Functional Brain Changes Associated with Learning a Novel Phonological Contrast

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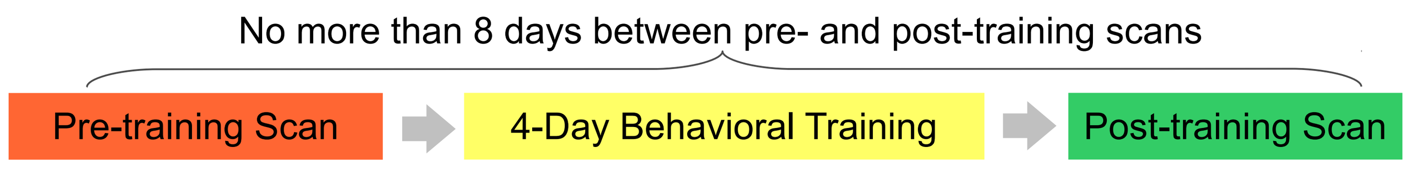
Summary

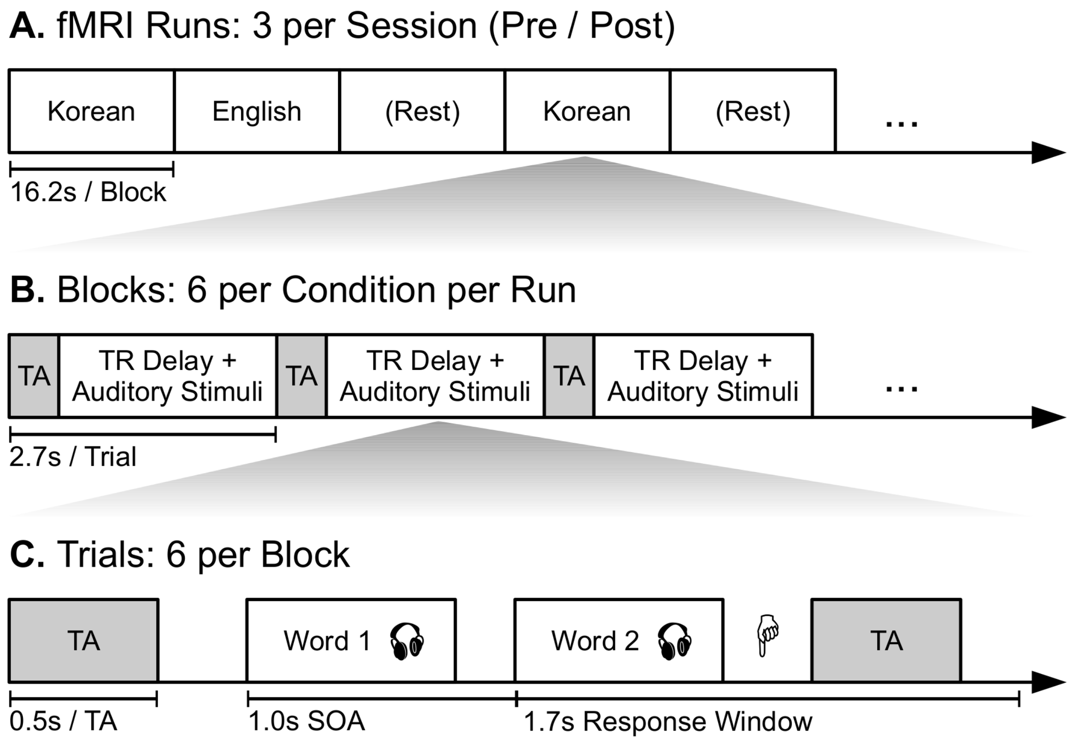
- Adults learned to use a new phonological contrast to recognize words.
- Learners achieved varying degrees of success, which were reflected in pre- and post-training brain differences.
- More successful learners showed greater recruitment of higher-order language areas when processing new speech sounds, such as IFG and SMG.
- White-matter microstructure of left superior longitudinal fasciculus before training was predictive of short- and long-term speech sound learning.

