Adaptation and Perceptual Learning

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And now for something completely different

--Monty Python

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Outline

My initial charge was to consider H as a component in a HM system.
My knowledge about M=0, so concentrate on H

Humans are not passive listeners. We seek certain types of information from the acoustic stream depending on:

- individual strategies/biases
- cognitive influences
- what the experimenter asks about

Bottom line: The necessity of a *functional fit* or *complementarity* between H and M is likely to be a critical part of the HM system.

Dynamic balance between adaptability and stability

My second charge was to talk about *adaptation and perceptual learning.*

Choose to do that as examples of the continuous flexibility of perception and learning

Adaptation/adjustment to altered environment (auditory localization)

Example 1: Using displacing wedge prism goggles, change perceived position of visually tied sound source

Initially mislocalize.

With practice, can accurately point to the sound source

Remove goggles: Negative aftereffect.

NB: Fit little prism goggles to a barn owl → shift in neural auditory receptive fields in tectum that correspond to the change in visual displacement (Knudsen & Brainerd, 1995. *Ann. Rev. Neurosci. 18*, 19-43.).

Example 2: Change perceived position of visually tied sound source via excitation of muscle spindles

Activation of muscle spindles of biceps of one arm via vibration ➡ illusion of forearm extension.

A sound source attached to the finger moves with the perceived finger location ➡ mislocalize sound.

After practice with visual or tactile feedback ➡ auditory localization is accurate again.

Remove vibration: Negative aftereffect.

Example 3:

Sit stationary in an rotating drum moving around you.

There is a sound source attached to the drum, so it is rotating around you too

At first, you feel yourself as stationary while the sound is moving.

After a little while, you feel yourself moving while the drum and the sound seem to be staying still.

NB: Person perceives the chair they're sitting on to be moving with them (Lackner & DiZio, 2000. *Trends in Cognitive Sciences 4*, 279-288).

Stop the rotation of the drum: Negative aftereffect of self-movement

Current theories of perceptual adaptation

- Re-calibration of internal models (forward or inverse).
- Complex re-mapping of many variables (visual, auditory, tactile, vestibular, proprioceptive, etc. *and cognitive factors)* into a space of intrinsic or extrinsic control variables.
- Error feedback used to update/calibrate the internal model (e.g. Imamizu, Uno, & Kawato, 1998; *JEP:HPP 24*, 812-829; Wolpert & Ghahramani, 2000; *Nature Neuroscience 3*, 1212-1217.)

Cognitive information can guide the hierarchy of constraints for the re-mapping/perceptual adaptation

Re-mapping is incredibly fast and flexible.

Take home message:

Perceptual adaptation, and the negative aftereffects, are evidence that what is learned is *constantly and continuously modified:*

Motor learning (Caithness et al, 2004. *Journal of Neuroscience 24*, 8662-8671).

Phonotactic rules

Phonological learning

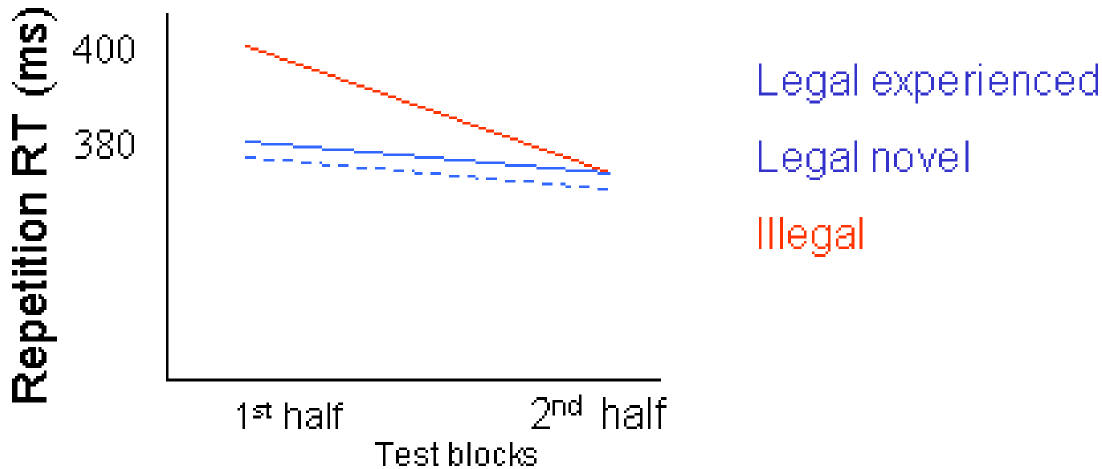
Continuous modifiability of phonotactic sensitivity

