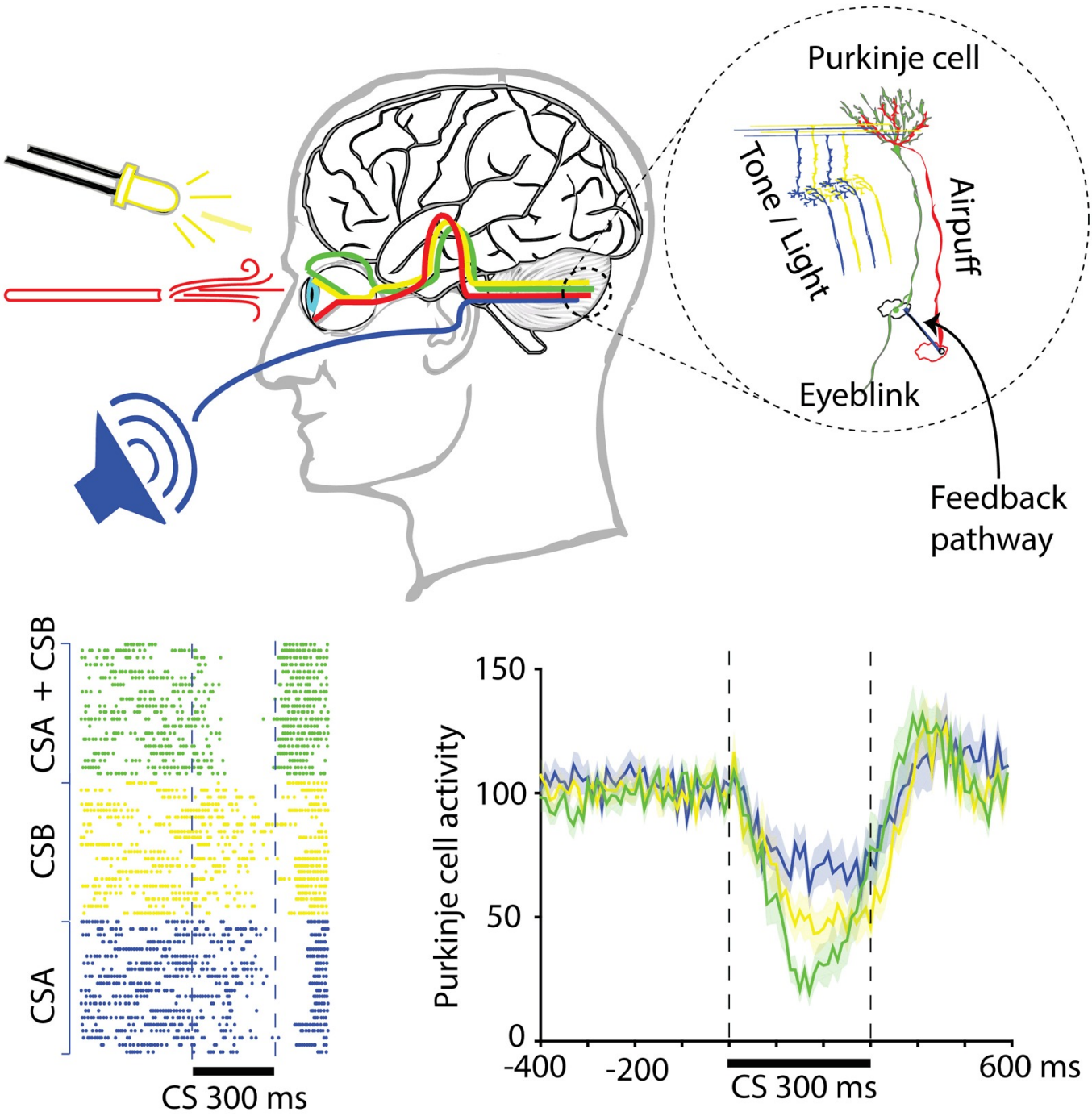
We learn and forget to correct our expectations

Learning and forgetting are, to a large extent, about tuning your expectations so that they match your experience. So while it is usually good to learn new things, we sometimes also need to forget things.

We constantly learn associations between things around us and these associations help determine our behavior. For example, if you see a ball flying towards you, you will duck or catch the ball because you know that otherwise the ball will hit you and that will hurt. Similarly, if you repeatedly hear a tone or see a light, and then receive an air puff in the eye you will learn to blink in response to the tone or the light to avoid the air puff. This type of learning is called classical conditioning, the light, and the tone are conditional stimuli, and the learned blink response is a conditioned response.



But what happens if, having already learned associations between a tone and the air-puff as well as between the light and the air-puff, you are presented with the tone and the light at the same time, and then receive the air puff? Surely, presenting two stimuli, each of which is associated with the rather unpleasant feeling of getting a puff of air in your eye, will make that association even stronger. No! Surprisingly, this will reduce the likelihood that you blink. In other words, the association will weaken.

The reason for this is that you need your expectations match your experience. When you hear the tone and see the light at the same time, you expect a more intense air puff than before. When you realize that the puff is not more intense, you change your expectations which result in a weaker association between the light and tone, and the air puff.

For reasons that should now be clear, this phenomenon is known as overexpectation. Two researchers, Rescorla, and Wagner predicted the phenomenon from their mathematical model of learning more than 40 years ago. Their model has since guided research in psychology as well as neuroscience, and overexpectation has been demonstrated many times in various species. However, the neural mechanisms underlying the Rescorla-Wagner model have remained a mystery.

In our study, we show that individual brain cells, like people, change their firing when expectations are violated. Previous research has shown that conditioned responses are elicited by pause responses in Purkinje cells that reside in the cerebellum. These pause responses, apart from making you blink and thus prevent the air puff from reaching the eye, also suppress the air-puff signal that gives rise to the learning in the first place. It is as if Purkinje cells are students telling their teacher: Be quiet, we know this now! When Purkinje cells are presented with two conditional stimuli, a light, and a tone, simultaneously they produce an even stronger pause response causing an even stronger suppression of the teaching signal (the students are essentially sending the teacher home). As a result, the Purkinje cells will begin to forget the association until, once again, expectations match experience.

So the next time your associations go awry, be lenient on your brain. Your brain, after all, is merely trying to tune associations between an almost unlimited number of stimuli so that your behavior will be adaptive. Sometimes that means forming new associations. But sometimes it means forgetting or weakening existing associations.

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Publication

Purkinje cell activity during classical conditioning with different conditional stimuli explains central tenet of Rescorla-Wagner model.
Rasmussen A, Zucca R, Johansson F, Jirenhed DA, Hesslow G
Proc Natl Acad Sci U S A. 2015 Nov 10