Declarative and procedural memory substrates of the categorical perception of speech

M. A. P. S. LAB Memory and Perception of Speech

UCONN

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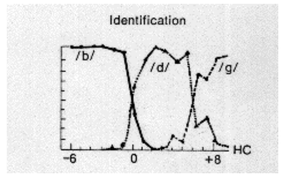
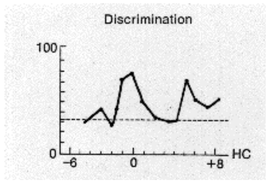
Introduction

- Categorical perception of speech is experimentally defined as a combination of two perceptual behaviors:



Non-linear **identification** of sounds across a linear continuum

&



Better across-category than within-category **discrimination**

(Lieberman et al., 1958)

- Based on this definition, it is often assumed that performance on these tasks index a common underlying speech sound representation.
- However, growing behavioral evidence suggests that these two tasks may reflect qualitatively different types of speech knowledge (e.g. Schouten, Gerrits, & van Hessen, 2003; Antoniou, Best, & Tyler, 2013; Earle & Myers, 2015).
- We propose that the building of phonological categories involves capture of acoustic-phonetic information by the declarative and procedural memory systems in parallel (Earle & Myers, 2014).
- Under this view, observed dissociations in performance on speech-perceptual tasks (such as **identification** and **discrimination**) may reflect task-specific, preferential recruitment of declarative or procedural knowledge.

Hypotheses:
Following training on a 'new' (non-native) speech sound contrast:

H1: changes to speech **identification** performance will rely on learning and consolidation of declarative memory

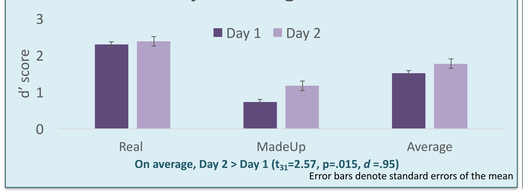
H2: changes to speech **discrimination** performance will rely on learning and consolidation of procedural memory

- In examining the relationships between speech-perceptual tasks and declarative and procedural memory, we explicitly tested the memory processes (i.e. post-training consolidation) that act upon the learned information. This was done in order to rule out differences in preexisting knowledge that could potentially contribute to differences in initial learning.

Results

Declarative Learning

Object Recognition

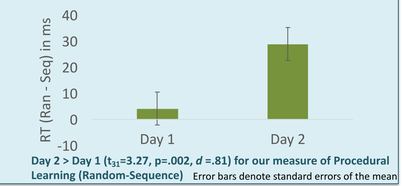


On average, Day 2 > Day 1 (t_{31}=2.57, p=.015, *d* =.95)

Error bars denote standard errors of the mean

Procedural Learning

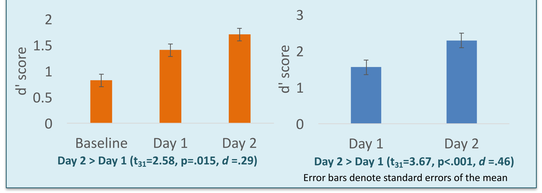
Serial Reaction Time



Day 2 > Day 1 (t_{31}=3.27, p=.002, *d* =.81) for our measure of Procedural Learning (Random-Sequence)

Error bars denote standard errors of the mean

Speech Learning

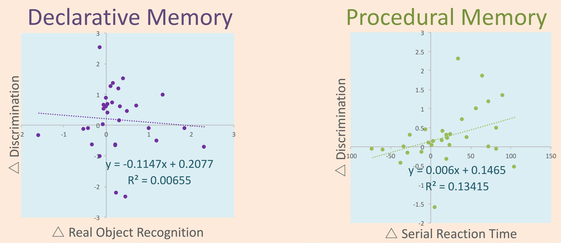


Day 2 > Day 1 (t_{31}=2.58, p=.015, *d* =.29)

Day 2 > Day 1 (t_{31}=3.67, p<.001, *d* =.46)

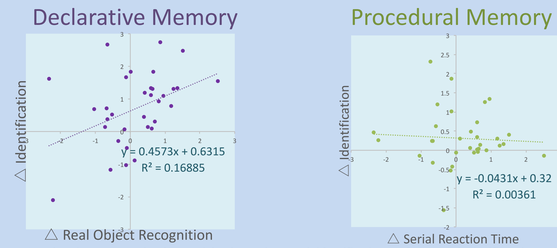
Error bars denote standard errors of the mean

Discrimination ~ Memory Consolidation



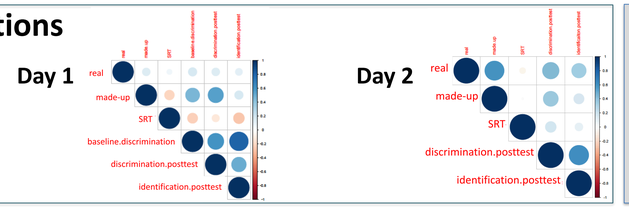
ΔDiscrimination ~ ΔDeclarative + ΔProcedural: overnight change in speech discrimination performance is significantly predicted by overnight change in overnight change in SRT performance ($F_{1,30}$= 5.82, p=.022), but not real object recognition memory performance ($F_{1,30}$=.05, p=.818)

Identification ~ Memory Consolidation

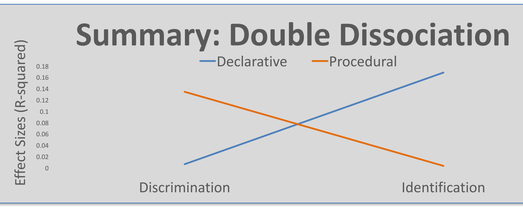


ΔIdentification ~ ΔDeclarative + Δprocedural: overnight change in speech identification performance is significantly predicted by overnight change in real object recognition memory performance ($F_{1,30}$=6.03, p=.020), but not SRT ($F_{1,30}$=.13, p=.723).

