REPLY TO BRUGGEMAN:

# Learning is robust to noise in decentralized networks

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Our study (1) presents a theoretical model and experimental test of how social influence affects the wisdom of crowds. Our theoretical simulations (SI appendix of ref. 1) show that the accuracy of the group mean can improve in decentralized networks when the weight that individuals place on their own estimates is positively correlated with their accuracy. Empirically, our findings confirm this prediction, showing that a correlation between individual accuracy and self-weight can explain how social influence improves the mean of the group estimate.

Bruggeman (2) raises the insightful concern that noise in the relationship between accuracy and self-weight might undermine the collective learning process. Bruggeman (2) suggests that "human self-confidence tends to be noisy, with self-deceivers among the self-confident." We think that this is an interesting observation, which merits discussion. Here, we show that our study (1) offers three arguments that address Bruggeman's concern and demonstrate the robustness of learning in decentralized networks.

First, as stated on the second page of our study, we find that the accuracy of the group mean, group median, and individual estimates all improved significantly as a result of social influence in decentralized networks. However, only the improvements in the group mean depend upon a positive correlation between self-weight and individual accuracy. Improvements in the group median and individual accuracy did not depend upon this correlation.

Second, we show empirically (1) that despite nontrivial levels of noise in participants' estimates of their own accuracy, social learning in decentralized networks nevertheless consistently improved the accuracy of the group mean. Specifically, although we find an imperfect correlation ($\rho = 0.25$) between accuracy and revision magnitude, we show that decentralized networks produced an average 10% reduction in the error of the group mean. Moreover, despite this noisy correlation, the average error of the group mean decreased consistently, in 12 out of 13 trials, as reported in the SI appendix to our study.

Third, we show theoretically that a perfect correlation between accuracy and self-weight is not necessary to ensure that social influence reduces the error of the group mean. As shown in figure S9 of our study, any correlation greater than zero is sufficient for social influence in decentralized networks to reduce error in the mean belief.

Finally, Bruggeman (2) poses the possibility that actors may choose their ties according to status-based factors, such as reputation. The anticipated result would be that individuals of high reputational status would garner a disproportionate number of ties, generating a centralized network. However, it must be cautioned that network centralization, even based on reputation, poses a risk to the wisdom of crowds, because reputation does not always correspond to accuracy (3, 4). As shown in figure 1 of ref. 1, while centralized networks may offer a benefit when central nodes are accurate, they can just as easily lead groups astray if the correlation between reputation and accuracy is "noisy." Decentralized networks, by contrast, generate robust social learning dynamics, allowing social influence to reliably improve the wisdom of crowds.


**1** Becker J, Brackbill D, Centola D (2017) Network dynamics of social influence in the wisdom of crowds. *Proc Natl Acad Sci USA* 114:E5070–E5076.

**2** Bruggeman J (2017) Solving problems in social groups. *Proc Natl Acad Sci USA* 114:E9183.

**3** Ryan J (2011) Accuracy and bias in perceptions of political knowledge. *Polit Behav* 33:335–356.

**4** Bunderson J (2003) Recognizing and utilizing expertise in work groups: A status characteristics perspective. *Adm Sci Q* 48:557–591.


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The authors declare no conflict of interest.



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