Classical view of the past tense

- The English past tense rule is a morphological rule: add -ed.

  talk → talked (phonologically: add /t/)

  aid → aided (phonologically: add /u//d/)

  sail → sailed (phonologically: add /d/)

But it has lots of exceptions

go/went

is/was

bring/brought,

sing/sang [not sought]

seek/sought, but

[but leak/leaked, not lought]

feed/fed

read/read

[but need/needed, not ned]

think/thought

drink/drank

[but blink/blinked, not blought]

bite/bit

light/lit [or lighted], but:

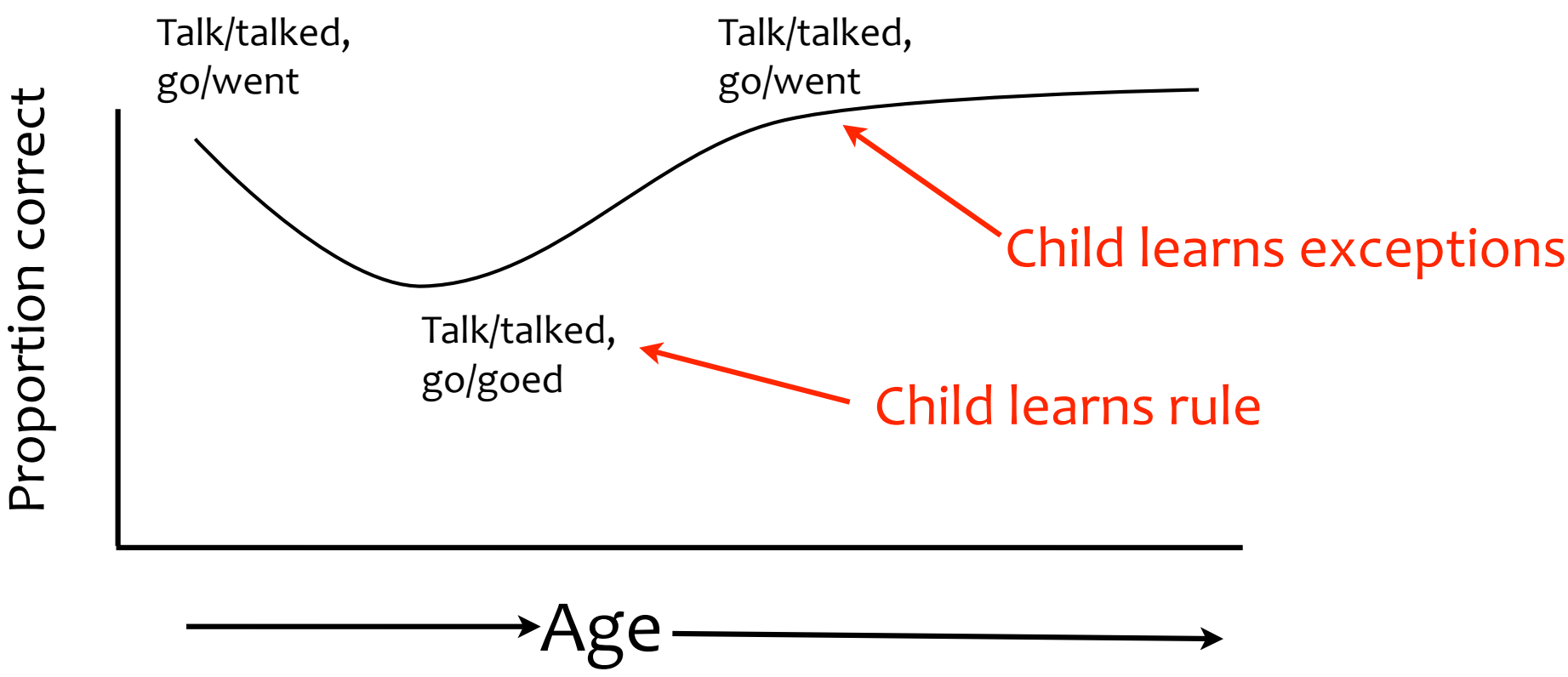
fight/fought

write/wrote

meet/met

[but eat/ate]

The U-shaped curve

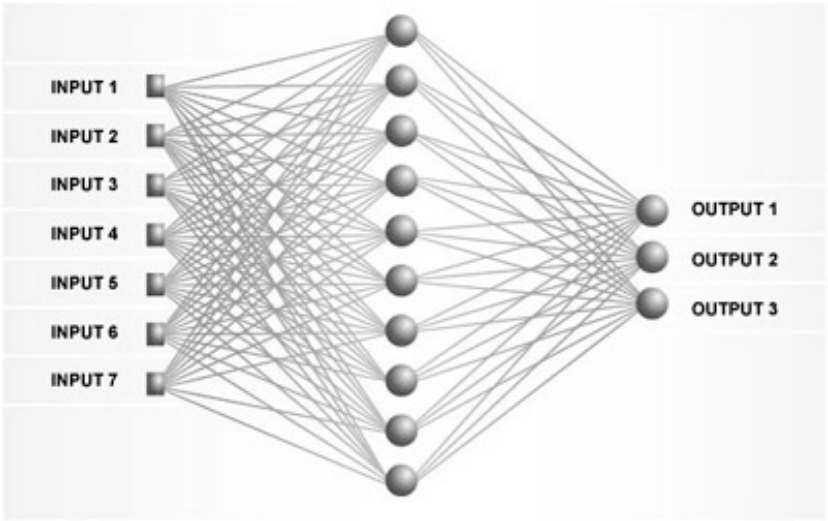


The wug test: "Today I will wug, yesterday I _____"?

Past tense neural network (McClelland & Rumelhart, 1986)

Learns the correct input-output by backpropagation

- in a parallel distributed fashion
- without rules
- without morphemes
- without any distinction between regulars and irregulars

talk		talked
go		went
think		thought
wug		wugged

The war over the past tense

- McClelland & Rumelhart (1986) proposed to explain this most rule-like and symbolic phenomenon without rules

  Thus past tense learning would be an application of general learning mechanisms not specific to language

  Their network even replicated the U-shaped learning curve

- Pinker & Prince argued

  The network generalizes incorrectly

  mail/membled

  bear/bore but bare/bared; steal/stole but steel/steeled

  fly/flew but fly out/flied out

  U-shaped performance is rigged by input

The return of connectionism…

- About 2010, key technical advances allowed for training of networks with more than 3 layers

  - Such networks are called Deep Neural Networks (DNNs)

- DNNs are now routinely applied to databases with millions or billions of examples

- Such networks have been very successful in practice, but suffer from some of the same theoretical problems as classical connectionist networks

Deep learning of "concepts"

- Supervised learning

  - Many labeled examples

  - Evaluate performance on a distinct set

Bedroom

Bedroom

Bedroom

…

Training

Highway

Highway

Highway

…

?

?

Test

?

?

But: Does the system know what a bed is? A car? A highway sign? Does it have "concepts?"

Successes of DNNs

- DNNs are the most effective current techniques for automated
  - speech recognition (Siri, Alexa, etc.)
  - image classification (ImageNet, etc.)
  - machine translation
  - etc.
- DNNs are routinely used as models of the brain
  - Nodes in DNN correspond to neurons
  - Layers of DNN corresponds to layers in the brain