessibility and data citation:
It is a condition of publication that you make available the data and research materials supporting the results in the article. Datasets should be deposited in an appropriate publicly available repository and details of the associated accession number, link or DOI to the datasets must be included in the Data Accessibility section of the article (https://royalsociety.org/journals/ethics-policies/data-sharing-mining/). Reference(s) to datasets should also be included in the reference list of the article with DOIs (where available).

In order to ensure effective and robust dissemination and appropriate credit to authors the dataset(s) used should also be fully cited and listed in the references.

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Online supplementary material will also carry the title and description provided during submission, so please ensure these are accurate and informative. Note that the Royal Society will not edit or typeset supplementary material and it will be hosted as provided. Please ensure that the supplementary material includes the paper details (authors, title, journal name, article DOI). Your article DOI will be 10.1098/rspb.[paper ID in form xxxx.xxxx e.g. 10.1098/rspb.2016.0049].

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Thank you for submitting your manuscript to Proceedings B; we look forward to receiving your revision. If you have any questions at all, please do not hesitate to get in touch.

Best wishes,
Dr Robert Barton
mailto: proceedingsb@royalsociety.org

Associate Editor
Comments to Author:
We have now heard from two experts. I am pleased to say that both are enthusiastic about your manuscript. Nevertheless, they have raised some issues that you will have to deal with before we can move forward. I invite you to submit a revised manuscript.

Reviewer(s)' Comments to Author:

Referee: 1

Comments to the Author(s)
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Author's Response to Decision Letter for (RSPB-2020-0825.R0)

See Appendix A.

Decision letter (RSPB-2020-0825.R1)

15-Jun-2020

Dear Miss Wang

I am pleased to inform you that your manuscript entitled "Idiosyncratic Perception: A Link Between Acuity, Perceived Position and Apparent Size" has been accepted for publication in Proceedings B.

You can expect to receive a proof of your article from our Production office in due course, please check your spam filter if you do not receive it. PLEASE NOTE: you will be given the exact page length of your paper which may be different from the estimation from Editorial and you may be asked to reduce your paper if it goes over the 10 page limit.

If you are likely to be away from e-mail contact please let us know. Due to rapid publication and an extremely tight schedule, if comments are not received, we may publish the paper as it stands.

If you have any queries regarding the production of your final article or the publication date please contact procb_proofs@royalsociety.org

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All supplementary materials accompanying an accepted article will be treated as in their final form. They will be published alongside the paper on the journal website and posted on the online figshare repository. Files on figshare will be made available approximately one week before the accompanying article so that the supplementary material can be attributed a unique DOI.

Thank you for your fine contribution. On behalf of the Editors of the Proceedings B, we look forward to your continued contributions to the Journal.

Sincerely,
Dr Robert Barton
Editor, Proceedings B
mailto: proceedingsb@royalsociety.org

Associate Editor:
Board Member
Comments to Author:
I have good news. I am recommending that your manuscript be accepted for publication in Proceedings. It is an excellent set of studies. Congratulations.

Appendix A

Responses to Referees

Referee: 1

Comments to the Author(s)

This study builds on this lab's previous work on idiosyncrasies in stimulus localisation biases across the visual field. They report that areas of the visual field (which broadly appear to be whole wedge-shaped regions) where position biases are pronounced (Exp 1) are asssociated with poorer Vernier acuity (Exp 2) and also with more reduction in perceived size (Exp 3). These findings are interesting in that they link previously reported idiosyncratic perceptual fingerprints and suggest a common neural substrate for them. This is a high quality study and I only have a few minor comments.

Response: Thank you very much for your positive review, careful reading, and constructive feedback. We have made each recommended change in the manuscript.

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there was in performance at the easiest Vernier displacements. Moreover, this effect should really occur mostly in the lower-left quadrant.

Responses: Good point, and good idea. Following the advice above, we have confirmed that there was no difference in lapse rates at different locations [No significant performance difference between upper (M = 96.43%, SD = 4%) and lower (M = 96.87%, SD = 3%) visual field ($F(1,52) < 0.2$, $p > .5$). There is no significant difference between left (M = 97.32%, SD = 4%) and right (M = 95.98%, SD = 4%) visual field ($F(1,52) < 1.6$, $p > .2$). The interaction between upper/lower and left/right visual field is not significant either ($F(1,52) < .6$, $p > .4$)]. All participants were well-trained and experienced in psychophysics, as well.

