Overview

- Biological background
- **Types of learning**
- Modern versions of learning

Operant conditioning

- Other names
  - Instrumental learning
  - Trial-and-error learning
- Behavior that acts ("operates") on the environment
- A ***voluntary response*** is encouraged by rewarding the response*
  - *This means the organism has to do the behavior at least occasionally to begin with

Operant conditioning

Behavior	Consequence (Reinforce/Punish)	Outcome	Type of reinforcement
X	Appetitive ("good") stimulus occurs	**+ behavior**	Positive **reinforcement**

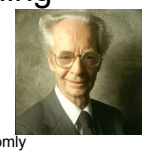
Operant conditioning

Behavior	Consequence (Reinforce/Punish)	Outcome	Type of reinforcement
X	Appetitive ("good") stimulus occurs	**+ behavior**	Positive **reinforcement**
X	Aversive stimulus ends	**+ behavior**	Negative **reinforcement**

Operant conditioning

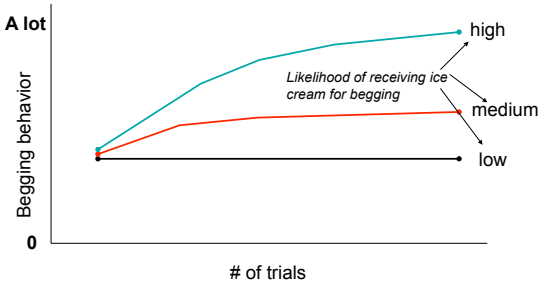
- Reinforcers
  - Primary reinforcers (food, water, mating)
  - Secondary reinforcers
    - Strong association with primary
    - E.g. money
- Punishers
  - Pain
  - Nausea
  - Darkness

Operant conditioning



- In the lab
  - "Skinner box"
    - Behavior: keypeck, bar press
      - Pigeon/rat will do sometimes randomly
    - Reinforcement: food
    - (Or punishment, e.g. footshock or nausea)
    - Directly manipulate frequency of behavior by changing contingencies of behavior

Operant conditioning



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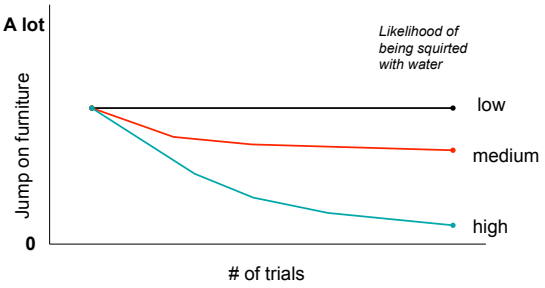

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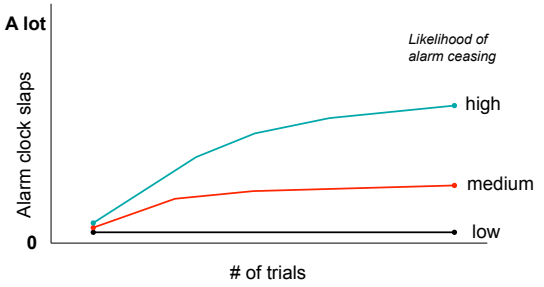

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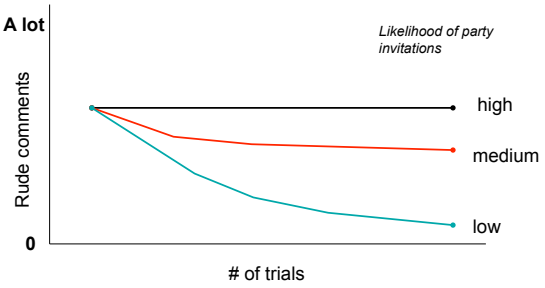


Paired associates

- Human analog to instrumental learning?
- Pair words, flashcard-style ("car"-"coche")

  Stimulus → response → reward (good feeling when you guess right)
- Anticipate word 2 till it's readily recalled
  - BUT bidirectional (word 2 --> word 1)

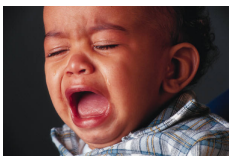
Paired associates

- Each time a pair is learned, strengthened associations
- Learn nonwords--"new" associations
  - But depends greatly on existing knowledge

Conditioning wrap-up

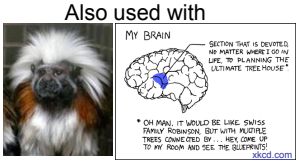
- Weaknesses of 'conditioning' approach
  - Ignore biological influences on behavior
  - Ignores role of top-down info (knowledge)
- Nonethless, still useful in many practical contexts, including…

Infant methods



- Definitely cognitive stuff going on.
- But how to investigate in non-verbal organisms?
- By looking at behavior.

