of its surveyed environment driven by the need to economize neuronal computation. This study is unusual in linking a detailed survey of the visual space as seen by the animal and a detailed description of the morphological and functional adaptations of the sense organ.

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Auditory Perception: *Laurel* and *Yanny* Together at Last

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https://doi.org/10.1016/j.cub.2018.06.002

An auditory illusion caught the world's attention recently. For the same noisy speech utterance, different people reported hearing either 'Laurel' or 'Yanny'. The dichotomy highlights how perceptions are inferences from inherently ambiguous sensory information, even though ambiguity is often unnoticed.

When Katy Hetzel, a high-school student, went to the website *Vocabulary.com* to look up the word 'Laurel', she could certainly not have imagined how events would unfold. The website had hired professional singers to record words with a clear pronunciation. But, as Katy saved her sound clip with presumably a low-quality recorder, she serendipitously realized that she did not hear 'Laurel' anymore: rather she heard, very clearly, 'Yanny'. Thanks to another high-school student, Fernando Castro, the sound clip was released on social media. A minor meltdown ensued. Opinions were split, sharply. Some heard 'Laurel', others heard 'Yanny'. Commentators expressed incredulousness, bewilderment, consternation, sometimes down to outright aggression toward each other from different sides of the perceptual divide. Yet others could not even understand how anyone could be fooled by such a poor trick, as for them the sound clip obviously could be heard as either. Celebrities took up the meme, politicians, the media: at long last, the world had the auditory equivalent of the visual sensation known as #TheDress [1].

What is the reason for this dichotomy in the way people interpret the same sound? Figure 1A shows a visual representation of the contentious sound clip (middle, Audio S1), displaying the simulated output of peripheral auditory processing. Also illustrated are processed versions of the clip, for which either the low-frequency content (left, Audio S2) or high-frequency content (right, Audio S3) is emphasized. We ran an online experiment asking participants (N = 289) to choose between 'Laurel' and 'Yanny' for these sounds. The original clip produced both 'Laurel' and 'Yanny' responses as expected. The lowpass versions were heard more as 'Laurel', whereas the highpass versions were heard more as 'Yanny'. Remarkably, for some people, the bias was very strong; they heard the same word for more than 90% of trials, irrespective of acoustic filtering (N = 93 'Laurel', N = 41 'Yanny'; Figure 1B).

These observations suggest a simple interpretation to the effect. The time-frequency content of the original sound clip contained enough acoustic cues to hear 'Laurel', whereas the high-frequency content was close enough to 'Yanny'. Interestingly, a cue in the middle of the range — the wavy line visible in all examples in Figure 1A — was compatible with either interpretation: it could be the second formant of 'Laurel', or the third formant of 'Yanny' (or 'Yari', 'Yelli', 'Yowee'; all forms having been reported but for simplicity we treat them as 'Yanny'). So, as is common with many illusions [1,2], the available evidence was ambiguous and compatible with more than one percept. We suggest that listeners perceptually emphasized different parts of the frequency range, leading to a greater weight of the 'Laurel' or 'Yanny' cues.

Frequency biases varied widely across listeners, as shown by the histogram of the acoustic point of subjective equivalence for the group of people who reported each

