# Evidence for reward learning in speech production

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## Reward learning in speech

Reward learning has been suggested to be a critical component of early speech motor plan acquisition [1,2,3].

There is little direct behavioral evidence for reward learning in speech motor control.

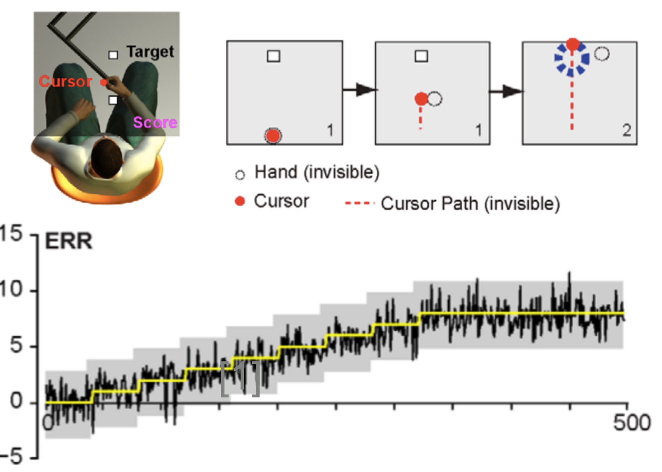
**Can adult speakers learn a new production target based only on reinforcement learning?**

## Mechanisms of motor learning

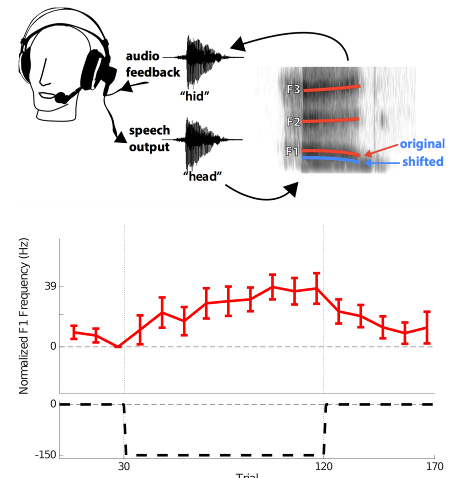
### Sensory-prediction error (SPE) learning:

*Learning from a mismatch between expected and perceived sensory outcomes of one's actions.*
*(≈ learning how to do a particular action)*

<u>Reaching [4]</u>
*visuomotor rotation*



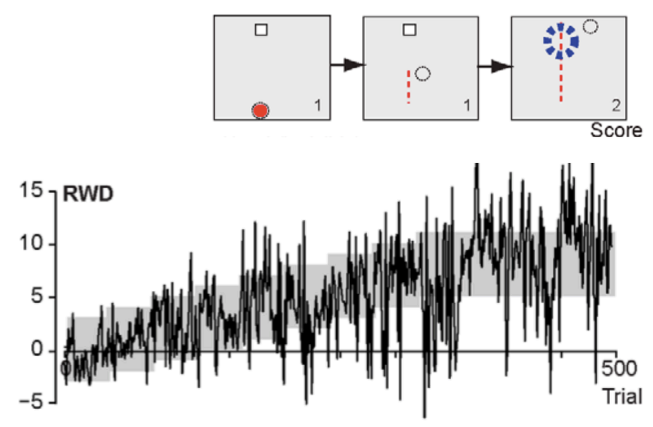

<u>Speech [5,6…]</u>
*F1 perturbation*



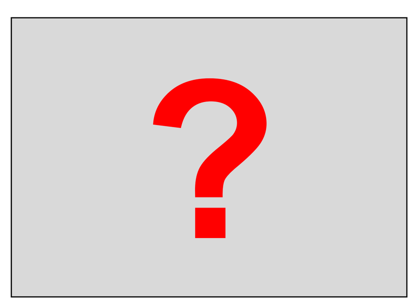

### Reinforcement or reward learning:

*Learning from whether an action was judged to be successful or unsuccessful, separate from whether it matches sensory expectations.*
*(≈ learning which actions to perform)*

