Letter

The overlooked role of unisensory precision in Multisensory Research

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In a recent study of perceptual processing in professional football players, Quinn *et al.*[1] compared the susceptibility to the sound-induced flash illusion[2] (SiFI) of goalkeepers, outfield players and a control group to investigate whether goalkeepers have a better multisensory temporal integration. They found that the goalkeepers perceived the illusion less frequently and had a narrower temporal binding window, and suggested that they had an enhanced tendency to segregate the multisensory signals. The authors attributed the decreased degree of perceived illusions solely to the reduction in the prior tendency of audiovisual integration. Here we present an alternative explanation through a Bayesian causal inference model, suggesting that better unisensory precision in goalkeepers can also count for the observed behavioral outcomes.

Several previous studies have demonstrated that the Bayesian causal inference (BCI) model[3] can account for multisensory temporal numerosity tasks such as SiFI very well[4,5]. While Quinn *et al.*[1] suggested that the differences between groups is due to the difference in the prior integration tendency as per the BCI model, no quantitative analysis was performed to test or verify this hypothesis. This interpretation may overlook the role of unisensory precision for the following two reasons. First, BCI is a normative Bayesian model that makes an inference based on the congruency between sensory inputs as well as prior expectation of a common cause[6], and the perceived sensory congruence would be impacted by noise in each modality (σ_A and σ_V, representing the standard deviations of likelihood distributions associated with auditory and visual representations, respectively)[3,7,8] . And second, a prior study of auditory–visual integration[9] provided evidence supporting the independence of likelihoods and prior in human Bayesian causal inference. Therefore, a change in the sensory reliabilities would not necessarily entail a change in the prior tendency to integrate the senses.

Thus, we believe that there is an alternative interpretation for the results of Quinn *et al.*[1]: the differences among the responses of three groups can be explained merely by differences in unisensory precision. Under the framework of the BCI model, we fixed all parameters at constant values except σ_V (visual noise), and simulated the model using various values of σ_V. The results clearly show that, even with prior integration tendency (*Pcommon*) staying constant, the frequency of illusion increases as the reliability/precision of vision decreases (σ_V gets larger) (Figure. 1A). To account for the varying SOAs in the Quinn *et al.*[1] study, we extended the classic BCI model[3] to encompass temporal factors. In BCI, prior expectations and current sensory information are used to infer whether sensory stimuli originate from a common cause[3,7]. In the model used to explain the data in this study, the sensory information consists of the numerosity as well as timing of each stimulus (for more details see Supplemental Information).

In simulating the model, we kept all parameters the same except for visual noise (σ_V). As demonstrated in Figure. 1B, change in just visual precision can replicate the reported results well. The fitting results show that goalkeepers have a better visual precision (σ_V = 0.31) than outfield players (σ_V = 1.99) and a control group (σ_V = 1.51). We also explored the scenario in which both sensory reliabilities are different across groups. Not surprisingly, as shown in Figure 1C, allowing both sensory precisions to vary (σ_V and σ_A) can also replicate the behavioral data. The fitting results indicate that goalkeepers exhibit both higher visual (σ_V = 0.27) and auditory (σ_A = 0.22) precision compared to outfield players (σ_V = 2.31, σ_A = 0.54) and a control group (σ_V = 2.09, σ_A = 0.53). In addition, we quantitatively investigated the integration tendency as well as unisensory precisions of individual observers by fitting the model parameters to individual participants' data (see Supplemental Information). The results suggest no difference in the integration tendency among the groups, but a statistically significant difference in visual precision consistent with the simulation results discussed above. However, these findings should be considered with caution as the fitting results might not be very reliable given the small number of trials in the experiment and the fact that subjects were not asked to report the number of beeps.

Altogether, the results demonstrate that the narrower temporal binding window and fewer perceived multisensory illusions by the goalkeepers might be due to their higher unisensory precision. It is conceivable that compared to other players and the general public, goalkeepers need to have a more accurate estimate of the position of the ball, thus requiring a higher visual and/or auditory precision. Note that our quantitative model-based analysis only provides an alternative explanation, and it does not entirely rule out the possibility of differences in integration tendency (*Pcommon*). A recent multisensory perceptual training study[10] did propose that the modality precision improved after the training, but did not discuss the effect of prior integration tendency. It is crucial to tease apart these possible accounts for the behavioral data to help with the interpretation of findings. One possible approach would be to fit each subject's behavioral data with the BCI model.

In conclusion, while a weaker prior tendency to integrate multisensory information might lead to a narrower temporal binding window and fewer illusions, here, we show that another interpretation can also account for the findings, without involving any change in the tendency to integrate or segregate the auditory–visual sensory signals. Using the BCI model, which is a well-established and validated model of multisensory perception, we show that the reported behavioral effects can be replicated based on a mere difference between the groups in unisensory visual precision. Therefore, we argue that a change/difference in the overall degree of illusion and/or temporal binding window cannot be necessarily attributed to a change/difference in the tendency to integrate the sensory inputs, and quantitative and computational analyses are generally required to determine the role of the unisensory factors (such as unisensory precision) and multisensory factors (namely, the tendency to integrate stimuli) in changes/differences in behavioral outcomes. This highlights the importance of examining unisensory precisions in studies of multisensory processing, either by directly comparing unisensory to multisensory conditions, or through computational modeling that is able to encapsulate the unisensory aspects.

Supplemental Information

Supplemental information contains 1 table, 1 figure and supplemental results.

Declaration of Competing Interest

The authors declare no competing interests.

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Author Contributions

Conceptualization, L.S. and U.B.; Formal Analysis, H.Z., U.B., and L.S.; Visualization, H.Z. and L.S.; Writing – Original Draft, H.Z., L.S., and U.B.; Writing – Review & Editing: H.Z., L.S., and U.B.

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Figure. 1 Simulation of the model under different sensory parameters.

(A) We simulated the fission illusion condition (F1B2, one flash paired with two beeps) with $Pcommon$ = 0.6, σ_A = 0.6, σ_p = 3, μ_p = 1.5, and σ_V varied from 1.2 to 0.3 (step = 0.3). The results show that susceptibility to fission illusion decreases with increasing visual precision. (B) The one-free-parameter (σ_V) fitting results. We fixed all the parameters except σ_V. (C) The two-free-parameters (σ_V and σ_A) fitting results. We fixed all the parameters except σ_V and σ_A.

Supplemental Information

Document S1. 1 table, 1 figure and supplemental results.

In Brief:

Zhu et al. present an alternative explanation for the weaker multisensory illusions in football goalkeepers compared to outfielders and non-athletes, showing that better unisensory precision in goalkeepers can also account for this effect.