2. Line 309: What exactly do you mean by collapsing data into a super-subject? Does this mean a long pooled vector where each entry is a position from one given observer? An alternative approach would be to establish the correlation between measures for each observer first, and then establish the ground average correlation is different from zero. There are advantages and disadvantages to either approach and I am not suggestion which one the authors should use as the results are typically fairly consistent. But please clarify.

Responses: Thank you for asking about it. Our analysis of data from Experiment 2 originally followed the first analysis that Referee 1 mentioned here. However, as Referee 2 suggested, this analysis might be subject to the problem of pseudoreplication (Lazic, 2010). Therefore, instead of analyzing the super-subject data, to separate multiple dependent observations from each observer and independent observers, we performed the second analysis Referee 1 suggested here with additional analyses listed below.

1. We calculated the Pearson's correlation between spatial distortions and Vernier acuity on every observer separately. This yielded 7 Pearson's *r* values, which were transformed to Fisher *z* values, averaged together and then transformed back to Pearson's *r*. This resulted in an average correlation of 0.34. We also performed a bootstrap procedure on these correlation values. On each iteration, we randomly sampled 7 correlation values with replacement from the 7 empirical correlation values and applied a Fisher transformation on each sample. Then the 7 Fisher *z* values were averaged together and transformed back to Pearson's *r* to estimate a mean bootstrapped correlation among observers. We repeated this procedure for 1,000 times and estimated the 95% bootstrapped confidence interval of mean correlation among observers. This additional analysis yielded a 95% bootstrapped confidence interval of [0.06, 0.56], which suggested that the average correlation from different observers is significantly different from 0. We have now included this additional analysis in the main manuscript.
2. We also fitted a linear mixed-effect model (which specifies the association between spatial distortions and Vernier acuity as fixed effect and the inter-individual difference as a random effect) to examine whether individual differences play a role in the association between Vernier acuity and spatial distortions. The model results suggested a significant and positive association between spatial distortions and Vernier acuity, with a fixed effect coefficient of 0.63 (standard error: 0.23, $F(1, 48) = 7.59$, $p < .01$). We have also included the linear mixed-effect model results in the main manuscript.
3. We believed that showing individual observer correlations will also be helpful, so we now included individual observer correlations in the supplementary materials (Fig. S3).