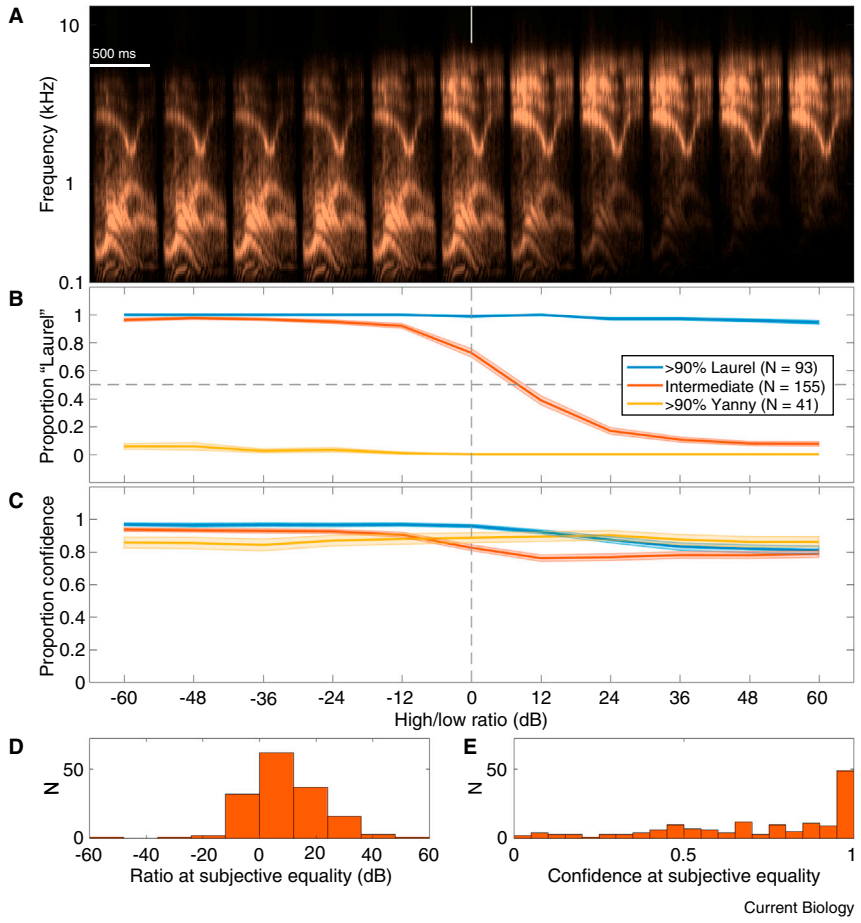

Figure 1. Sound illustrations and behavioral results of an online experiment.
(A) Auditory spectrogram of the original sound (middle, marked by a vertical white line) and lowpass (left) or highpass (right) filtered versions. (B) Probability of reporting 'Laurel' for each sound, for three groups of participants sorted by the strength of their bias on one interpretation. Shaded areas are standard errors about the mean. (C) Reported confidence, format as above. (D) Histogram of the point of subjective equality estimated for each listener of the 'Intermediate' group. (E) Histogram of confidence at the point of subjective equality for the "Intermediate" group.

word on more than 10% of trials (Figure 1D). This would be consistent with guesses made by internet commentators. Listening equipment should matter, as it imposes a frequency weighting on the sound itself. We observed a significant effect of self-reported listening equipment (here and for all other claims; see Supplemental Information). Age may also matter, as age-related hearing loss often elevates thresholds for high frequencies. We did not find any correlation between age and the proportion of 'Laurel' reports; however, we did find unexpected sources of variation: men were more likely to report 'Laurel' compared to women, as were musicians compared to non-musicians, and to a lesser extent, Anglophones compared to French speakers. Thus, a large part of the inter-individual differences could reveal idiosyncratic frequency weighting, perhaps related to factors impacting covert attention.

A prediction of this frequency weighting hypothesis is that the reported word should depend on the preceding context. At the extreme, if one heard sounds that gradually changed from, for example, lowpass to highpass, covert attention should initially be attracted toward the low frequency regions, and then remain there because of spectral continuity [3] or auditory binding [4]. The percept 'Laurel' could then be favored (Audio S4, S5). We looked for such context effects on a trial-by-trial basis. A logistic regression modeled the influence of the current stimulus and previous response on the current response [5]. Reporting one interpretation strongly increased the likelihood to report it again in the next trial. This is consistent with hysteresis of covert attention, but further experiments would be needed to disentangle this interpretation from simple response hysteresis.

All binary analyses described so far omit another interesting feature of the phenomenon. We analyzed the first 180 posts on the feed of a celebrity who asked her fans about what they heard, @chrissyteigen. Of all of the responses we could make sense of (N = 106), 34% reported only hearing 'Laurel', 43.5% reported hearing only 'Yanny', but, interestingly, 22.5% reported hearing both or something else altogether. This is a reminder that there was no *a priori* reason for listeners to be unaware of the acoustic ambiguity of the sound clip.

