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CORRECTION

# Correction to: Detecting distortions of peripherally presented letter stimuli under crowded conditions

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**Correction to: Atten Percept Psychophys**
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We discovered an error in the implementation of the function used to generate radial frequency (RF) distortions[1] in our article (Wallis, Tobias, Bethge, & Wichmann, 2017). Specifically, the phase offset (φ in Eq. 3 of Wilkinson, Wilson, & Habak, 1998) was specified incorrectly. Instead of causing a "rotation" of the RF pattern, the phase offset instead altered both the angular and radial components of the distortion, causing "swirls" that depended on the phase (see Fig. 1A). This means that the magnitude of the stimulus distortions depended on an interaction between the (randomized per stimulus) phase of the distortion and the shape of the letter.

We corrected this bug and generated new stimuli (Fig. 1B). To assess to what extent this bug might have affected our results, author T.W. and a new naïve observer repeated the experiments from the original article.

Sensitivity to distortions applied to letters is subject to crowding, and sensitivity to RF distortions follows a lawful relationship with distortion frequency. In Experiment 2 we found little evidence for an effect of distortion pop-out. In effect, this stimulus bug means we have demonstrated crowding for distortion sensitivity using three types of distortions rather than only two.

Thus, the conclusions of our study remain, despite this stimulus software bug. The data, code, and stimuli pertaining to this correction can be downloaded from https://doi.org/10.5281/zenodo.3236251.

## Experiment 1

Author T.W. collected new psychophysical data on the same task as in Experiment 1 from the original article, with both the original and the bug-fixed stimuli interleaved. We fit T.W.'s data (from the original and bug-fixed images and from the data collected in the original experiment) with Weibull psychometric functions (as parameterized by Schütt, Harmeling, Macke, & Wichmann, 2016) using a Bayesian framework in the R statistical language (Bürkner, 2017, 2018; Carpenter et al., 2017; R Core Team, 2019).

The thresholds in each condition are shown in Fig. 2. Although T.W.'s thresholds are lower for the true RF-distorted stimuli (i.e., the "bugfix images"), similar patterns emerge. First, the thresholds are higher when the target letters were flanked by other letters (flanked vs. unflanked), and the thresholds decrease approximately linearly (in log–log coordinates) as distortion frequency increases.

To supplement this dataset collected by one of the authors, we recruited a new naïve observer (W.R.), who did not participate in the original experiment. The procedure and details were as in the original article, with the exception that the bug-fixed and original images were interleaved. W.R.'s

[1] We thank Christina Funke for noticing the problem when applying the function to new stimuli.

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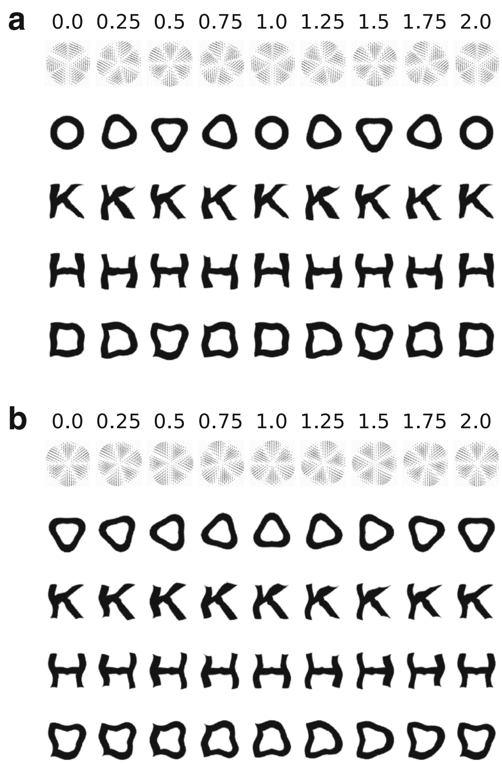


**Fig. 1** Demonstration of the effect of the radial frequency (RF) distortion bug. (A) Original images. Columns show the distortions produced for different phases (the numbers show multiples from 0 to 2π). The top row shows the vector flow fields of distortion, and the further rows show the distortion applied to different Sloan letters. (B) Images with the RF bug fixed; the arrangement is as in panel A. Now the phase correctly "rotates" the RF distortion