<u>Reaching [4]</u>




<u>Speech</u>

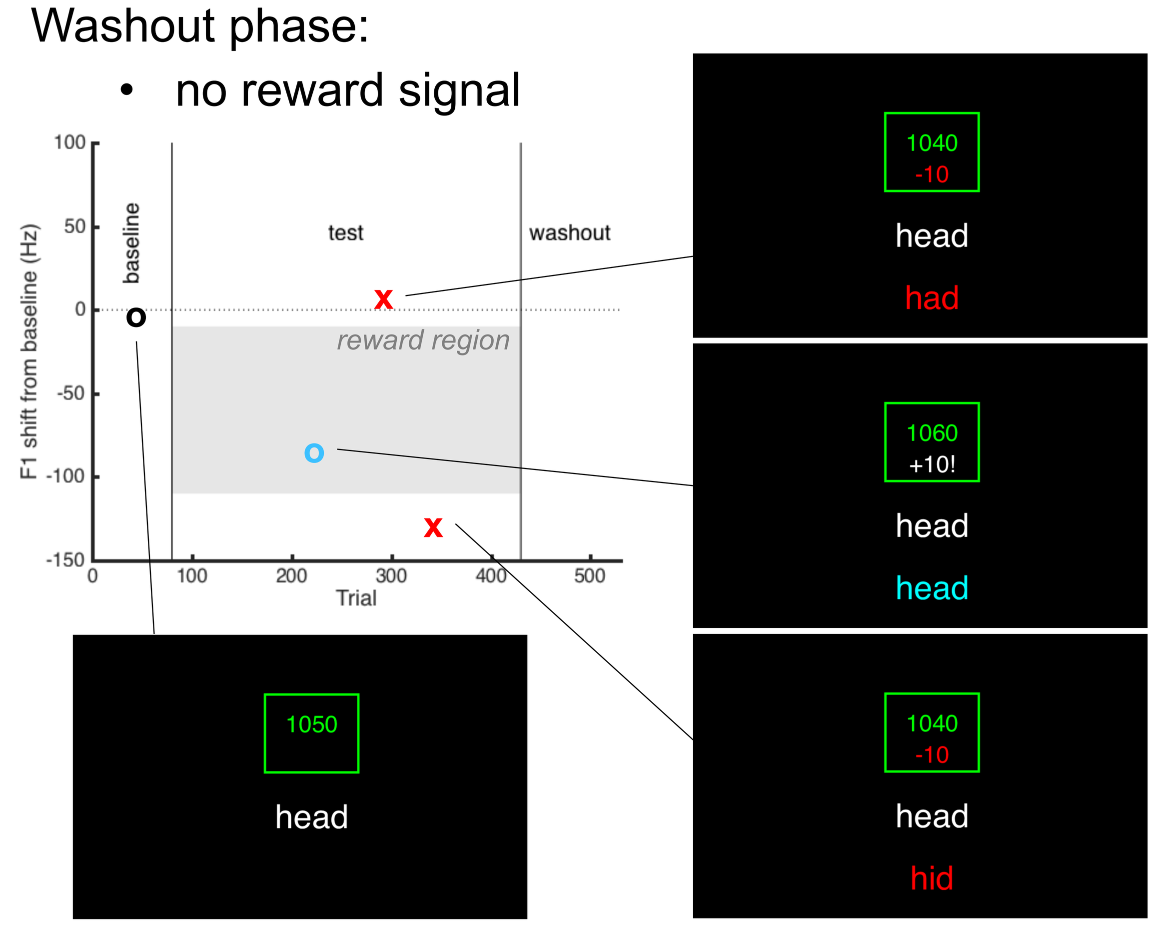



## Experiment design

Baseline phase:
- measurement of baseline F1 for /ɛ/ vowel (EH, e.g. "head") and /ɪ/ vowel (IH, e.g. "hid")
- no reward signal

Test phase
- participant starts with 1000 points
- tokens produced in "reward region" (-110 to -10 Hz below baseline F1) earn +10 points
- productions outside this region lose -10 points

Washout phase:
- no reward signal




## Conditions

### Sensory feedback:

EXP 1/2: Masking noise (speech-shaped, 85 dB)
EXP 3: Normal auditory feedback
***Q:*** *Does the presence of sensory feedback in the unmasked condition interfere with reward learning?*