Methods

- **Participants:**
  Native English-speaking adults (N=37) with no prior Korean experience
- **Functional imaging**: *(pre- and post-training)*
  Acquisition: TR=2.7s, TA=0.5s, 3mm³ voxels, 36 slices (4 simultaneous),
  Analysis: FSL, FreeSurfer, and ANTS via Nipype workflows (motion correction, spatial smoothing, sparse-sampling optimized model estimation)
- **Diffusion imaging:** *(pre-training)*
  Acquisition: 60 directions (*b*=700 s/mm²), TR=8.04s, TE=84ms, 2.0mm³ vox.
  Analysis: DTIPrep and TRACULA (with FSL *bedpostx*) via Nipype workflows

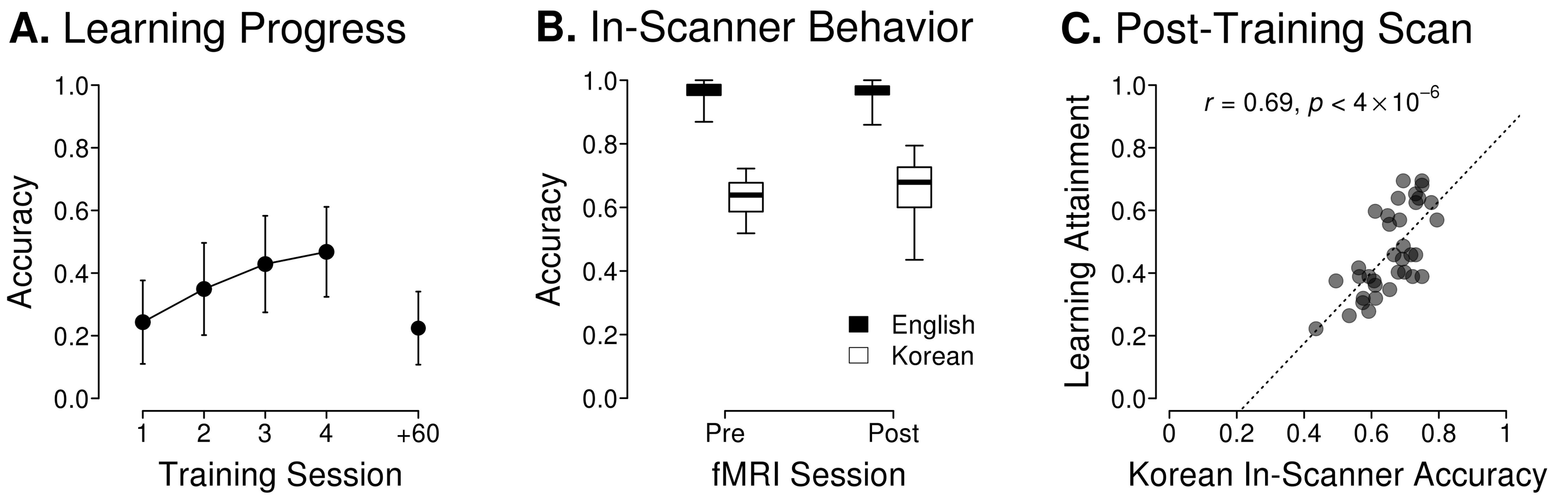