(Onishi, Chambers, & Fisher, 2002. Cognition 83, B13-B23):

People simply listened to lists of C_1VC_2 syllables with structured phonological constraints:

First-order regularities: [b,k,m,t] could only occur as C_1
[p,g,n,ch] could only occur as C_2
e.g., bap not nuk

Second-order regularities: if V= [ae], [b] could be C_1 and [p] as C_2.
but if V= [ɪ], legal positions of C reversed
e.g., bap not pab *and* pib not bip



After listening, word repetition for "legal" CVCs [both experienced (LE); and novel (LN)] was faster than for "illegal" CVCs, as defined by the constraints of the initial list.

Effect disappeared as the test session went on (and the statistical skew in the material disappeared)

Phonotactic constraints rapidly learned and continuously modified from listening (no overt instruction)

An alternative to re-calibrating internal models as a mechanism for learning and adaptation that may be more conducive to continuous modification:

Learning as a form of *coordination dynamics:* equations of motion that govern how a system's coordination states (attractors) on a given level of description

1. evolve in time
2. emerge from the nonlinear interactions among component subsystems
3. react under the influence of boundary conditions (perception, intention, task demands, and intrinsic constraints)

Together, these suggest a focus on how the information to-be learned cooperates or competes with the individual's intrinsic dynamics.

(*see* Kelso, J.A.S. 1995, Dynamic Patterns: The Self-Organization of Brain and Behavior, MIT Press, for an overview)

To do this, need to look at individual's intrinsic dynamics and learning over time.

Much evidence that group data don't reflect how individuals learn.

e.g., In several commonly used conditioned-learning paradigms in animals, the shape and time scale of typical learning curves is an artifact of averaging over individuals (Gallistel, Fairhurst, & Balsam, 2004. *PNAS 101*, 13124-13131).

Yesterday: Individual differences in head turning for sound localization.

But HM systems need to work for individuals!

How do individual speaker/hearers learn to perceive reliably a sound that is not in the phonological inventory of their native language?

- Determine intrinsic dynamics, capabilities, of an individual (e.g., Sporns & Edelman 1993,*Child Development 64*, 960-981; Zanone & Kelso, 1997. *JEP:HPP 23*, 1454-1480; Zanone & Kelso, 2002. *JEP:HPP 28*, 776-797).

- Observe whether the learning process is affected by whether the sound to-be learned cooperates or competes with the individual's intrinsic dynamics.

AE monolinguals: trained to perceive voiced Hindi dental stop consonant /d̲/ produced by 6 speakers (4 H, 2 AE) in many phonetic environments (Case, Tuller, & Kelso, 2003. *Speech Pathology*).

Stimulus variability is informative and aids learning (Lively, Logan, & Pisoni, 1993. *JASA*, *94*, 1242-1255.

3 test tasks with a synthetic /da/ - /d̲a/ continuum:

a. judged goodness task (internal structure of a category)

b. Identification task (encourages phonetic coding)