Also used with



Learning

- Figuring out what things go together
- (And also what things *don't* go together)

- Lookattheprettybabyeveryone
- Whereisthebabynowprettygirl
- Thislittlebabyisprettygood

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- Whereisthebabynowprettygirl
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- ty->ba: unlikely (.33 transition probability)
- ba->by: likely (1.0 transition probability)
- by->ev: unlikely (.33)

- Lookattheprett**tyba**byeveryone
- Whereisthebabynowprett**tygirl**
- Thislittlebabyisprett**tygood**

- ty->ba: unlikely (.33 transition probability)
- ba->by: likely (1.0 transition probability)
- by->ev: unlikely (.33)

Other cues to word boundaries

- Stress
  - English: most words are stress-initial
  - ThePREttyBAbyWANTSaBOTtle

Other cues to word boundaries

- Jusczyk, Houston & Newsome
  - 7.5. Months:
    - Familiarize infants with stress-initial words
      - KINGdom
    - Play passages with KINGdom vs. HAMlet
    - Infants listen longer to kingdom >hamlet passages
    - **Recognize words**

Other cues to word boundaries

- Jusczyk, Houston & Newsome
  - 7.5. Months:
    - Stress-initial OK
    - Familiarize with guiTAR
    - Test with guiTAR, surPRISE
    - No difference in looking times

Other cues to word boundaries

- Jusczyk, Houston & Newsome
  - 7.5. Months:
    - Stress-initial (**king**dom) OK
    - Stress not initial (gui**tar**) XX

Other cues to word boundaries

- Jusczyk, Houston & Newsome
  - 7.5. months:
    - Stress-initial (**king**dom) OK
    - Stress not initial (gui**tar**) XX
  - 10.5 months:
    - Stress not initial (gui**tar**) OK

But…

- Not all languages have this kind of stress pattern.
- (Similar to the segmentation problem in object recognition--how do you know what the **properties** of objects/words are if you don't know what the objects/ words are **themselves**???)

Statistical learning

- Saffran, Aslin & Newport (1996)
  - 8-month-old infants

golabubidakutupiropadotitupirobidakupad otigolabupadotibidakugolabutupiro golabupadotitupirobidakupadotibidakutu pirogolabupadotibidakugolabutupiro …

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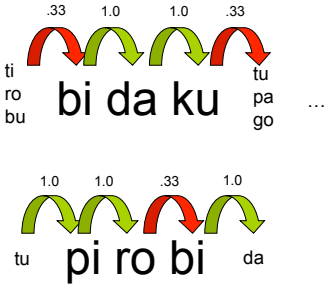

Statistical learning

- Play for 2 minutes
- Present kids with bidaku or piro.bi type words
- What do they listen to longer?
  bidaku < piro.bi
  - (novelty preference)
- *At 8 months infants can segment words based on statistical cues*

But what about stress?

- BRILligSLIthyTOVES.

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- Johnson & Jusczyk (2001)
  - 8-month-olds
  - Stress vs. statistics: Stress wins

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  - Statistics wins @ 7 mos
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  - Stress wins @ 9 mos
- *Segmentation precedes stress.*

Statistical learning

- What's getting learned?
  - Frequency
    - Thedog > hassock
    - But "thedog" isn't a word, and hassock is (srsly)
  - *Conditional* probability
    - Given X, Y is __ likely to happen
    - *Predictiveness*
- Aslin, Saffran & Newport (1996)

Statistical learning

- What's getting learned?
  - Aslin, Saffran & Newport (1996)
    - golabu/padoti 2x as often as tupiro/bidaku
    - So ti.gola is as frequent as bidaku (45x each)
    - But

1.0 1.0
bi->da->ku

.33 1.0
ti->go->la

Statistical learning

- What's getting learned?
  - Aslin, Saffran & Newport (1996)
    - golabu/padoti 2x as often as tupiro/bidaku
    - So tiba.go is as frequent as bidaku (45x each)
    - 3 min of listening; then test

Frequency:

=

1.0 1.0
bi->da->ku

.33 1.0
ti->go->la

Cond. prob.:

<

Statistical learning

- Infants are indeed learning conditional probabilities, not just frequency.

Language specificity?