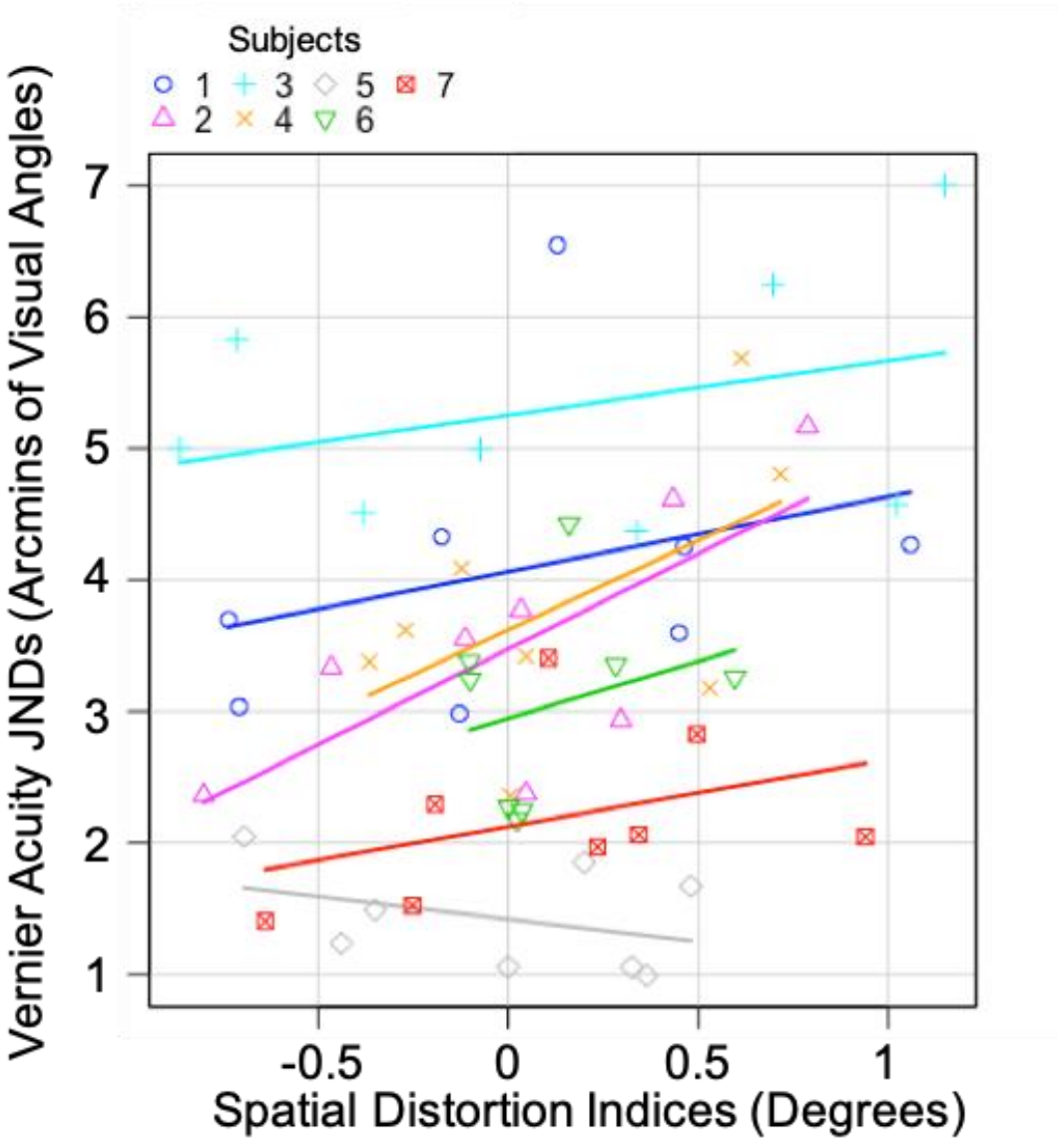

Figure S3. Correlation between spatial distortion indices and Vernier acuity JNDs for each observer. Each observer had 8 pairs of data, corresponding to 8 angular locations tested in Experiment 2. Different symbols represent different observers. Lines are regression lines fitted based on each observer's data. The Pearson's correlations for individual subjects were 0.31, 0.73, 0.34, 0.55, -0.37, 0.26, 0.38 (listed in the same order as the figure legend) and the mean correlation calculated from Fisher transformation was 0.34. Note that the only observer who did not show the same trend (displayed as gray diamond) had the smallest JNDs (i.e., best acuity), so we speculated that it might be subject to a ceiling effect. This could affect the measured variability of Vernier acuity across different locations and thus influence the correlation calculated based on it.

3. Sample sizes: Why were there only 3 observers in Exp 3? I don't think this is a problem as the results are pretty clear and you can treat each observer as an independent replication. But

it is at odds with the other experiments so could probably use some explanation.

Responses: Our reasoning was that since Experiment 1 and 2 have made it clear that this idiosyncratic association is observer-specific, we believed that a dense spatial sampling within a single subject would be more helpful to establish the relationship between variations in perceived size and heterogeneous spatial distortions. Therefore, in Experiment 3, we recruited fewer participants but with more locations tested for each participant. We now added our reasons in the Method section of Experiment 3 of the revised manuscript.

4. Terminology: You refer to low spatial distortion as contraction and high distortion as expansion. This makes sense to me but I think that terminology may be confusing, especially later when you discuss the relationship to perceived size where *expansion* results in *smaller* perceived size. To avoid confusion it would help to signpost this more and explicitly define this again at this point.

Responses: The reason why we used expansion and contraction to describe the spatial distortion is based on our operational definition of them. Since a positive distortion index indicates that two adjacent objects were localized to be further away from each other compared to their actual physical distance, we believe that it indicated that the visual space between these two locations were effectively expanded, and the opposite was true for a negative distortion index. Thus, “expansion” and “contraction” were defined based on biased perceived position rather than size perception. We revisited the definition of the terminology in the discussion section to avoid confusion between perceived position and perceived size.

