

Neural networks

Deep learning - motivation

NEURAL NETWORK

Topics: multilayer neural network

- Could have L hidden layers:

- ▶ layer input activation for $k > 0$ ($\mathbf{h}^{(0)}(\mathbf{x}) = \mathbf{x}$)

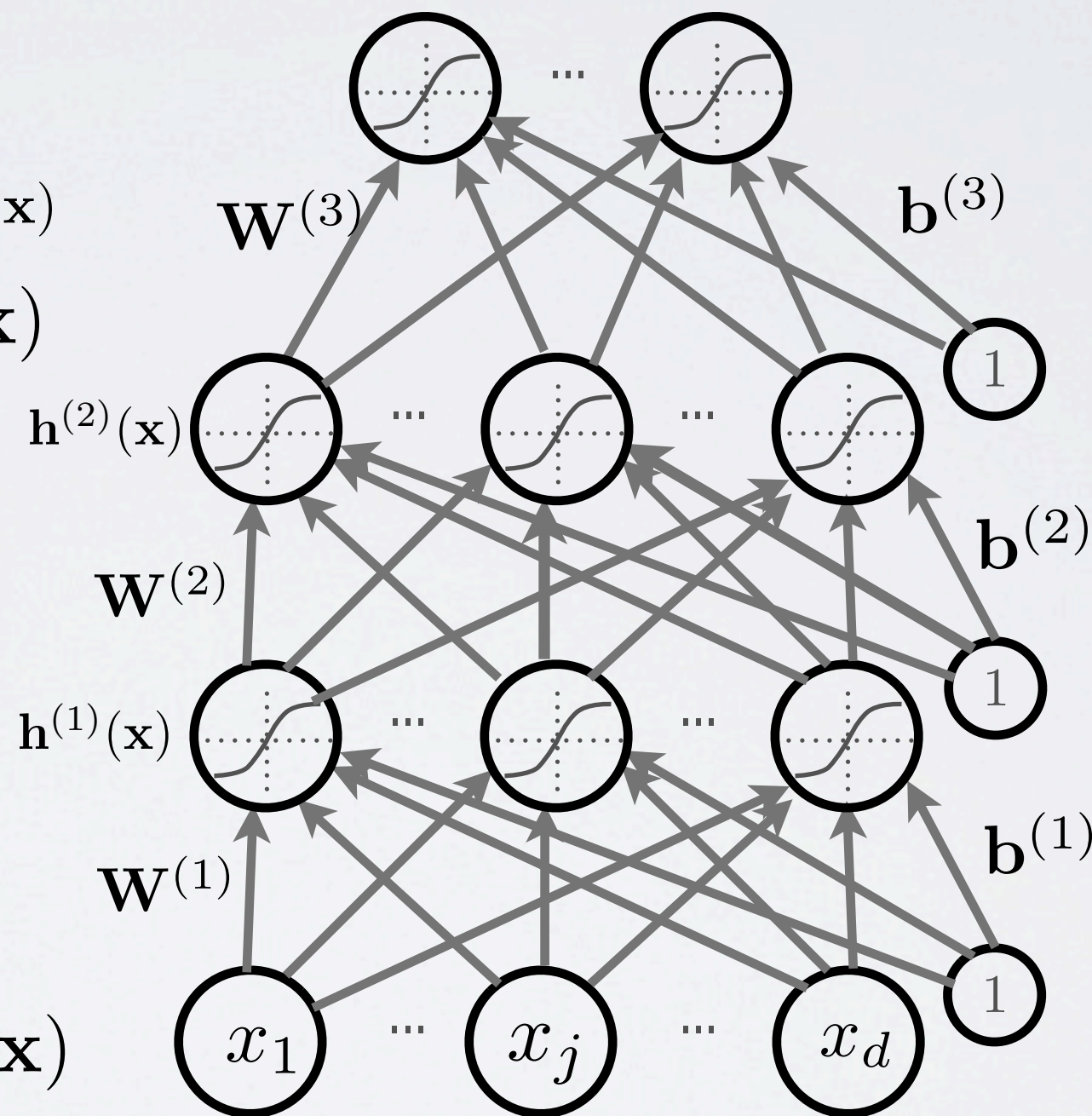
$$\mathbf{a}^{(k)}(\mathbf{x}) = \mathbf{b}^{(k)} + \mathbf{W}^{(k)} \mathbf{h}^{(k-1)}(\mathbf{x})$$