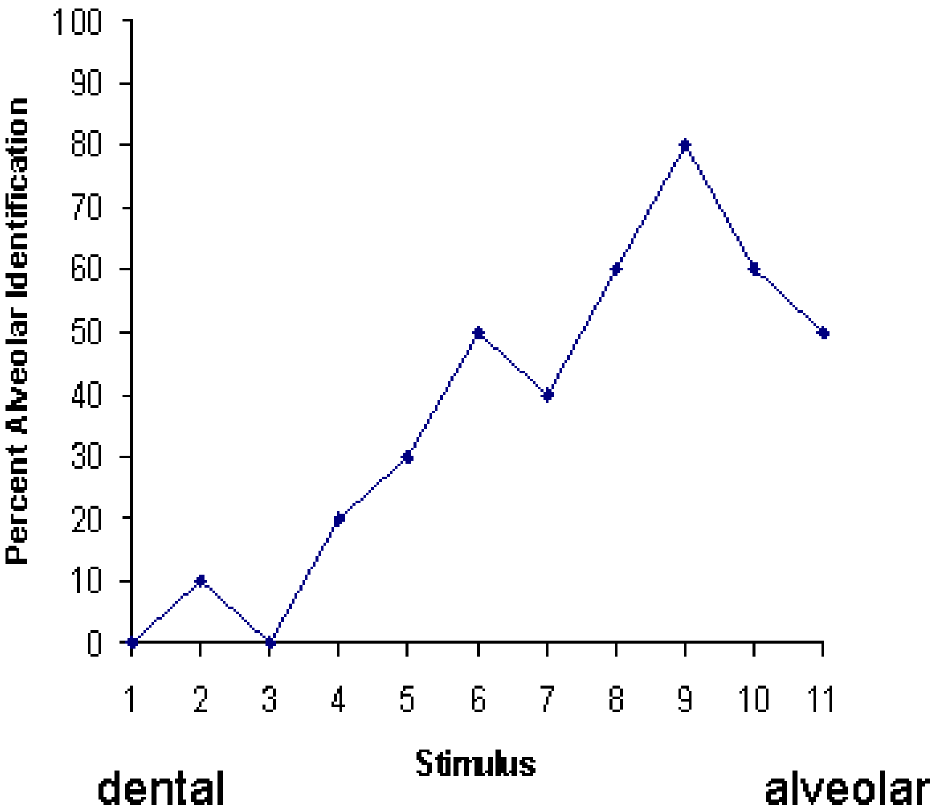
c. difference ratings between stimuli (relationships within and between categories). Used for a MDS analysis over time.

Comparing the results of these tasks gives a fuller picture of how a given listener perceives the stimuli.

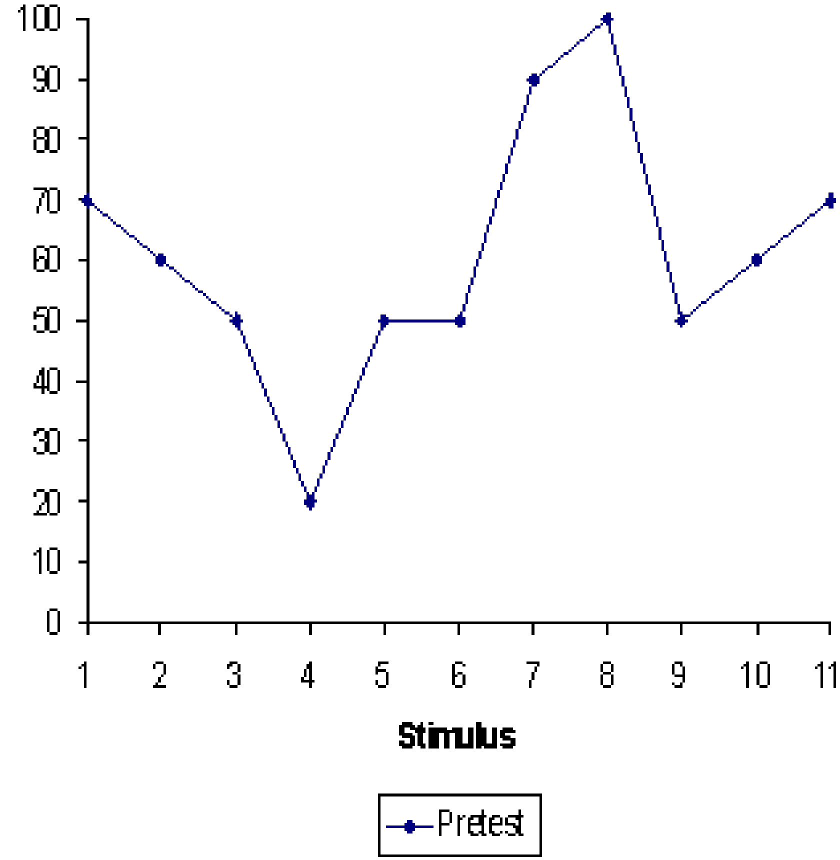
Individuals show very different learning processes:

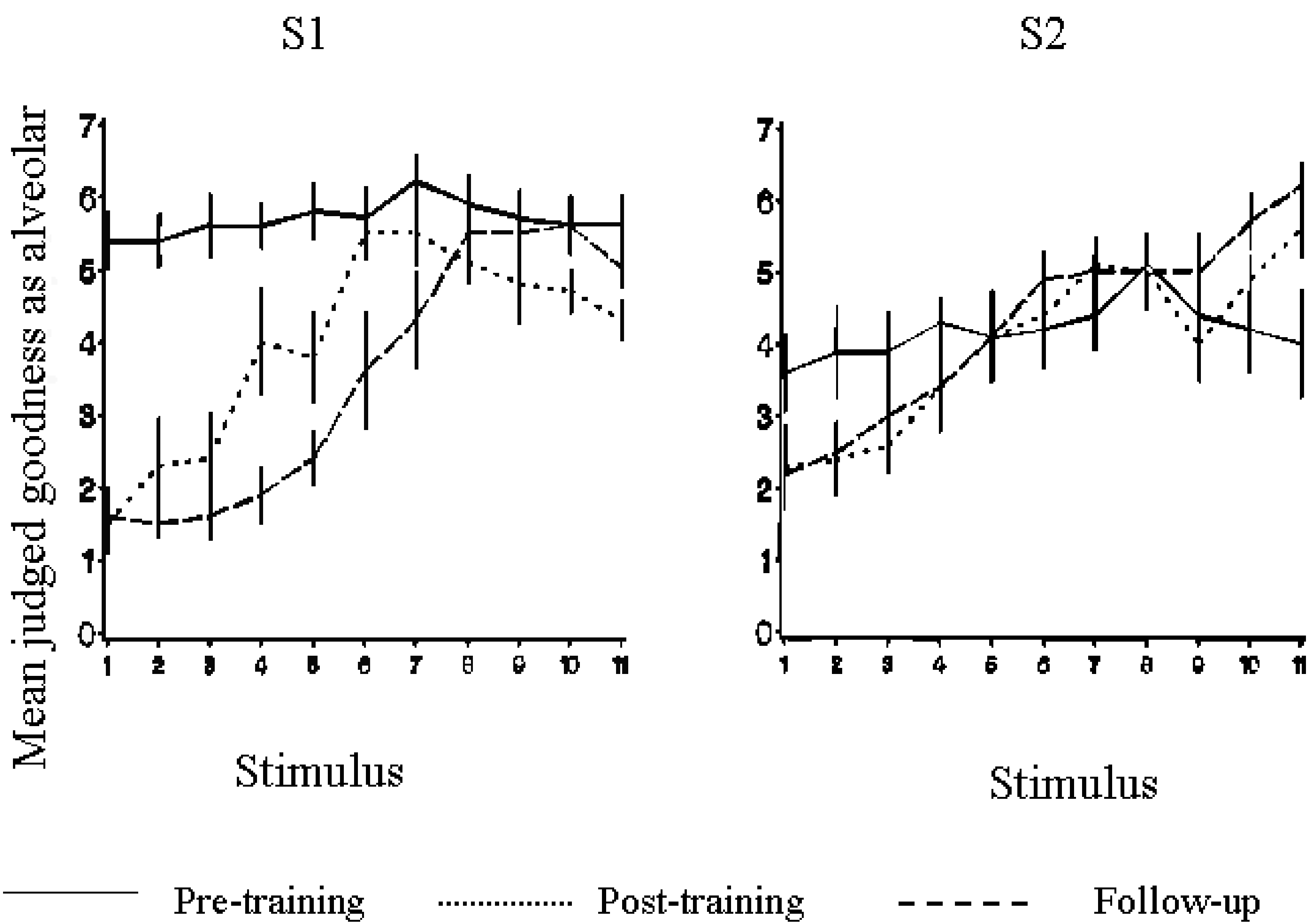
Identification results *prior to training*