5. Figure 1: Panel label C is missing from the figure itself.

Responses: Thank you so much for catching this mistake and we have updated the figure to include the label “C”.

Referee: 2

Comments to the Author(s)

The authors investigated idiosyncratic distortions of spatial vision in three experiments by measuring perceived position, acuity and perceived size at multiple locations in the visual field. The results show idiosyncratic and correlated distortions in all three tasks, which points to a common origin. The measurements are very extensive and carefully conducted. I have only a few comments for improving the presentation of the results in the manuscript.

Response: Thanks for your thoughtful review and constructive comments. We have made all of the recommended changes to the manuscript.

Presentation of individual biases: For Vernier acuity and perceived size, only the correlation with the spatial distortions from Experiment 1 is shown in Figures 2 and 3. I think it would be useful to show Vernier acuity and perceived size as a function of location for all observers to get a full picture of the spatial variations in those tasks as well.

Responses: This is a great suggestion. We have included the change of Vernier acuity and perceived size as a function of locations for each individual observer in the supplemental figures (see supplemental figure S2 and S4).

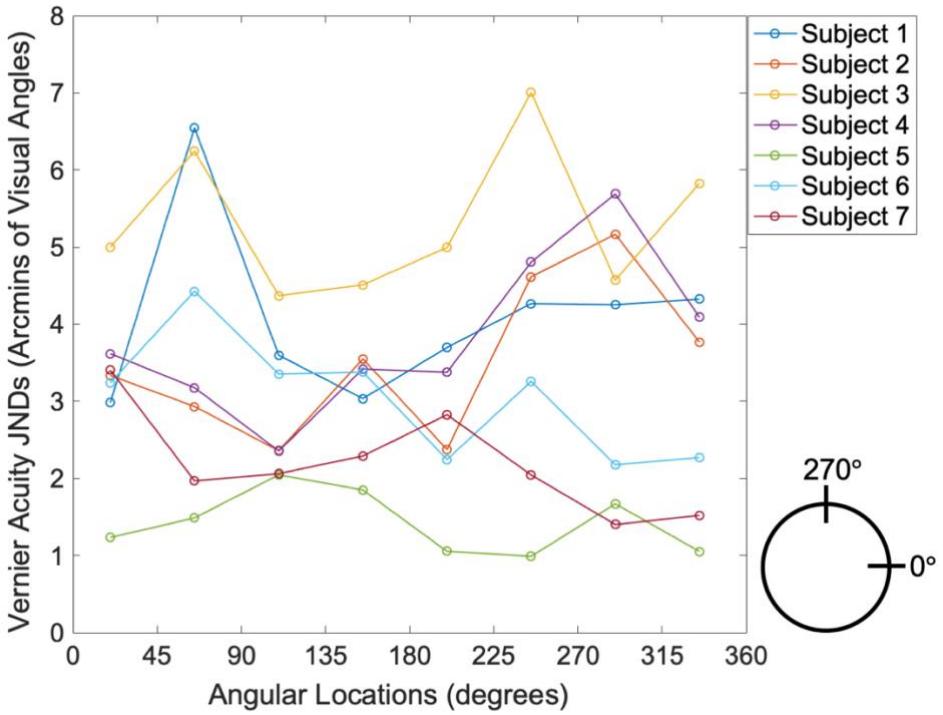

Figure S2. Change of Vernier acuity as a function of the angular locations tested for every observer. Subject 1 and Subject 4 are authors. The layout of the angular locations is shown on the bottom right corner.