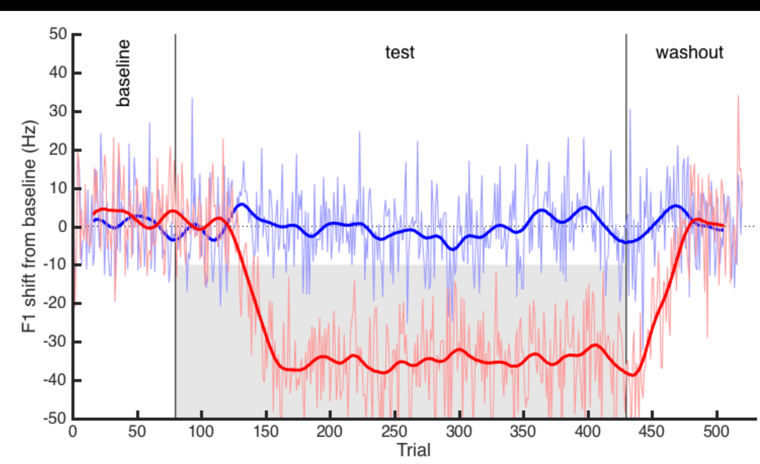
### Reinforcement signal:

EXP 1/3: Participant's own speech, with F1 shifted to center of reward region
EXP 2: Arbitrary noise (chime)
***Q:*** *Do participants benefit from a "reformulation" of their own speech with an implicit auditory target?*