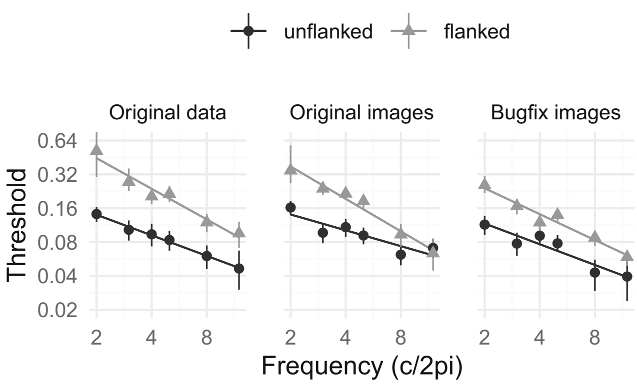


**Fig. 2** Results of repeating Experiment 1 for observer T.W. (cf. Fig. 3 of the original article, lower panel). The threshold amplitudes for detecting letters distorted with radial frequency (RF) distortions are shown as a function of distortion frequency (c/2π). The panels plot the thresholds for T.W.'s data from the original article (*Original data*) and new data collected on the original images (*Original images*) and on images with the RF bug fixed (*Bugfix images*). Note that both the *x*- and *y*-axes are logarithmic. Points show the posterior mean estimates for the psychometric function threshold, error bars show 95% credible intervals, and lines show the fits of a log–log regression. The plotted data are based on a total of 11,040 trials. T.W.'s thresholds are lower for the true (bug-fixed) RF images than for the original images, but otherwise, similar patterns are evident

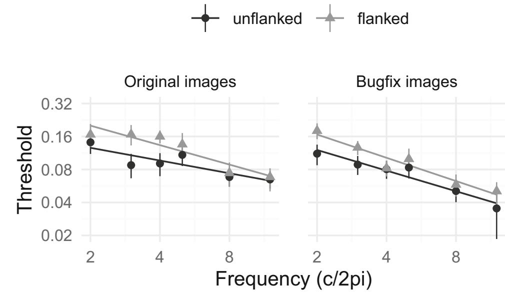


**Fig. 3** Results of repeating Experiment 1 for observer W.R. (the elements are as in Fig. 2). The results are based on a total of 8,635 trials

thresholds for Experiment 1 are shown in Fig. 3. As for T.W., W.R.'s thresholds are higher in the flanked than in the unflanked condition (although W.R. shows a smaller effect than T.W.), and the log thresholds also decrease approximately linearly as the distortion log frequency increases.

## Experiment 2

The first experiment demonstrated the core result of our article: Sensitivity to two distortion types was reduced in the presence of flanking letters (crowding). In a second series of experiments, we examined the extent to which this result depended on target–flanker similarity and task, in order to probe the possibility of "distortion pop-out." Briefly, the results in the original article provided little evidence for symmetrical distortion pop-out. In Experiment 2a, the thresholds were higher as more flanker letters were distorted. In Experiment 2b, the thresholds for detecting an undistorted letter were more similar to those for detecting a distorted target among four distorted flankers than for a distorted target among zero distorted flankers. In Experiment 2c, the thresholds for detecting a distorted letter among four highly distorted flankers were also higher than those for detecting distortions among zero distorted flankers.

Observer W.R. participated in the second experiment from the article for the RF distortion type. As above, the original and bug-fixed images were interleaved. Note that while replicating this experiment, we also noticed a minor typographical error in the methods of the original Experiment 2. On page 856 of the original article, the amplitudes of the RF distortions were reported as "0.05, 0.125, 0.2, 0.275, 0.25, 0.425, and 0.5," but the value of 0.25 was actually 0.35 (consistent with an ascending series of amplitudes).

