

## On recent findings and clarifications regarding the ventriloquist aftereffect

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Mendonça et al. (2015) analyzed the impact of different sequences of audiovisual events on the posterior localization of sounds. Recently, Frane and Shams (2015) issued a Letter to the Editor of this Journal with the intention of presenting further clarifications of that study and its relation to another study by Wozny and Shams (2011). This letter addresses the above-mentioned articles and clarification letter.

In their clarification letter, Frane and Shams (2015) begin by stating that several findings by Mendonça et al. (2015) were replications of findings by Wozny and Shams (2011), namely: (1) “recalibration occurred rapidly, after exposure, and without feedback”; (2) “recalibration was enhanced by increasing the number of recent discrepancies in a consistent direction”; (3) “the most audiovisual (AV) exposure had the greatest influence on recalibration”; and (4) among recent AV exposures, earlier exposures had lingering influence on recalibration, but had less influence than later exposures in the sequence.

In our opinion, findings 2–4 are not replications of Wozny and Shams (2011) in the strict sense of the word. Indeed, finding (1), regarding a fast calibration following a single exposure to an audiovisual pair, had already been found by Wozny and Shams (2011). This finding was appropriately described by Mendonça et al. (2015) as not novel in sentences like “we explored recent evidence suggesting that a single brief exposure to an audiovisual discrepant trial could lead to a subsequent auditory

localization shift” and “This finding is in line with that by Wozny and Shams”.

Finding 2, according to which the recalibration was enhanced by increasing the number of recent discrepancies in a consistent direction, was shown as a clear correlation ( $r^2 = 0.33$ ,  $p = 0.02$ ) by Mendonça et al. (2015). The same tendency was suggested by Wozny and Shams (2011), in Fig. 4, but only a figure is shown, along with increasingly large SEM values, and one descriptive sentence in the main text. No statistical tests were presented regarding that figure. Therefore, it may be suspected that the slight tendency presented in the figure was not statistically significant. In an attempt to clarify who found what, one could state that Wozny and Shams (2011) suggested the possible existence of an effect that was demonstrated by Mendonça et al. (2015).

Regarding finding 3, about the most recent AV event having the largest influence on the recalibration, this was clearly shown by Mendonça et al. (2015). Indeed, none of the audiovisual events prior to the last had a statistically significant effect on the recalibration. Also, adding each of those previous events to our model did not lead to better explanation of the aftereffect than just using the most recent event. Again, Wozny and Shams (2011) did present data that were suggestive of the last event being more influential than the previous ones, but no actual test comparing them is presented. Partial significant effects are reported for influence of the AV events two trials and three trials back, which could mean that all three most recent events are most relevant. That finding would be unconfirmed by Mendonça et al. That finding was also insufficient to clearly quantify which event had the largest influence.

Finally, Frane and Shams (2015) describe a finding 4 according to which, among recent AV exposures, earlier exposures had lingering influence on recalibration, but

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had less influence than later exposures in the sequence. As described in the above paragraph, this was not found to be true by Mendonça et al. (2015), and therefore cannot be described as a finding of that study. There was indeed a general auditory localization shift effect, observed throughout the experiment, indicative of a longer-term recalibration mechanism that is independent of recent multisensory experience. There was also a very high weight attributed to all of the recent AV exposure together, including the last exposure, in the best predictive model. But regarding the recent AV exposures, earlier exposures in the sequence had no significant lingering effect. And again, no specific test was presented by Wozny and Shams (2011) to address that issue. Wozny and Shams found no statistically significant effect whatsoever from the fourth or fifth AV trials back, so one should also not assume a lingering influence from earlier exposures. More importantly, Wozny and Shams did not quantify the influence of each AV exposure, so no conclusions should be taken at that level from that study.