- Works for language
- Works for tone sequences (C-C#-G…)
- Works for visual stuff
- Rats do it
- Babies, kids, adults do it

- **Parallel results: language and music**
- **Slightly differing: sound and sight**

Nonadjacent dependencies

- Phenomenon in language
- Not only…but also
  - Either…or
  - Who…with?
  - Got _____ed
- Dependent on linguistic structure, or learnable from input?

Nonadjacent dependencies

- Nonadjacent dependency learning:

Nonadjacent dependencies

go 1.0 la 1.0 bu .33 tu…

.33 pa…

.33 bi…

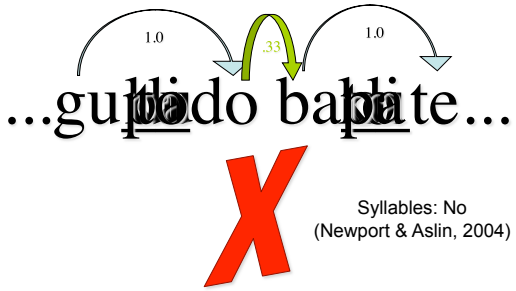
Nonadjacent dependencies

go 1.0 la 1.0 bu .33 tu…

.33 pa…

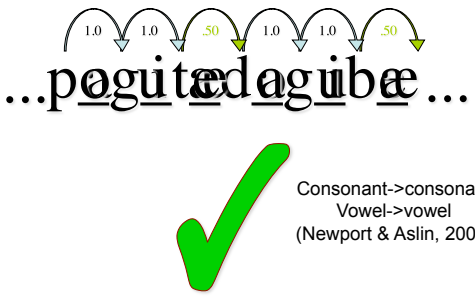
.33 bi…

Nonadjacent dependencies



Syllables: No
(Newport & Aslin, 2004)

Nonadjacent dependencies



Consonant->consonant
Vowel->vowel
(Newport & Aslin, 2004)

Nonadjacent dependencies

- For nonadjacent speech information to be learned, the information must be of "like kind" (segment type, C or V)

How do we know what sounds go together?

- Gestalt grouping cues (e.g. Bregman, 1990)
- Frequency of co-occurrence (e.g. Saffran, Aslin, Newport, 1996)

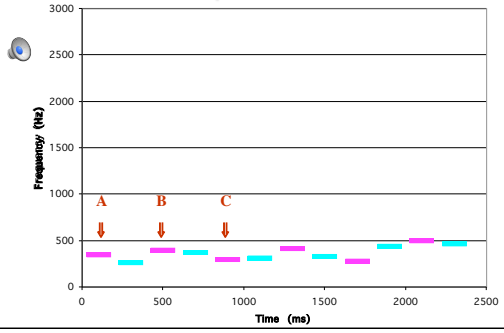
(Perception vs. learning, kind of)

How do these types of information interact with each other?

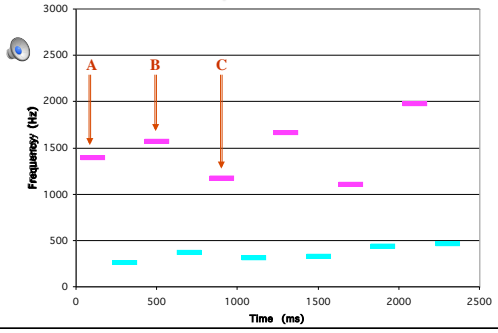
Nonadjacent dependencies

- Creel, Newport & Aslin (2004)
  - Tones in two statistical groupings
  - Same or different pitch ranges
  - Streams interleaved
  - Two “words” (triplets)
- Group by statistics?
- Group by pitch range?

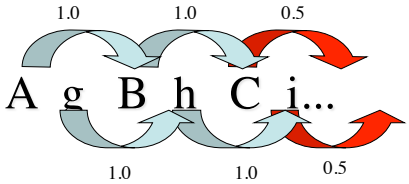
Similar-pitch condition



Different-pitch condition



Statistics



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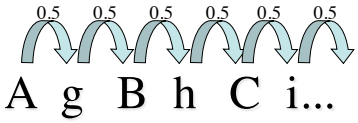

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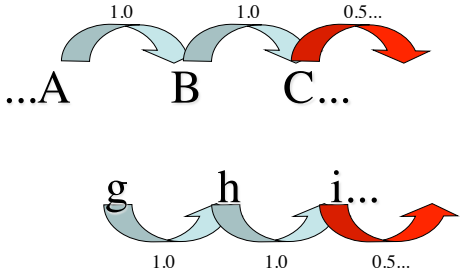