- ▶ hidden layer activation (k from 1 to L):

$$\mathbf{h}^{(k)}(\mathbf{x}) = \mathbf{g}(\mathbf{a}^{(k)}(\mathbf{x}))$$

- ▶ output layer activation ($k = L + 1$):

$$\mathbf{h}^{(L+1)}(\mathbf{x}) = \mathbf{o}(\mathbf{a}^{(L+1)}(\mathbf{x})) = \mathbf{f}(\mathbf{x})$$



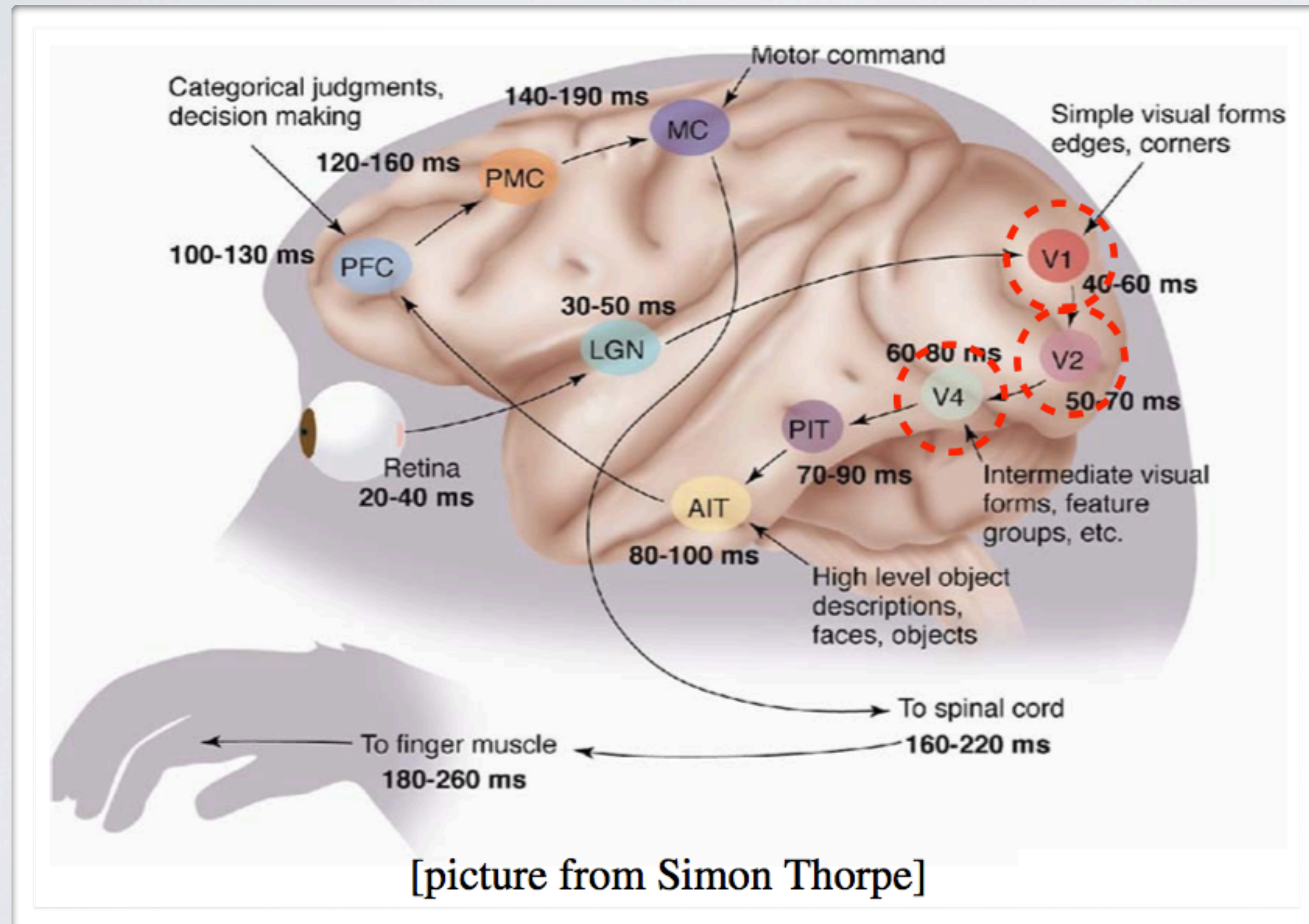
DEEP LEARNING

Topics: deep learning, distributed representation

- Deep learning is research on learning models with multilayer representations
 - ▶ multilayer (feed-forward) neural network
 - ▶ multilayer graphical model (deep belief network, deep Boltzmann machine)
- Each layer corresponds to a “distributed representation”
 - ▶ units in layer are not mutually exclusive
 - each unit is a separate feature of the input
 - two units can be “active” at the same time
 - ▶ they do not correspond to a partitioning (clustering) of the inputs
 - in clustering, an input can only belong to a single cluster