To investigate this further, we included a confidence rating after each 'Laurel'/'Yanny' forced choice in the online experiment. Confidence is one measure of 'metacognition', which is our ability to access and monitor our knowledge and performance, most often accurately [6,7]. In our case, confidence was high for all three groups of participants, irrespective of whether they heard only one word or varied their reports during the experiment (Figure 1C). We further looked at the histogram of confidence for the point of subjective equality, as estimated for each individual participant in the group that varied their responses (Figure 1E). Again, confidence was generally high, even in this most ambiguous of cases. This was observed even though participants used the confidence scale in a sensible manner, giving higher confidence to their preferred percept. So, most but not all participants seemed truly oblivious to the ambiguous nature of the stimulus.

All of these observations are fully consistent with what had been observed previously for other auditory illusions, which did not necessarily involve speech. For instance, in the 'Tritone paradox' [8,9], listeners report either large upward or downward pitch shifts for the same ambiguous stimulus. Its perception can be biased by context [5] and the confidence in responses with maximally ambiguous stimuli is high [10]. Thus, our quick online experiment with its many flaws captured features observed in more controlled experimental conditions.

To get back to the broader picture, we believe that several deep issues were

touched upon by the 'Laurel'/'Yanny' meme. First, the meme vividly reminded everyone that perception is not a passive registration of external information. Sensory information is always fragmentary and noisy, so by nature it cannot unambiguously reflect the state of the world at every instant. Rather, perception must make inferences, which are often unconscious [2,11,12]. These inferences draw prior information from past experience, be it long-term expertise or immediate context.

Another striking feature shared by 'Laurel'/'Yanny' and #TheDress is that, for some, perception was firmly locked to one perceptual choice. There was no possibility to will or even access the other one. Ambiguous stimuli have been extensively used in vision [13,14] and other modalities [15], because they tend to produce spontaneous 'multistable' switches between percepts. Take the example of an ambiguous figure such as Rubin's famous face/vase. We may initially see the face, but after a while, the alternative interpretation as a vase will be accessible to awareness — spontaneously, or after being told about the make-up of the image. The percept is also amenable to willful biasing. A range of ease of accessibility and biasing has been observed for multistable stimuli, which may betray different neural loci for the competition [14]. In the case of 'Laurel'/'Yanny' and #TheDress, there seems to have been very poor accessibility and low willful biasing for most people.

The inability of most subjects to access both percepts in the 'Laurel'/'Yanny' stimulus, even over repeated exposure, is likely why the sound clip caught such attention. Most people were absolutely sure of what they heard, yet we see that a sizeable minority could get access to an ambiguity signal. Access or not to ambiguity is thus likely an interaction between stimulus feature and observer features, such as expertise [10]. Future studies may be able to clarify the factors involved.

'Laurel'/'Yanny' has not only brought auditory science into the limelight, but it has also revealed how fascinating some perennial questions in cognitive science may be for the general public. Thanks to a couple of high school students, poor recording equipment, and the internet's insatiable appetite for quirkiness, everyone can now ponder about how we do not all always hear the same thing for the same sound, and how we are so often blissfully unaware of the intrinsic ambiguity of all sensory information.

SUPPLEMENTAL INFORMATION

Supplemental information includes five audio files and Supplemental Experimental Procedures and can be found with this article online at https://doi.org/10.1016/j.cub.2018.06.002.

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Cell Competition: How to Take Over the Space Left by Your Neighbours

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https://doi.org/10.1016/j.cub.2018.05.023

Fast-growing cells can expand in a tissue by eliminating and replacing the neighbouring wild-type cells. A new study provides an elegant explanation for how cell elimination contributes to the preferential expansion of the invading population.

Developing tissues have an amazing capacity to cope with various perturbations and yet still give rise to tissues of the right size and proportions. This robustness is based on the capacity of every single cell to adjust its fate or behaviour to changes in the tissue environment. This includes the modulation of cell death, which, for instance, can contribute to the elimination