- **Scanner task:** discriminate onset sounds in English and Korean word pairs



Results

Behavioral Results

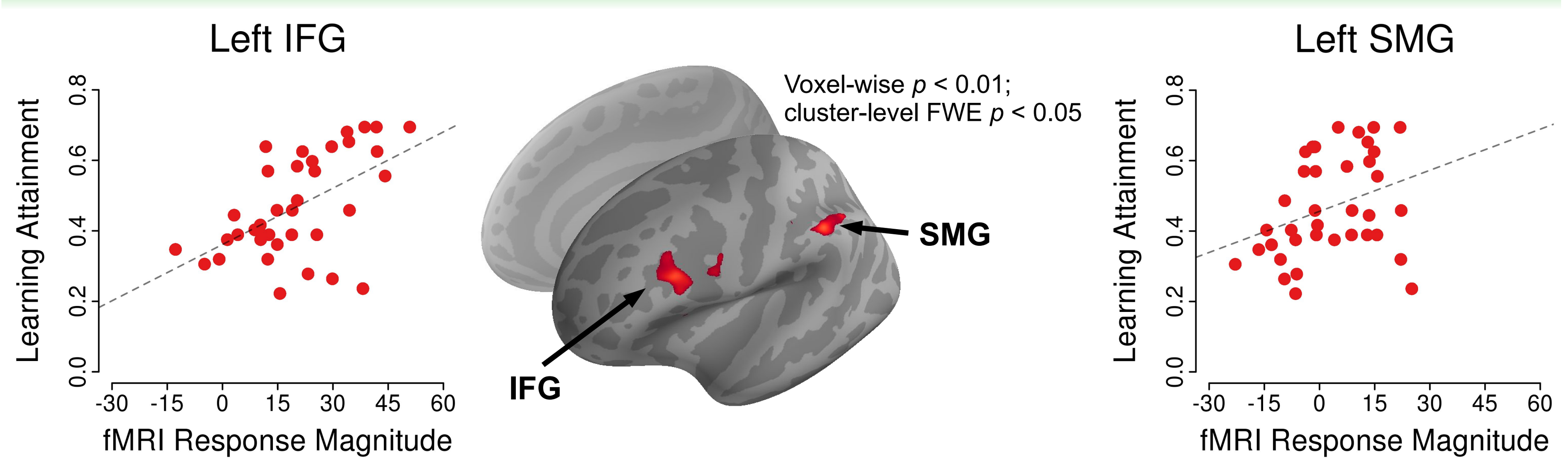


Participants' Korean word identification accuracy improved significantly over the course of training. (paired t_{36} = 12.43, $p < 0.001$)

In-scanner discrimination accuracy was at ceiling in English, and improved with training in Korean. (maximal MELM z = 2.21, $p < 0.028$)

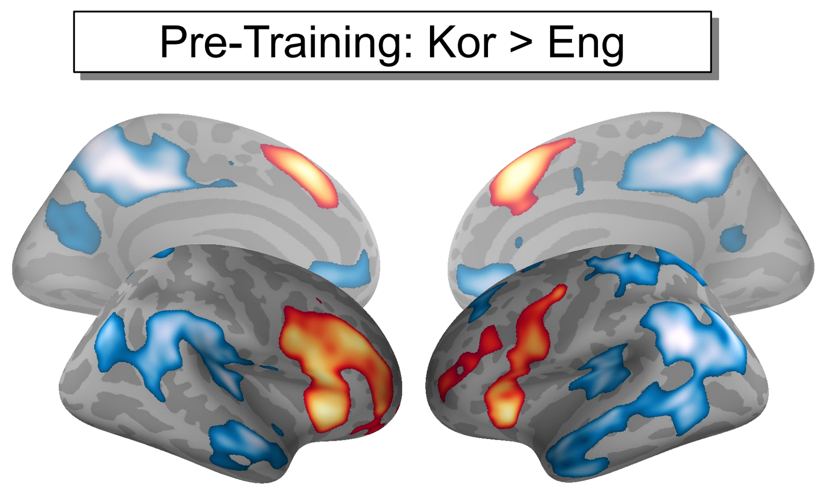
Learning attainment was significantly correlated with in-scanner discrimination accuracy after training. (Pearson r_{35} = 0.69, $p < 4 \times 10^{-6}$)

