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Consequences of failures to meet standards in learning and memory **Reply**

The article¹ criticized by Suga, Ji and Ma had two goals. The first was to show that an integration of approaches from the fields of sensory neurophysiology and learning/memory has revealed that associative learning involves the formation of specific memory traces in the primary auditory cortex. The second was to emphasize the importance of understanding and using key procedures and controls of both disciplines to draw valid conclusions in such dual-disciplinary research. The article's critique of Suga and colleagues relates to the latter. Gao and Suga claim that tuning shifts develop in the auditory cortex of the big brown bat as a result of fear conditioning^{2, 3}, and Ji and Suga have made the same claim^{4, 5}. However, application of accepted criteria in learning/memory indicated that this claim is unsubstantiated. These workers have provided no behavioural data, which is indispensable for showing learning, and have therefore failed to validate fear conditioning to an acoustic conditioned stimulus. Furthermore, Suga and colleagues use a conditioning protocol in which training trials (pairings of tone (CS) and shock (US)) were presented at fixed intervals of 30 seconds. As previously explained¹, fixed intervals can produce temporal conditioning, in which the subject responds to an anticipated US, such as shock, on the basis of elapsed time, rather than to the CS. In such circumstances, one cannot distinguish between the development of behavioral conditioned responses to a CS versus conditioned responses to time, and so random inter-trial intervals have long been used^{6, 7}. Suga, Ji and Ma did not address these issues in their critique. It would not be surprising to find that the bat does develop tuning shifts due to associative learning, because this has been well-established in other species¹. However, their claim remains unconfirmed until they provide behavioral validation of fear conditioning. The model of Suga and Ma⁸ was found to be incompatible with well-established findings. They propose that the auditory and somatosensory cortices are essential for fear conditioning to tone. However, neither lesions of the auditory cortex nor decortication prevent fear conditioning to sound¹. Suga, Ji and Ma did not address this issue either. They do argue that tone-shock convergence cannot first occur sub-cortically in multimodal regions of the medial geniculate/posterior intralaminar nucleus (MGM/PIN) because muscimol applied to the amygdala interferes with plasticity in the medial geniculate nucleus^{9, 10}. Aside from the potential problem of muscimol diffusion into the medial geniculate nucleus¹¹, their reasoning is dubious because it is still

logically possible that the amygdala gates plasticity of CS–US convergence in the MGM/PIN. Whether or not the role of the MGM/PIN is ultimately validated, the failure of Suga and colleagues to include circuitry for behavioral fear conditioning that is independent of the cerebral cortex requires that they explain why they ignore, or perhaps reject, the established cortical lesion literature.

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