## Predictions

**H0:**
**No learning**

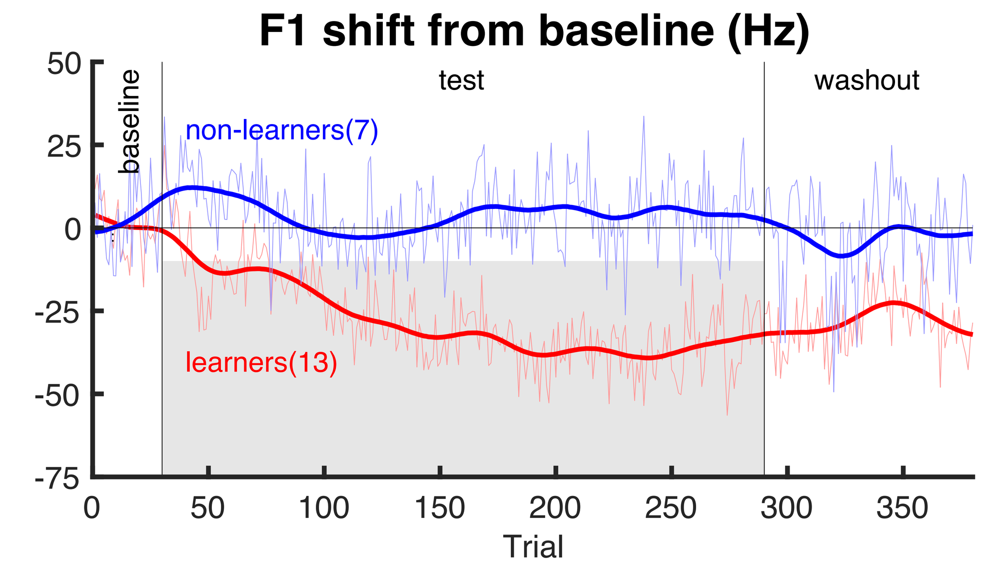
**H1:**
**Learning as in SPE learning**




## Results

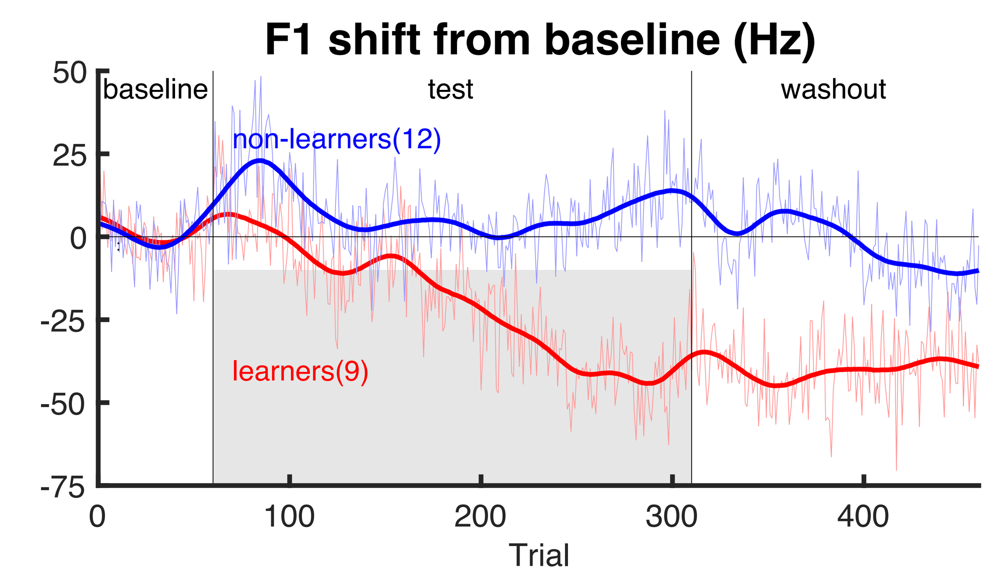
### <u>EXPERIMENT 1 (13/20 learners, 65%)</u>

- **Masking noise**
- **Negative reward**: participant's own production of incorrect word (closest to mean produced during the baseline phase)
- **Positive reward**: participant's own production of the target word from the *<u>baseline</u>* phase (closest to mean), with F1 shifted down by 60 Hz to the center of the reward region



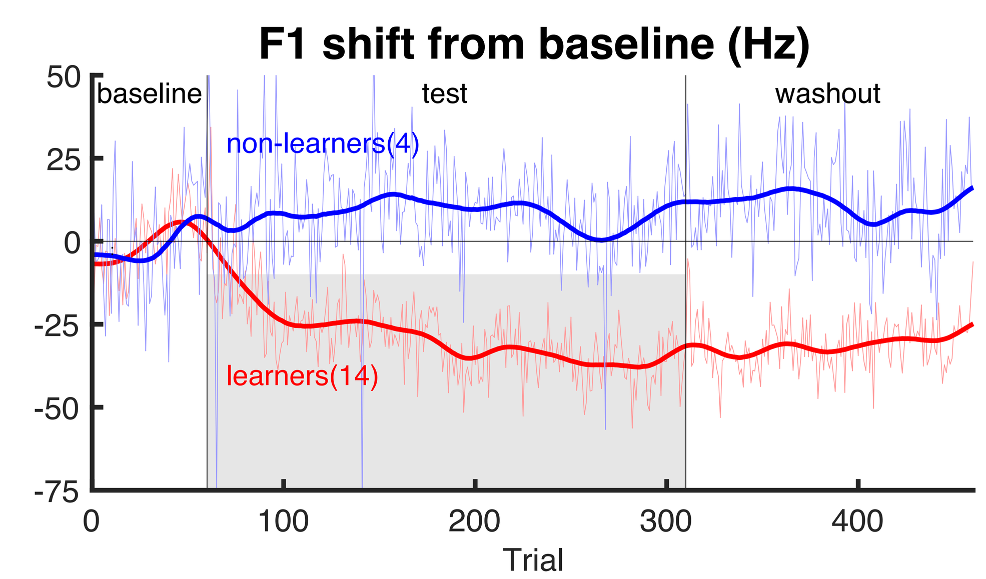

### <u>EXPERIMENT 2 (9/21 learners , 43%)</u>

- **Masking noise**
- **Negative reward**: external voice producing "heard" word
- **Positive reward**: chime