S1

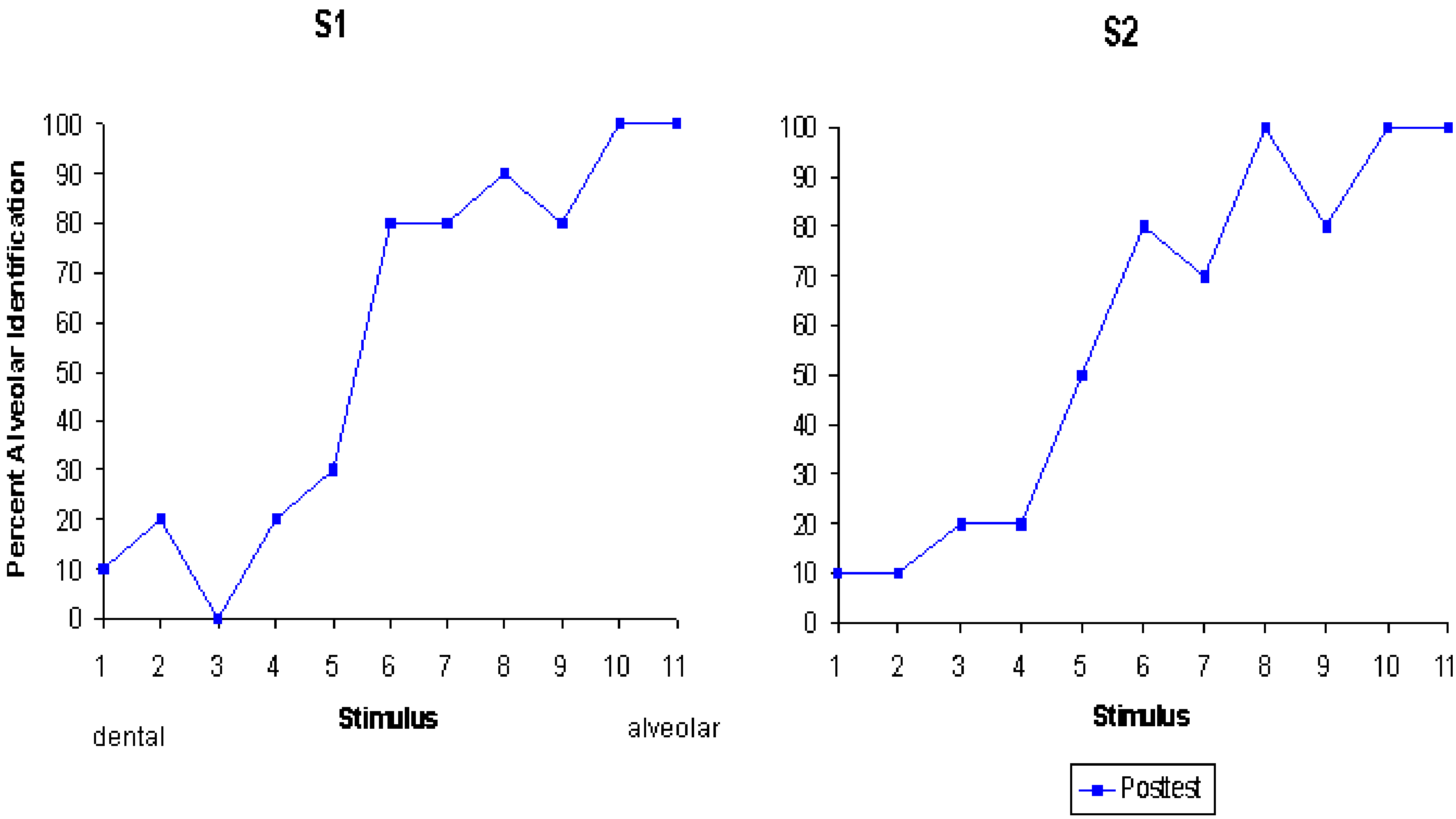


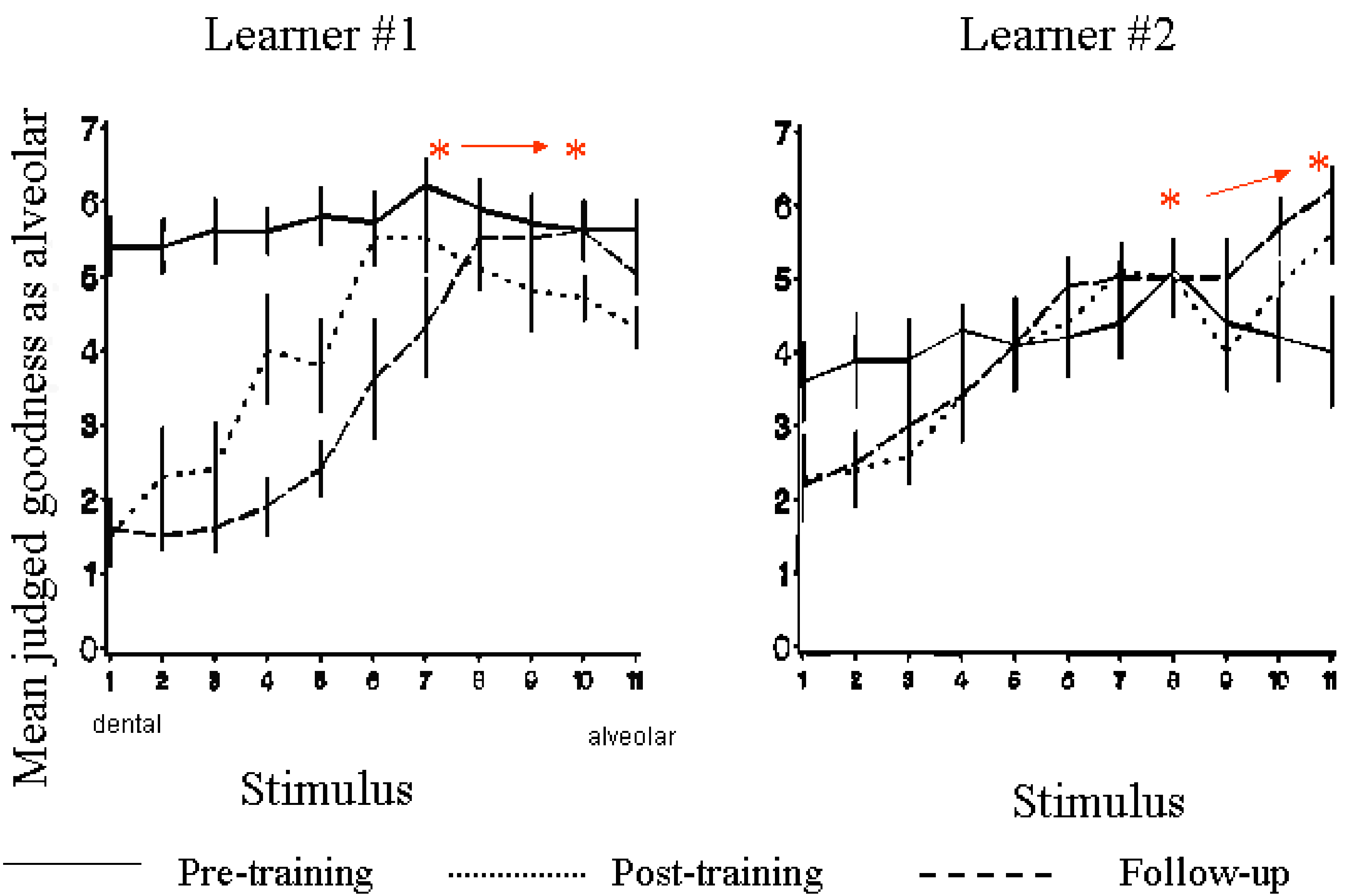
S2




S1
S2
Mean judged goodness as alveolar
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
Stimulus
Stimulus
Pre-training
Post-training
Follow-up