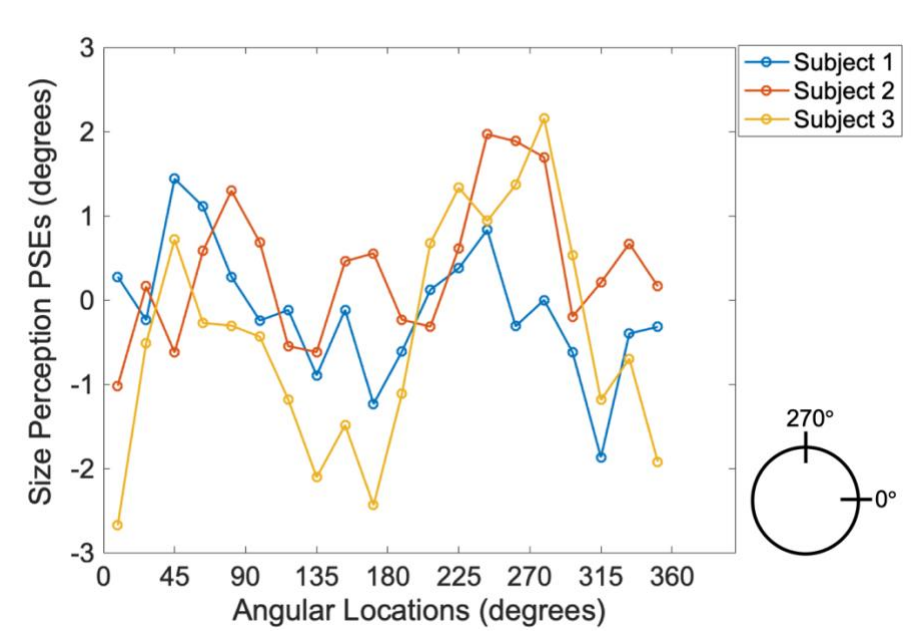

Figure S4. The change of perceived size of the arc stimuli as a function of the angular locations tested for every observer. Subject 1 and Subject 2 are authors. The layout of the angular locations is shown on the bottom right corner.

Stability of biases: The authors point out that they found stable biases at several places in the manuscript. While I tend to agree with that assessment, I think the time span over which stability was assessed should be stated more clearly.

Responses: Thank you very much for asking about it. Firstly, Kosovicheva & Whitney (2017) tested the stability of the localization biases across time so we cited their paper at the beginning of Experiment 1. To make it clearer, we mentioned this now in the revised introduction part of the manuscript. Although the time span within each of our experiments is limited (within a week), the time span between Experiment 1 and 2 was 1~2 months, and the time span between Experiment 1 and 3 was ~11 months. Since we still found a stable association between the biases estimated from different experiments, this indicates a kind of stability and is consistent with the temporally stable spatial distortions that Kosovicheva & Whitney (2017) reported. We have clarified this in the updated discussion section.

Minor comments

Stimuli in Experiment 1: The luminance of the background is not stated in the manuscript.

Responses: We reported the luminance of the gray background in the Procedure section in Experiment 1. It was 48.3 cd/m^2.

Line 78: The authors state that the monitor frame was covered by black tape to minimize the

influence of references. This would make sense if the background of the monitor was black, but Figure 1a suggests that it was actually gray.

Responses: We have corrected the language in the methods to specify what we meant. The black tape helped to minimize off-screen references: any visible references outside of the computer monitor including the difference between the monitor frame and the experiment room.

Figure 1b: I suggest using a color map with continuously increasing luminance. Positive and negative values are indistinguishable in gray scale print with the current color map.

Responses: We have created a version of this of figure using added luminance gradients and put in the supplemental material for reference (Fig. S1).