Correlation with Learning Attainment

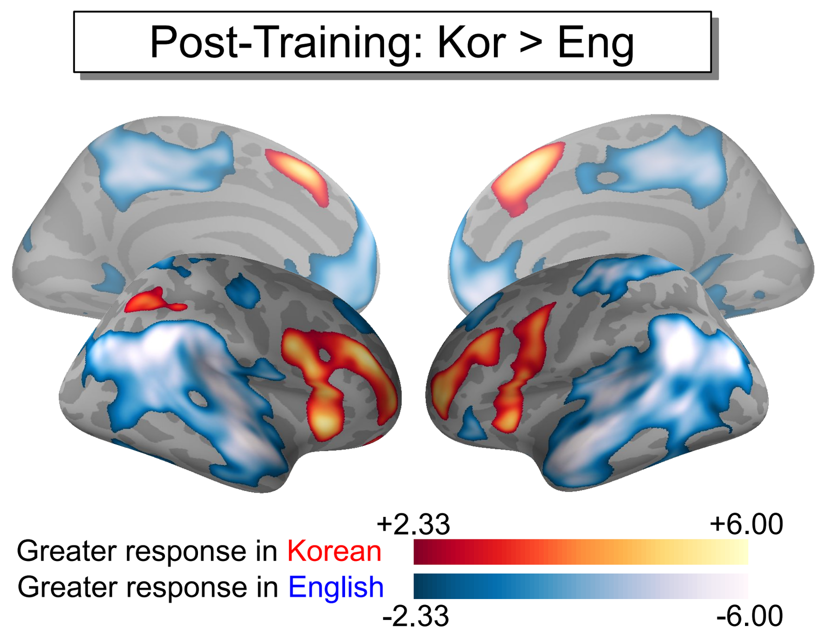


- Individuals' learning attainment was significantly correlated with their post-training functional activation in left IFG and left SMG.
- Left SMG has been implicated in phonological processing.
- Left IFG plays an important role in semantic and phonological processing.

Functional Results

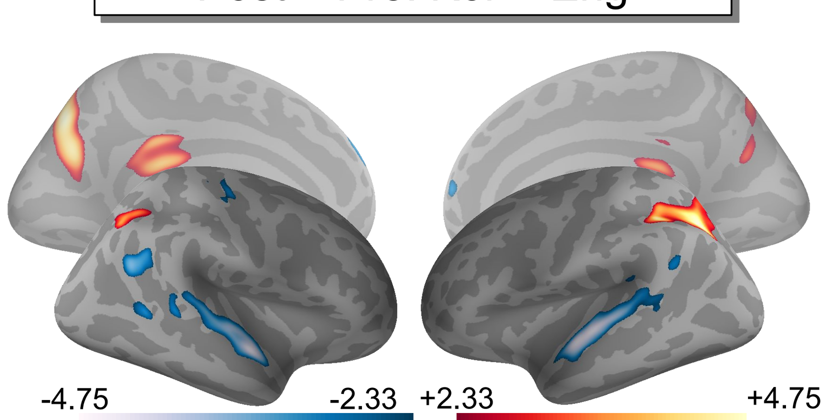


For all figures:
Voxel-wise $p < 0.01$; cluster-level FWE $p < 0.05$



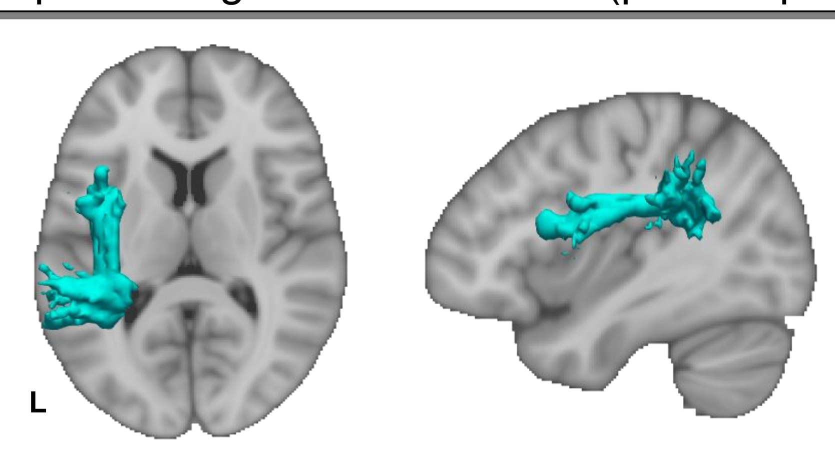
Before and after training:

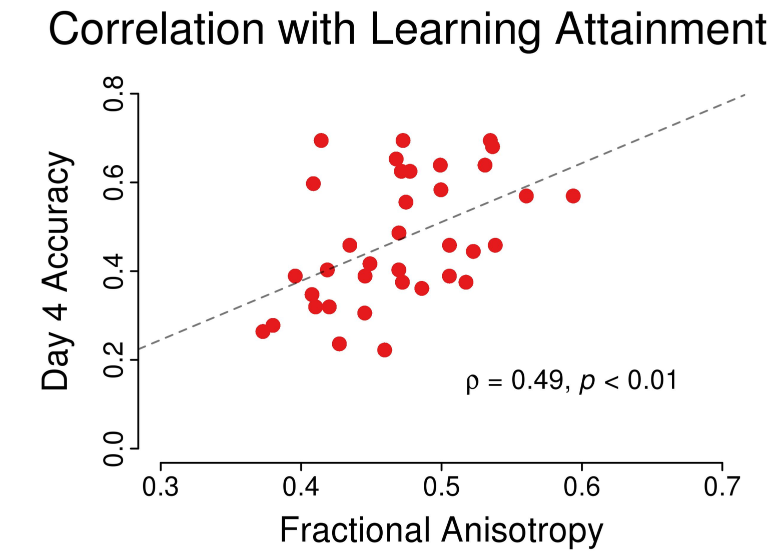
- Bilateral IFG, DLPFC and SMA were more responsive in the Korean condition than the English condition.
- Bilateral STS, SMG, and precuneus were more responsive in the English condition than the Korean condition.



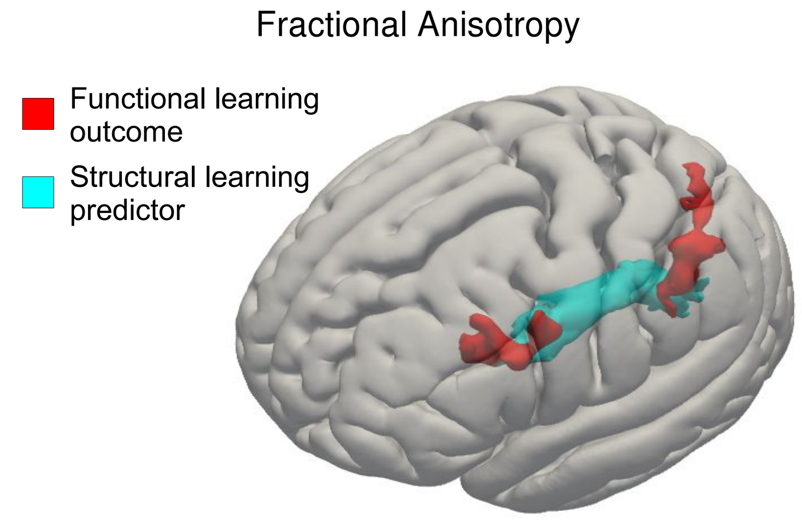
- Greater response to Korean speech increased the Korean > English effect in intraparietal sulcus after training.
- Reduced response to Korean speech increased the English > Korean effect in STG after training.

Diffusion Results





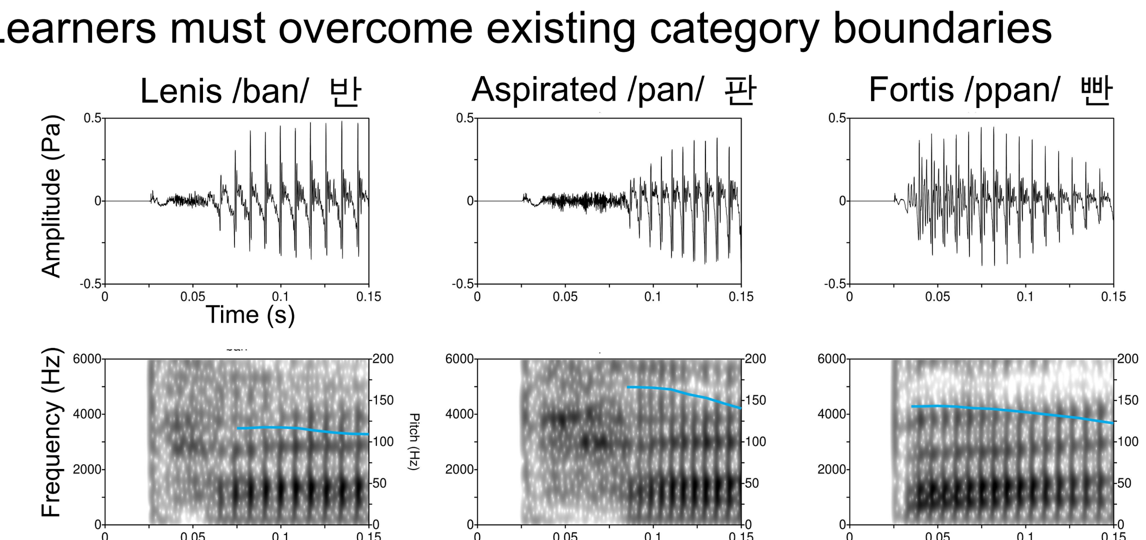
- Fractional anisotropy of left SLFp before training was significantly correlated with Korean vocabulary learning. (Spearman's ρ = 0.49, $p < 0.01$)
- FA of left SLFp was also correlated with participants' performance on Day 1 of training (learning speed) (Spearman's ρ = 0.46, $p < 0.01$)
- As well as their long-term retention of the vocabulary 60 days after training. (Spearman's ρ = 0.36, $p < 0.05$)