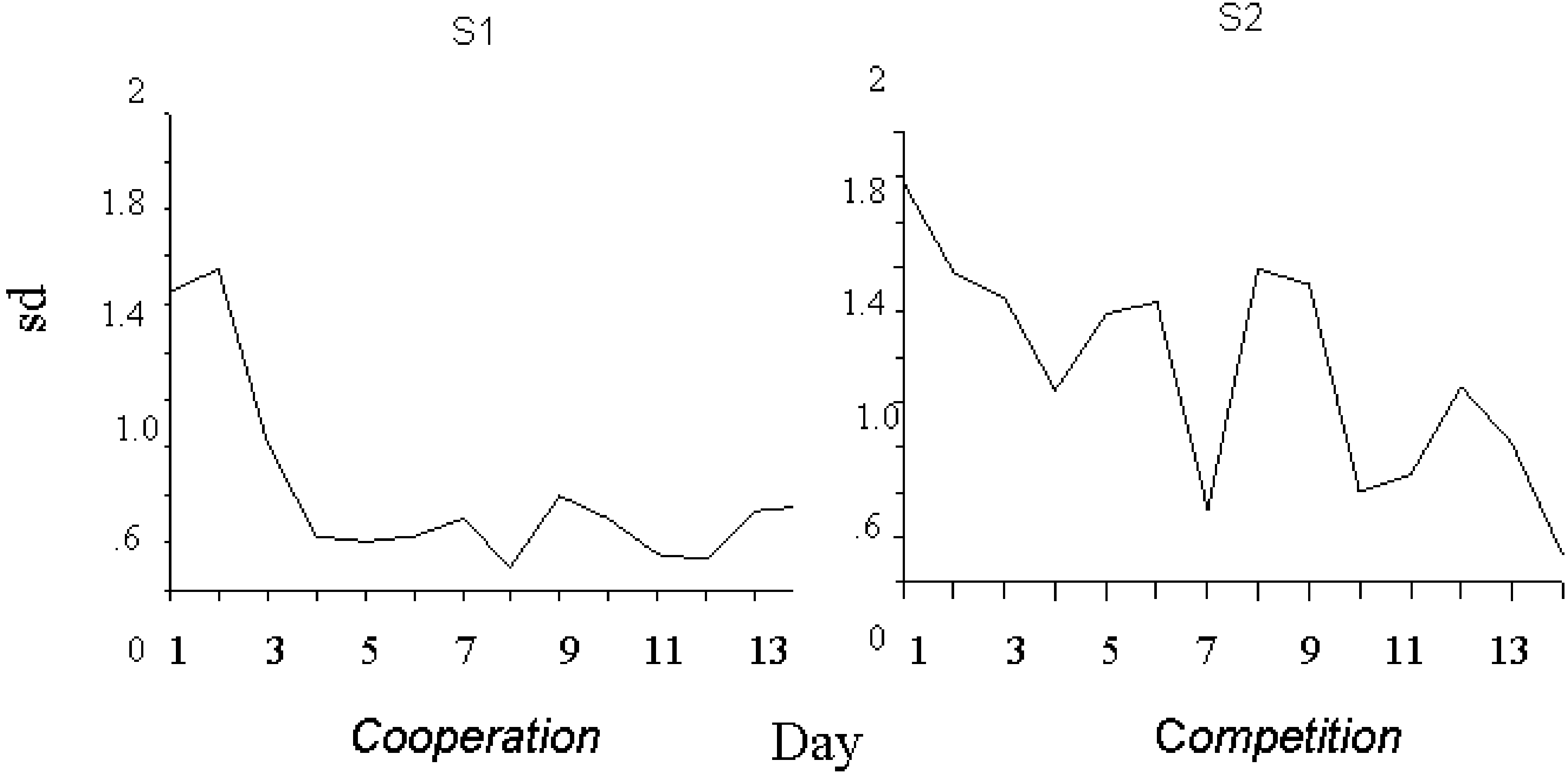
Identification results *after 15 training sessions*





"Best" exemplar changes after learning

Total variability in the MDS analysis on difference ratings as training progressed



Instability as the mechanism for perceptual change?

A conceptual approach to learning that incorporates dynamics – patterns of change over time -- and is based on the individual learner.

Learning patterns depend on:

1. Whether the information to-be learned cooperates or competes with the individual's intrinsic dynamics (complementarity).

2. What the experimenter asks (3 tasks could give different pictures of whether learning has occurred and how).

Bistable (duplex) perception (what you ask is what you get)

As part of a larger experiment:

80-tone sequence of:

150 Hz sinewave alternated with a complex tone with 150, 300, 600, and 900 Hz components (F0=150 Hz)

ISI= 50ms

1s after the sequence ended, Ss heard a) the 4-component complex tone, b) ISI=500ms, c) complex tone (300, 600, and 900 Hz)

Task: Judge rate of the sequence as "fast" or "slow" (pre-trained) *and* which test tone matched the one in the sequence.

Results:

	Fast rate (streamed)	
Match to 3-component tone (F0=300 Hz)	Streaming via old+new heuristic	30%
Match to 4-component tone (F0=150 Hz)	Duplex perception	65%

Summary

1. Duplex perception (non-exclusive allocation) in auditory streaming.

2. WYAIWYG

   Perception is multidimensional!!

3. Stimuli (normal or supranormal) may have perceptual effects on other interacting dimensions– implications for HM systems?.

In summary:

Source separation:

On physical basis (F0; ITD, etc.)

On physiological basis

ON FUNCTIONAL BASIS –ENTAILS COGNITION

To reiterate: The *functional fit* or *complementarity* between H and M is likely to be a critical part of the HM system.

Balance between adaptation/flexibility and stability.

Integration/ segregation

Resolving ambiguity ~ multidimensional perception