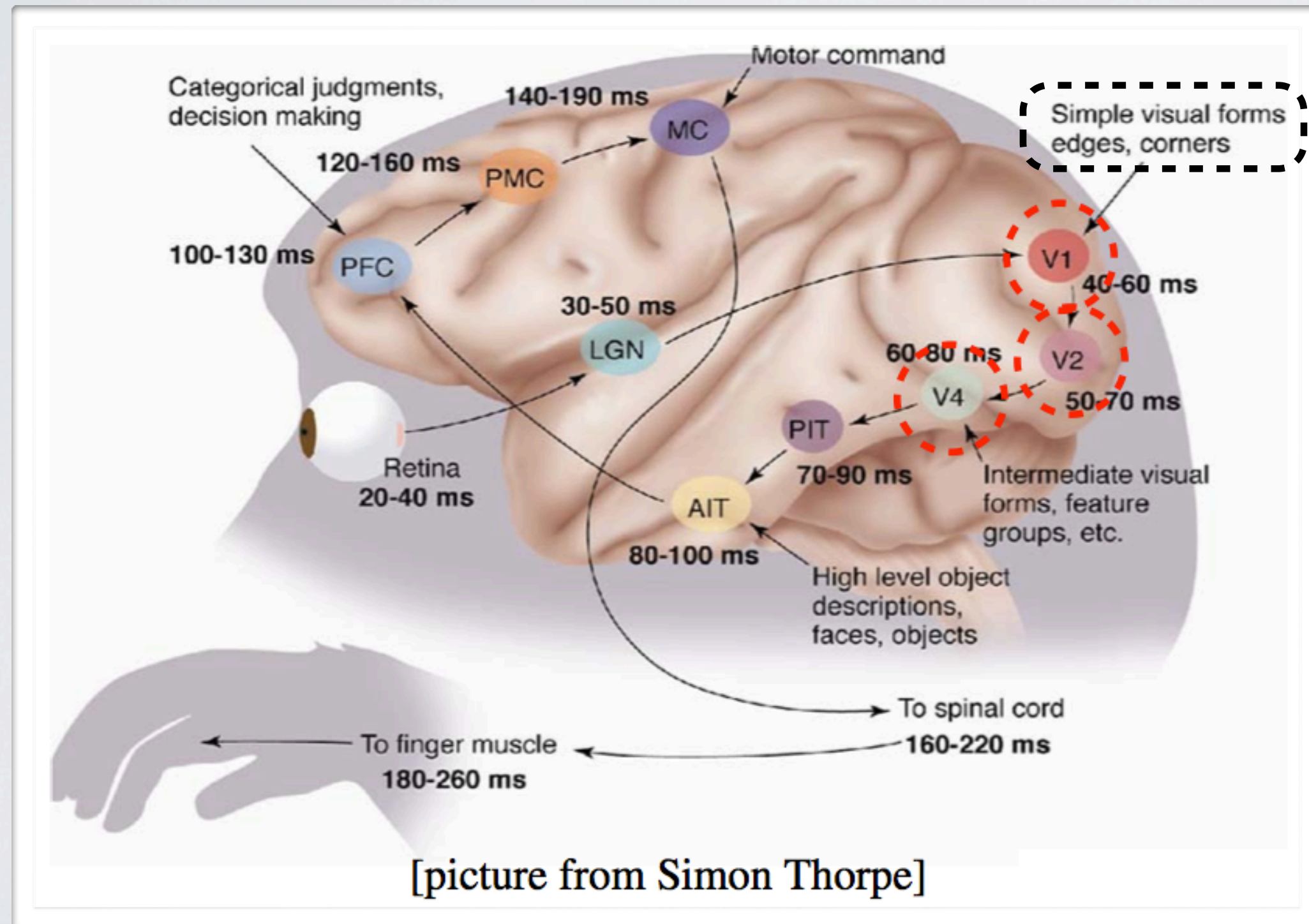
DEEP LEARNING

Topics: inspiration from visual cortex