W.R.'s thresholds are shown in Fig. 4. The first notable aspect of these thresholds is that they are substantially lower than those in the original article (for both the original and bug-fixed images). For example, in the four-distorted-flanker condition, the three original observers had thresholds of nearly 0.64 (see the original article, Fig. 5, lower panel), whereas W.R.'s thresholds in Experiment 2a were on average 0.2. We

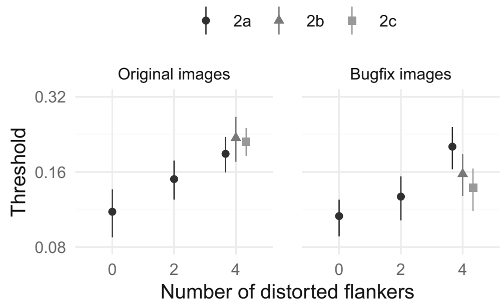


**Fig. 4** Results of the control Experiment 2 for observer W.R. (cf. Fig. 5 of the original article, lower panel): Threshold amplitudes for target letter distortions as a function of the number of distorted flankers. The panels plot thresholds for new data collected on the original images (*Original images*) and images with the radial frequency (RF) bug fixed (*Bugfix images*). Note that the $y$-axis is logarithmic. Points show the posterior mean estimates for the psychometric function threshold, and error bars show 95% credible intervals. Different shapes and shading denote the thresholds from Experiments 2a, 2b, and 2c (see the text). The results are based on a total of 5,880 trials

are unsure why W.R. is so sensitive under these conditions. W.R.'s thresholds were somewhat lower than those of the original observers in Experiment 1, so the differences could reflect some combination of individual sensitivity, individual practice effects, and fixation stability/eye movement noncompliance. We do not think differences in the experimental apparatus are a factor, since T.W.'s thresholds for Experiment 1 were similar. Nevertheless, further interpretation of the results should be considered with this overall effect of sensitivity (and potential floor effects) in mind.

For the original images, W.R.'s results unequivocally replicate the original article. The thresholds increase as the number of distorted flankers increases (Exp. 2a), and the thresholds for Experiments 2b and 2c are similar to (or even higher than) the threshold in Experiment 2a with four distorted flankers.

For the images using the corrected RF distortion function, W.R.'s results are also within the scope of the data from the original article. The thresholds increase with the number of distorted flankers (replicating Exp. 2a). The thresholds for Experiment 2b and 2c are somewhat lower than those for Experiment 2a in the four-distorted-flanker condition, approaching the thresholds in the two-distorted-flanker condition. This pattern of results is similar to those of observers S.T. and T.W. in the original article (A.M. is difficult to judge, due to uncertainty on the threshold measurement for two distorted flankers). The thresholds remain higher than those in the zero-distorted-flanker condition, indicating little evidence for distortion pop-out (as in the original article).

## References

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software*, *80*(1), 1–28. https://doi.org/10.18637/jss.v080.i01

Bürkner, P.-C. (2018). Advanced Bayesian multilevel modeling with the R package brms. *R Journal*, *10*, 395–411. https://doi.org/10.32614/RJ-2018-017

Carpenter, B., Gelman, A., Hoffman, M. D., Lee, D., Goodrich, B., Betancourt, M., . . . Riddell, A. (2017). *Stan*: A probabilistic programming language. *Journal of Statistical Software, 76*(1). https://doi.org/10.18637/jss.v076.i01

R Core Team. (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from www.R-project.org

Schütt, H. H., Harmeling, S., Macke, J. H., & Wichmann, F. A. (2016). Pain-free and accurate Bayesian estimation of psychometric functions for (potentially) overdispersed data. *Vision Research*, *122*, 105–123. https://doi.org/10.1016/j.visres.2016.02.002

Wallis, T. S. A., Tobias, S., Bethge, M., & Wichmann, F. A. (2017). Detecting distortions of peripherally presented letter stimuli under crowded conditions. *Attention, Perception, & Psychophysics*, *79*, 850–862. https://doi.org/10.3758/s13414-016-1245-x

Wilkinson, F., Wilson, H. R., & Habak, C. (1998). Detection and recognition of radial frequency patterns. *Vision Research*, *38*, 3555–3568.