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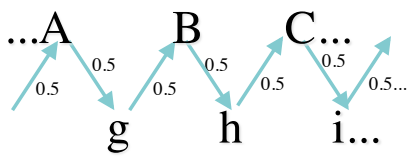


Nonadjacent dependencies

Test items

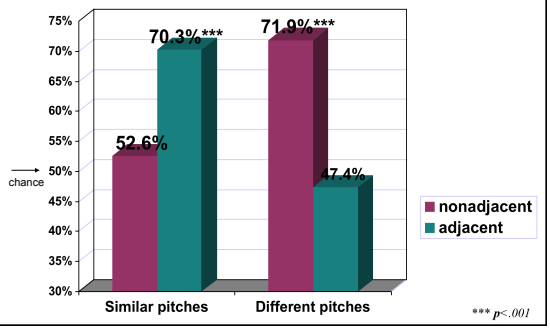
Nonadjacent items

- A_B_C_ (triplet)
- *E_D_F_ (scrambled triplet)

Adjacent items

- CiAgBh (legal 6-tone sequence)
- *FkDlEj (illegal 6-tone sequence)

Nonadjacent dependencies



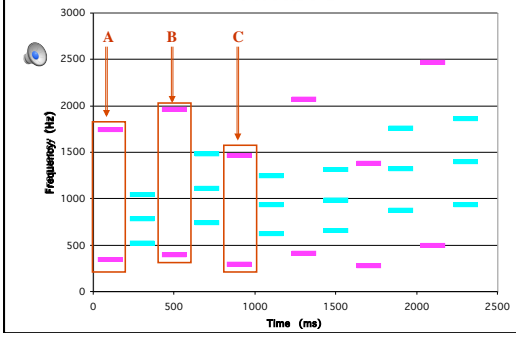
Nonadjacent dependencies

Is high v. low the only grouping cue?

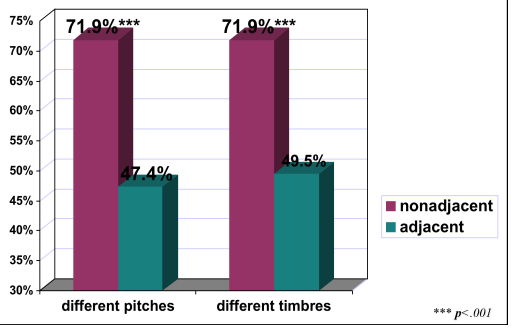
Redo different-pitch condition, but with complex tones of two different timbres

–Perceived fundamentals of each tone set in same frequency range
–Actual harmonics don't overlap

Timbre



Pitch vs. timbre learning

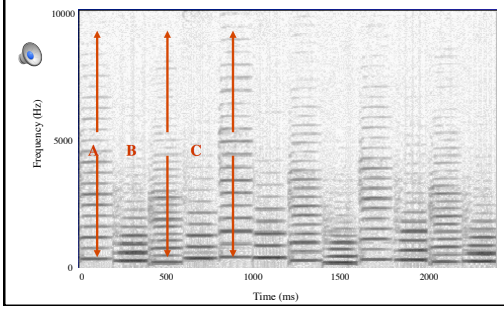


Really like speech?

All-or-none auditory effect?
- –Could be a low-level perceptual phenomenon
- –Not related to language-learning
  - – Speech doesn't "fly apart" like that

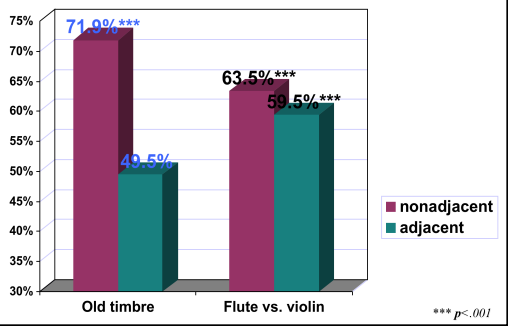
New timbre difference: flute vs. violin
- – Discernibly different but harmonics overlap

Flute/violin



Timbre

Learned both structures!



Nonadjacent dependencies

- General auditory perceptual principles may constrain learning of both speech statistics and nonspeech statistics
- Similar effects across two domains
  - – Within same modality

Vision vs. audition

- Temporal sequences:
  - – Audition better
- Simultaneous cooccurrence:
  - – Vision better
  - – But some auditory cooccurrences learned