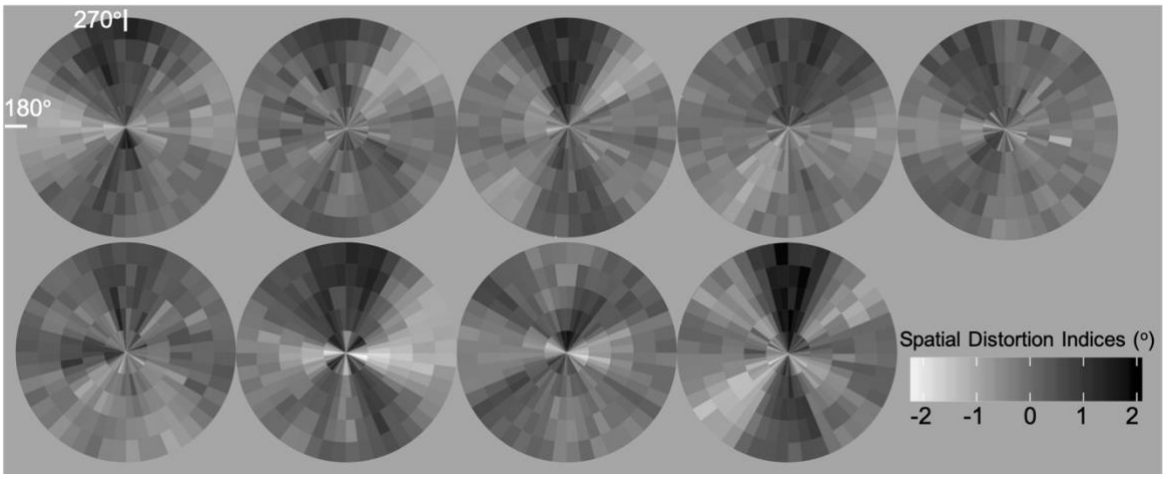

Figure S1. The gray-scale version of the spatial distortion maps reported in Experiment 1. Brighter color (negative spatial distortion indices) indicates contraction of visual space and darker color (positive spatial distortion indices) represents expanded visual space.

Line 253: The authors might want to mention that Vernier acuity unlike other acuity

measurements exceeds the spatial resolution limits imposed by the maximal cone density on the retina (thus also called hyperacuity, Westheimer, 1975) and therefore tests acuity at a cortical rather than a retinal level.

Responses: Thank you for the suggestion and we added a reference to it at the beginning of Experiment 2.

Line 328: I recommend to provide degrees of freedom of the test statistics and to specify exact p-values whenever they are larger than 0.001. Was that correlation calculated for all locations and for all observers? This might lead to the problem of pseudoreplication, where multiple observations on the same observers are treated as independent samples (Lazic, 2010).

Responses: This is a really good concern. The correlation was originally calculated for all locations across all observers (i.e., each entry is a position from one given observer) and this analysis is indeed subject to the problem of pseudoreplication. Therefore, instead of analyzing the super-subject data, to separate multiple dependent observations from each observer and independent observers, we performed the following analyses instead.

1. We calculated the Pearson's correlation between spatial distortions and Vernier acuity on every observer separately. This yielded 7 Pearson's *r* values, which were transformed to Fisher *z* values, averaged together and then transformed back to Pearson's *r*. This resulted in an average correlation of 0.34. We also performed a bootstrap procedure on these correlation values. On each iteration, we randomly sampled 7 correlation values with replacement from the 7 empirical correlation values and applied a Fisher transformation on each sample. Then the 7 Fisher *z*

values were averaged together and transformed back to Pearson's *r* to estimate a mean bootstrapped correlation among observers. We repeated this procedure for 1,000 times and estimated the 95% bootstrapped confidence interval of mean correlation among observers. This additional analysis yielded a 95% bootstrapped confidence interval of [0.06, 0.56], which suggested that the average correlation from different observers is significantly different from 0. We have now included this additional analysis in the main manuscript.

2. We also fitted a linear mixed-effect model (which specifies the association between spatial distortions and Vernier acuity as fixed effect and the inter-individual difference as a random effect) to examine whether individual differences play a role in the association between Vernier acuity and spatial distortions. The model results suggested a significant and positive association between spatial distortions and Vernier acuity, with a fixed effect coefficient of 0.63 (standard error: 0.23, $F(1, 48) = 7.59$, $p < .01$). We have also included the linear mixed-effect model results in the main manuscript.
3. We believed that showing individual observer correlations will also be helpful, so we now included individual observer correlations in the supplementary materials (Fig. S3).