Correlations



Summary: Double Dissociation



Conclusions

- Examined by each day independently, neither declarative nor procedural memory appear to correlate with perceptual task performance.
- However, *consolidation processes* acting upon declarative memory appear to facilitate changes in speech-perceptual **identification**
- In contrast, *consolidation processes* acting upon procedural memory appear to promote changes in speech-perceptual **discrimination**
- Speech-perceptual task performance may rely on knowledge acquired by declarative and procedural memory, and moreover, different aspects of speech processing may depend differentially on these types of memory

Methods

Participants

N= 33 (18-35, mean 22.04[2.64], 6M) adults with no hearing, or neurological impairments, and who do not have previous experience with a language that contains the dental-retroflex contrast in its consonant inventory, completed the experiment.

Protocol Overview

Day 1 (7:30-9PM)

Declarative Encoding & Recognition 1
Procedural Training & Test 1
Speech Training & Posttests 1

Between-session sleep monitored via wrist actigraphy

Day 2 (8-9AM)

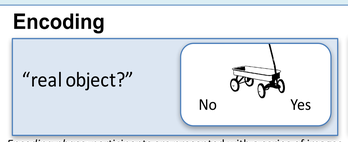
Declarative Encoding & Recognition 2
Procedural Training & Test 2
Speech Training & Posttests 2

Declarative Learning

Recognition memory

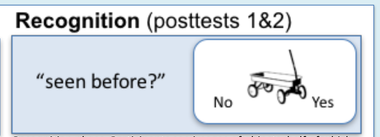
Outcome variable: proportions correct during *Recognition* converted to d' (z[HIT] – z[FALSE ALARM])

Encoding



Encoding phase: participants are presented with a series of images, and are asked to indicate if each object is real or not. After three practice trials, participants complete 64 trials (32 real/32 not real)

Recognition (posttests 1&2)

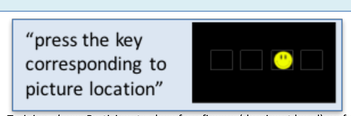


Recognition phase: Participants see images of objects, half of which they have seen in the previous task. Participants are asked to indicate if they saw the object or not before. Participants complete five practice trials, and then 128 trials (64 old objects/64 new objects).

Procedural Learning

Serial Reaction Time

Outcome variable: mean reaction time (RT) for Random - Sequence blocks from each *Test*



Test phase. Participants complete blocks of 40 Random trials, 80 Sequence, and 80 Random trials. Given a stimulus location per trial, the probability of the next location is kept constant between blocks.

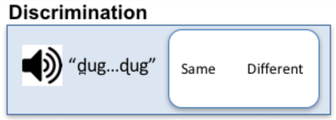
Training phase: Participants place four fingers (dominant hand) on four adjacent keys, and are told to press the key corresponding to the position in which the picture appears as quickly as possible. During the first four blocks (Sequence), the target occurs in a repeated order of ten positions (4,2,3,1,3,2,4,3,2,1). In the last block (Random), the presentation occurs in a pseudorandom order, so that the target occurs in each position the same number of times as the Sequence block.

Speech Learning

Nonnative contrast training

Outcome variables: proportions correct during *Discrimination* and *Identification* Tests converted to d' (z[HIT] – z[FALSE ALARM])

Discrimination



Discrimination assessments. Two tokens are presented (1s ISI). Participants are asked if the sounds at the beginning of the 'words' are the same or different. Each test block contains 64 trials (32 same/32 different). 'Different' trials contains dental and retroflex tokens (/ḍug/,/ḍug/). 'Same' trials contain acoustically different tokens of the same category (e.g. /ḍug$_1$/, /ḍug$_2$/).

Identification (training)

Identification training and assessments. Participants are instructed to choose the object on the screen corresponding to the 'word' that they hear, and they complete 200 trials w/feedback ('correct!' or 'incorrect') after every trial for training, and 50 trials w/out feedback during posttests.

References

Antoniou, M., Best, C. T., & Tyler, M. D. (2013). Focusing the lens of language experience: Perception of Ma'di stops by Greek and English bilinguals and monolinguals. *The Journal of the Acoustical Society of America*, *133*(4), 2397-2411.

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Liberman, A. M., Harris, K. S., Hoffman, H. S., & Griffith, B. C. (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of experimental psychology*, *54*(5), 358-368.

Schouten, B., Gerrits, E., & van Hessen, A. (2003). The end of categorical perception as we know it. *Speech communication*, *41*(1), 71-80.