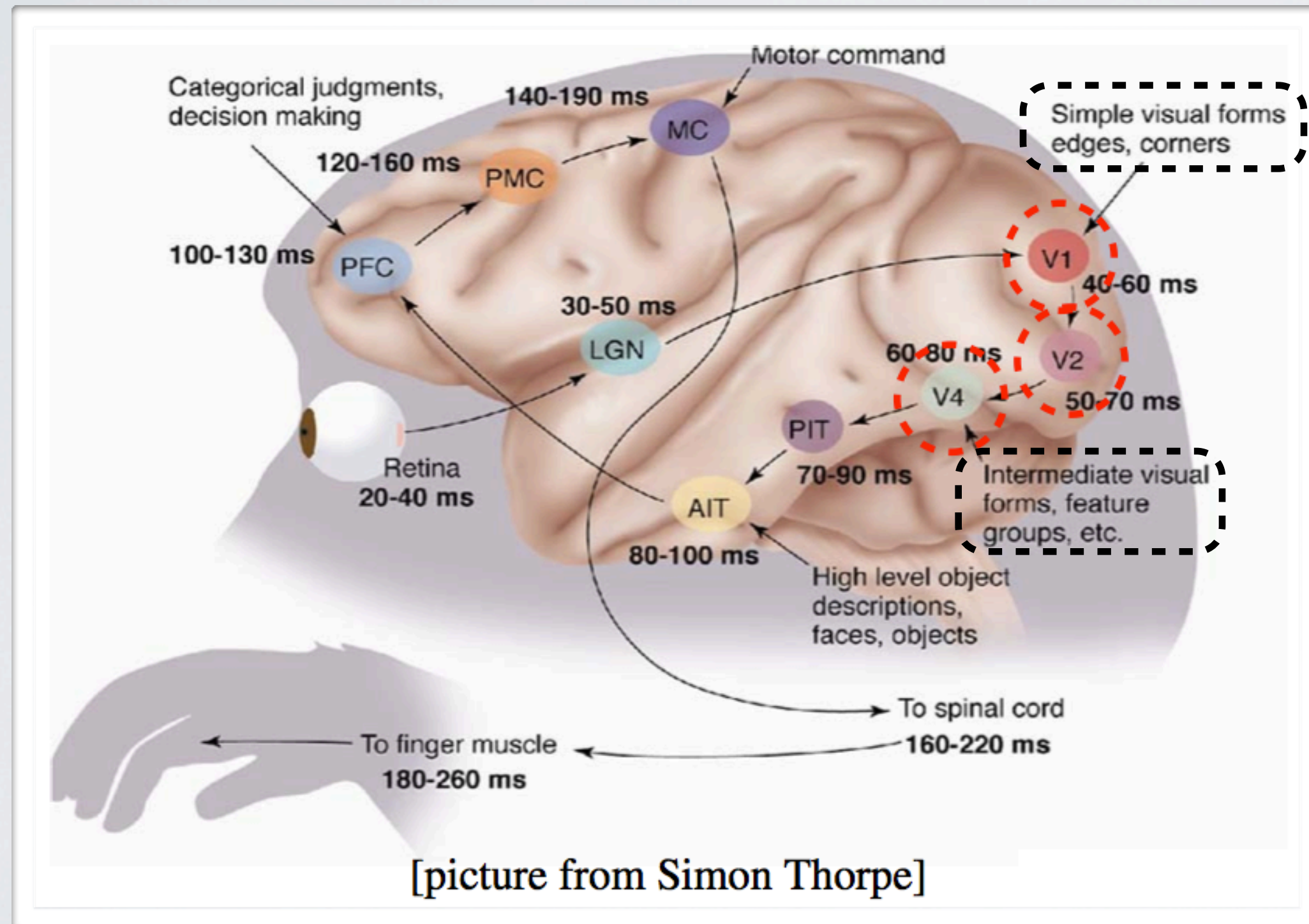
DEEP LEARNING

Topics: inspiration from visual cortex