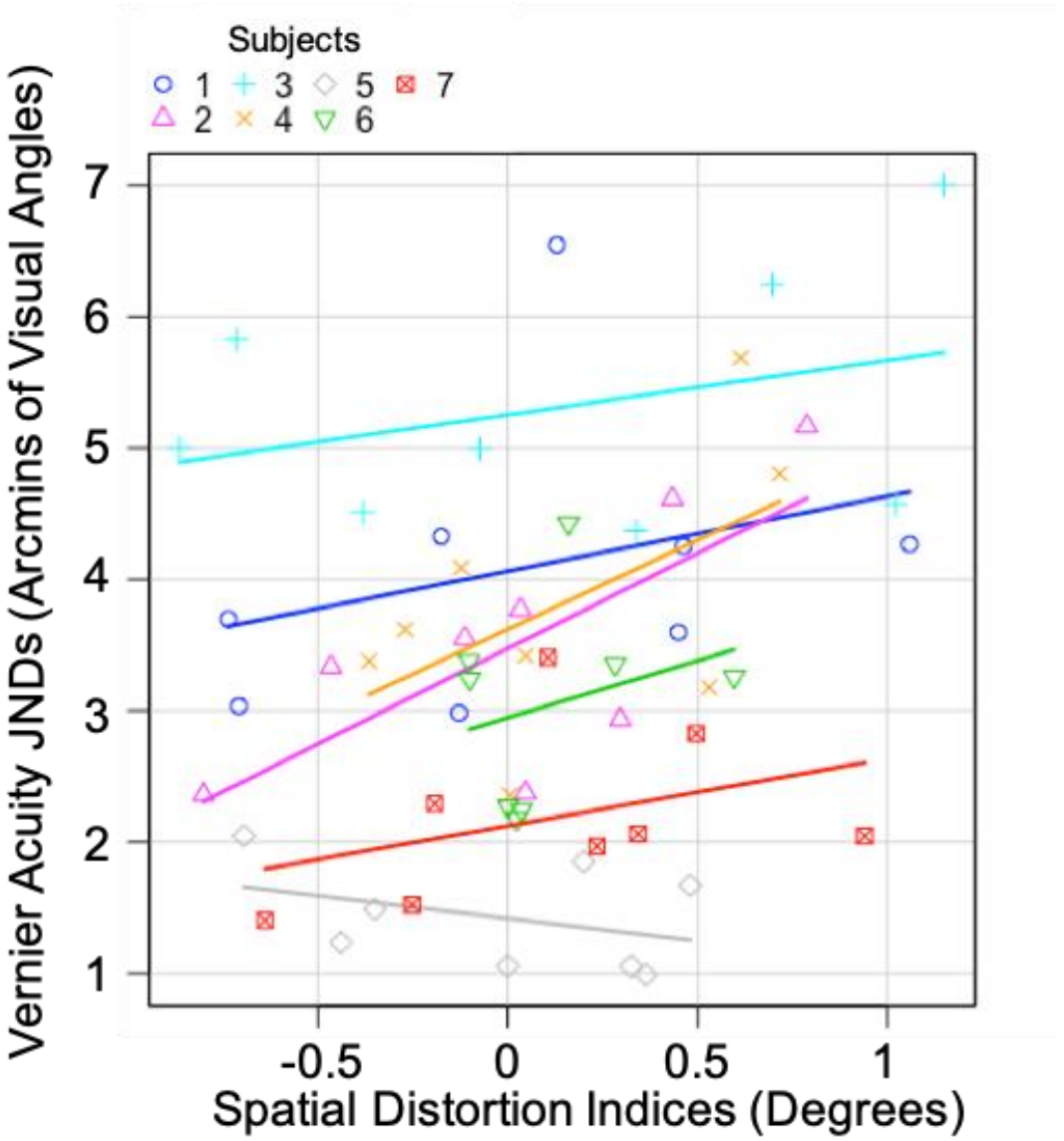

Figure S3. Correlation between spatial distortion indices and Vernier acuity JNDs for each observer. Each observer had 8 pairs of data, corresponding to 8 angular locations tested in Experiment 2. Different symbols represent different observers. Lines are regression lines fitted based on each observer's data. The Pearson's correlations for individual subjects were 0.31, 0.73, 0.34, 0.55, -0.37, 0.26, 0.38 (listed in the same order as the figure legend) and the mean correlation calculated from Fisher transformation was 0.34. Note that the only observer who did not show the same trend (displayed as gray diamond) had the smallest JNDs (i.e., best acuity), so we speculated that it might be subject to a ceiling effect. This could affect the measured variability of Vernier acuity across different locations and thus influence the correlation calculated based on it.

Lines 448 and 452: The caption of Figure 3 refers to left and right with respect to psychometric functions and correlation plots, but the arrangement in the figure is rather top

and bottom.

Responses: Thank you for catching this error and we have corrected the caption now.

Line 490: With respect to the asymmetry along the vertical meridian, the authors might want to relate to the seminal theory by Previc (1990).

Responses: Thank you for the suggestion and we also referred to it in our updated discussion session now.

Line 511: There are also idiosyncratic biases in motor decisions (e.g. Schütz, 2014).

Responses: Thank you very much and we included this in our discussion section.