Does learning occur in the absence of cues?

Sanne Poelstra[a], Jessie S. Nixon[b], Jacolien van Rij[a]
[a]University of Groningen, [b]University of Tübingen
s.poelstra.1@student.rug.nl, jessie.nixon@uni-tuebingen.de, j.c.van.rij@rug.nl

Discriminative, Error Driven Learning (EDL) is a theory and set of equations that model bottom-up learning by minimising the uncertainty in the learner's expectations about upcoming events. Well-known formalisations of EDL include the Rescorla-Wagner model (1972) and the almost identical Delta Rule (Widrow & Hoff, 1960). Generally, we model learning using a fully connected, two-layer network (i.e. input layer: cues; output layer: outcomes; no hidden layers). The informativeness of cues is a key notion in EDL: only if cues are present are the connection weights between cues and outcomes updated. With each learning event the connections between present cues and outcomes are strengthened, while the connections between present cues and absent outcomes are weakened.

However in their frequently cited paper, Van Hamme and Wasserman (1994) have argued based on experimental data, that we can also learn from absent cues. They proposed an adjustment to the Rescorla-Wagner model: An absent cue should be encoded negatively, which leads to a weakened connection between an absent cue and present outcome and a strengthened connection between an absent cue and an absent outcome.

In the present study we aim to disentangle these two models of EDL. We implemented two computational simulations that model the experimental study reported by Van Hamme and Wasserman (1994). One simulation implements the Rescorla-Wagner model; the second implements the adaptation proposed by Van Hamme and Wasserman, which allows for learning from absent cues. In this experiment, participants had to indicate how likely it was that certain foods caused an allergic reaction. There were three types of food, of which two occurred on each trial together with an outcome (an allergic reaction or not). The participants then estimated the causal relation on a scale from 0 to 8 for *all three foods*.

Figure 1 shows the results of our computational simulations. To model the rating scale, we calculated weights to *Allergic reaction* minus weights to *No reaction*. The simulations show that with the Van Hamme & Wasserman experiment design - specifically, when the response measure (rating) includes both outcomes (allergy, no reaction) - there are no substantial differences in weight development between the Rescorla-Wagner and the Van Hamme-Wasserman models. Although the strength of activations is numerically different, we do not have a link function sufficient to evaluate which model best describes the data. Therefore, the two models make essentially the same predictions. These simulations demonstrate that Van Hamme & Wasserman's experiment design was not able to tease apart which model performs better: so, whether or not we learn from absent cues remains an open question.

However, our simulations also showed that the two models do make different predictions during the later phases of the experiment – *if* the individual outcomes are tested separately (see Figure 2). When weights to *Allergic* are separated from weights to *No reaction*, the Rescorla-Wagner model (left) predicts that, for example, 'bran' continues to predict the allergic reaction; in contrast, by the end of Block 3, the Van Hamme-Wasserman model (right) predicts that 'bran' is a negative predictor of the allergic reaction.

Based on our simulations, in ongoing work, we are running a series of experiments, all modifications of Van Hamme and Wasserman's experiment, to test the predictions of the two model variants. We will test outcomes separately at the end of Block 3. In addition, it is not clear whether Van Hamme and Wasserman's experiment reflects implicit learning, because they explicitly measured participants' ratings of present and absent cues. However, we argue that EDL is an implicit process, which may be hindered by explicit inference. Therefore, we will also employ a forced-choice paradigm and a speeded response manipulation to test the effects of explicit reasoning vs. implicit error-driven learning.

References

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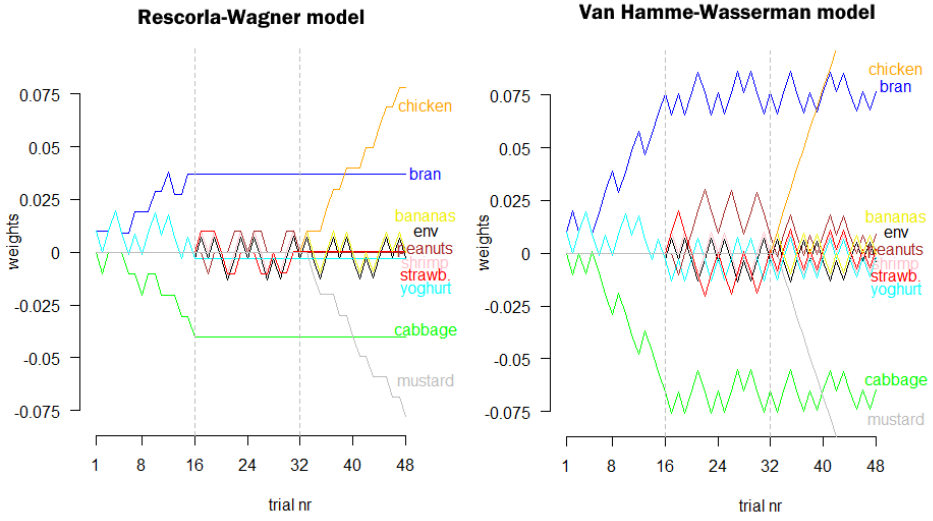

Figure 1: **Weights to *Allergic* minus the weights to *Not Allergic*** for each of the foods asked. Left: Rescorla-Wagner model. Right: Van Hamme-Wasserman model

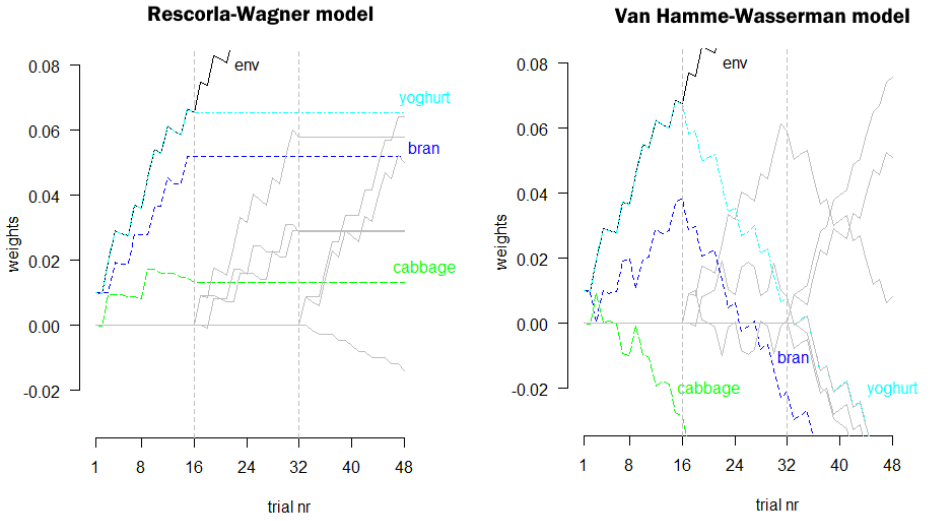

Figure 2: **Weights to *Allergic***. Left: Rescorla-Wagner model. Right: Van Hamme-Wasserman model