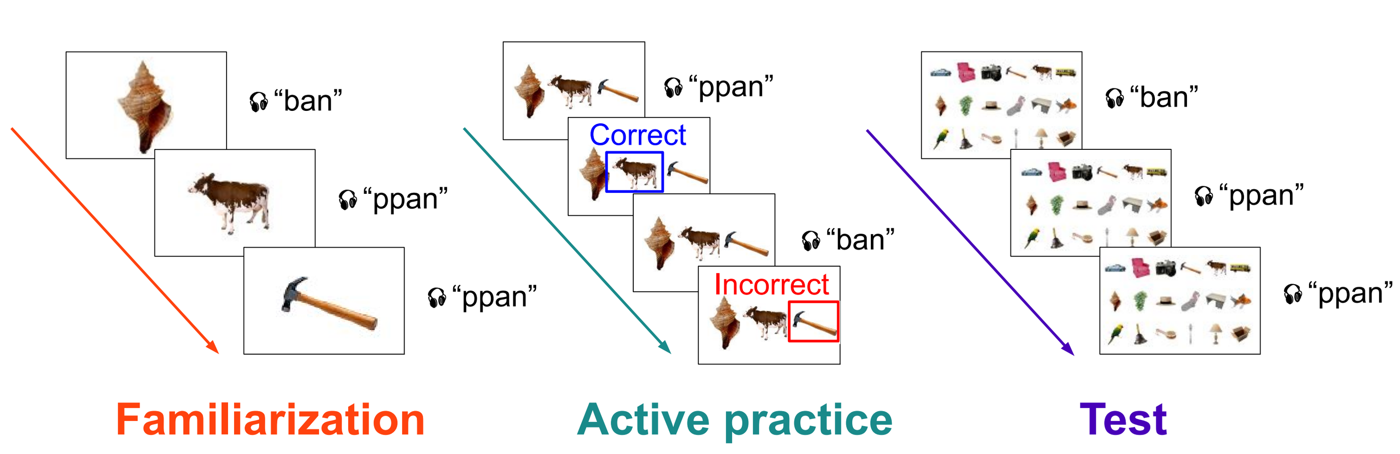
- **Structural connectivity between left IFG and SMG predicts foreign-language learning**
- **Functional change in left IFG and SMG reflects foreign-language learning**

Training Paradigm

- Korean three-way stop contrast: lenis, aspirated, fortis (/b/, /p/, /pp/)
  - Trading relation between voice-onset time and initial pitch
- English has a two-way stop contrast (/p/, /b/)
  - Based only on voice-onset time
- Learners must overcome existing category boundaries



- **Familiarization:** passive association of each word with a picture
- **Active practice:** actively matching each word with its associated picture; blocked by minimal triplets; corrective feedback
- **Test:** actively matching each word with its associated picture; shown all 18 pictures; daily test score used to determine learning attainment



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Acknowledgments

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