Frane and Shams (2015) proceed in their letter with a statement that needs indeed further clarifications. Mendonça et al. (2015) concluded that for the first time it was revealed that, within recent sensory experience, all audiovisual stimuli are actually relevant but it is the last one that is weighted the most. This conclusion might be at the origin of the confusion by Frane and Shams regarding “finding 4.” Indeed, it was found that all recent AV experience was highly weighted, as stated above. But only when averaged all together in the parameter  $D$ , which quantified the average amount of discrepant trials in all previous five AV exposures, including the most recent exposure. This parameter was very important, but one still needed to account for the last exposure alone to obtain the best predictive model. Therefore, the last exposure is beyond doubt the most relevant event in recent AV exposure to explain subsequent localization shifts. So, this should not be confused with the conclusion by Wozny and Shams (2011) according to which there is a quantifiable effect from all recent AV exposures, with lesser magnitude the farther back the exposure. At this level, the findings from both studies are actually conflicting.

Next in their letter, Frane and Shams (2015) state that “Mendonça et al. (2015) incorrectly assumed that Wozny and Shams (2011) suggested “perceptual fusion” (perceived co-localization) to be necessary for recalibration.” Mendonça et al. never suggested that Wozny and Shams considered “perceptual fusion” to be necessary. The original sentence in the paper by Mendonça et al. was as follows: “Wozny and Shams also found that the auditory shifts occurred mostly when, in the preceding audiovisual trial, visual and auditory stimuli were perceptually fused, or more specifically perceived as co-localized.” This original statement still stands correct. The effect observed by Wozny and

Shams when the visual and auditory events were not co-localized is extremely small in magnitude, and of questionable significance (again, no statistical data are available), compared to when they were co-localized. So indeed, the effect occurred mostly when they were co-localized.

On the final issue raised by Frane and Shams (2015), regarding how to design an experiment to specifically analyze sequential effects, here are our thoughts. The study by Wozny and Shams (2011) seemed exploratory. No specific sequences were presented, or specific sequence length. Instead, random stimuli of any random sensory modality and direction were presented. While this allowed to look into sequential effects, all the main findings were obtained by analyzing only a very small subset of all the data collected. Therefore, to analyze *specifically* sequential effects, one might consider it better suited to actually select sequences of events, have more repetitions per subject, and look into their effects. In this case, the main effects we discuss here and in the articles cited above, are specifically related to how audiovisual events affect the subsequent auditory event localization. So, it can only be expected that future experiments on the topic will study those effects by only presenting that specific type of sequences of events. As Mendonça et al. (2015) discussed when raising this issue, the methods were different, and therefore, the experiments are hard to compare.

Regarding the limitation referred by Frane and Shams (2015) in their letter, associated with using a consistent discrepancy, one should note that Wozny and Shams (2011) themselves also did this. When analyzing the cumulative effect of presenting discrepant trials—precisely what Mendonça et al. (2015) did—the authors looked exclusively into sequences of AV exposures that were discrepant in the same direction. We must, however, agree that a most robust methodological approach would have been to vary the direction of the discrepancy.

Finally, on the concern raised by Frane and Shams (2015) regarding Mendonça et al.’s “own very small sample” of 11 subjects, as a methodological limitation, we clarify that, to our knowledge, this sample size is well within the norm in psychophysics. Indeed, in psychophysics, samples with fewer than 10 participants are anything but uncommon. This should therefore not be cause of concern. It is assumed in this research field that such “small” samples should be enough to obtain statistically significant effects that are observed very consistently in all participants. If more than 100 subjects (which we still see as uncommon) are needed, then this might mean that effects would not be observed if a sample of conventional size were used. It might also ultimately mean that the perceptual effects reported do often occur in the general population, but do not necessarily always occur in all subjects. But we wish to stress that, indeed, by no means an unnecessarily large sample in a

psychophysical study should be read as methodological limitation.

In sum, the study by Mendonça et al. (2015) was designed specifically to identify and compare the factors causing the effect found by Wozny and Shams (2011), and specifically sequential factors. The idea was to find explanatory variables and quantify their relevance in a systematic way. Both articles are complementary and together make a clear case regarding the fact that the most recent AV exposure has a very prominent role on the subsequent auditory localization.

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