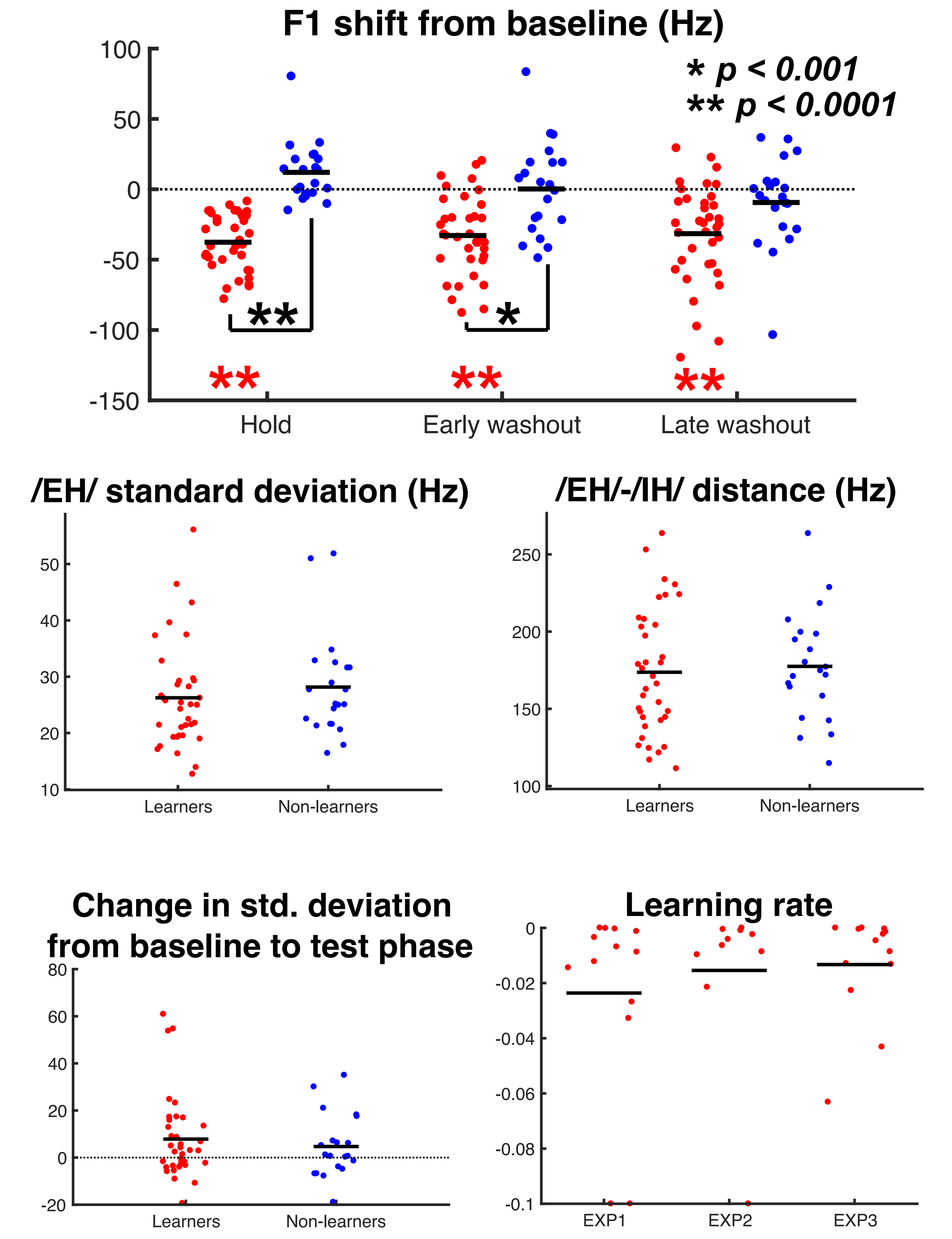



### <u>EXPERIMENT 3 (14/18 learners , 78%)</u>

- **No masking noise**
- **Negative reward**: participant's own production of incorrect word
- **Positive reward**: shifted version of participant's own production of the target word from baseline phase




### <u>COMBINED RESULTS</u>




## Key findings

**Some adult speakers can learn to alter their speech based purely on external reinforcement.**

**Reinforcement learning resulted in long-term changes to production even after reward was no longer given.**
This differs from SPE learning, where participants return to their baseline quickly but is similar to reinforcement learning in reaching [7].

**Sensory feedback does not inhibit reward learning.**
This differs from reaching tasks, where the presence of SPE interferes with reward learning [8].

**Participants were typically unable to adapt a useful explicit strategy to achieve this change.**
As assessed in follow-up surveys.

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## References

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