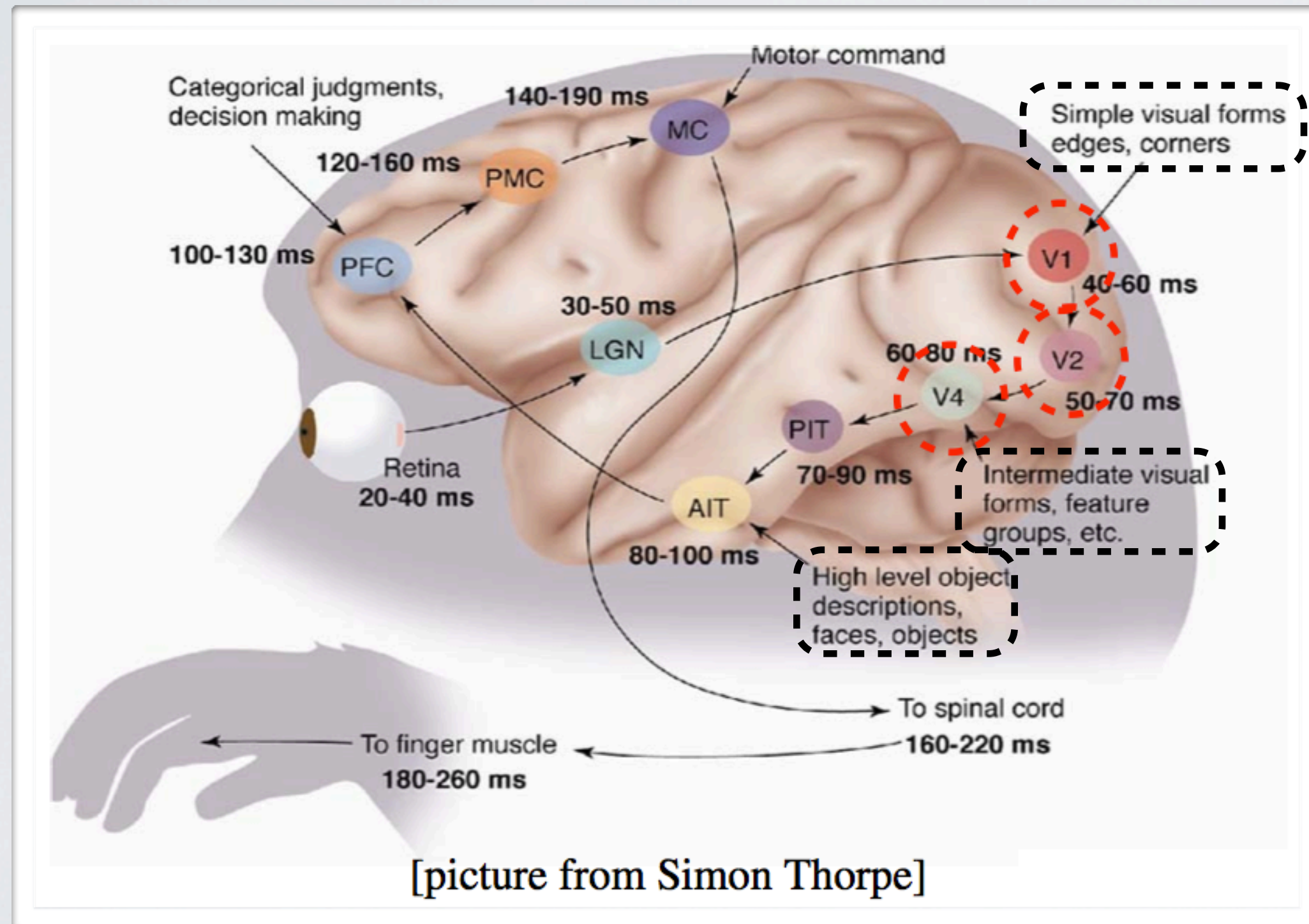
DEEP LEARNING

Topics: inspiration from visual cortex



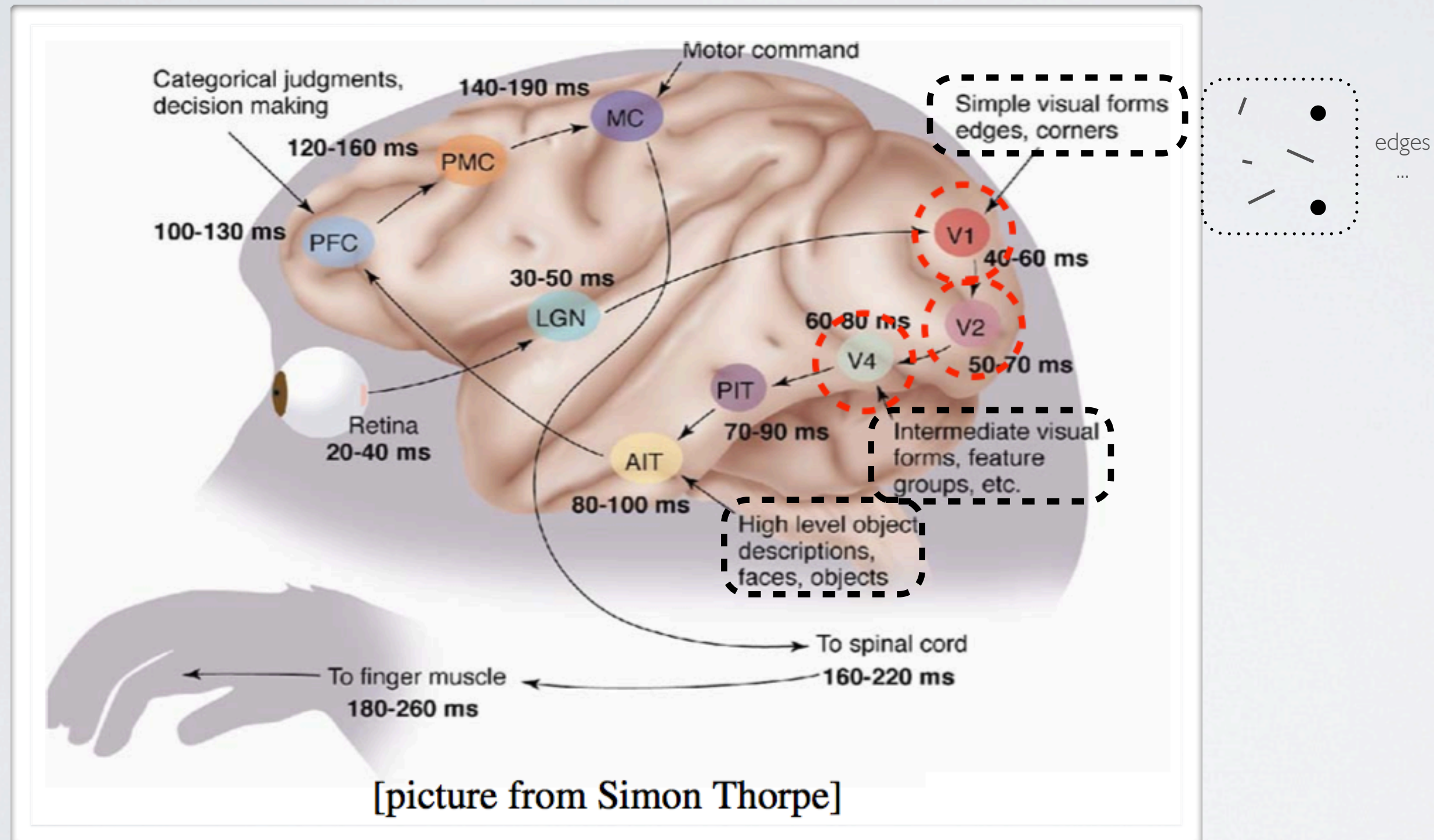
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Topics: inspiration from visual cortex



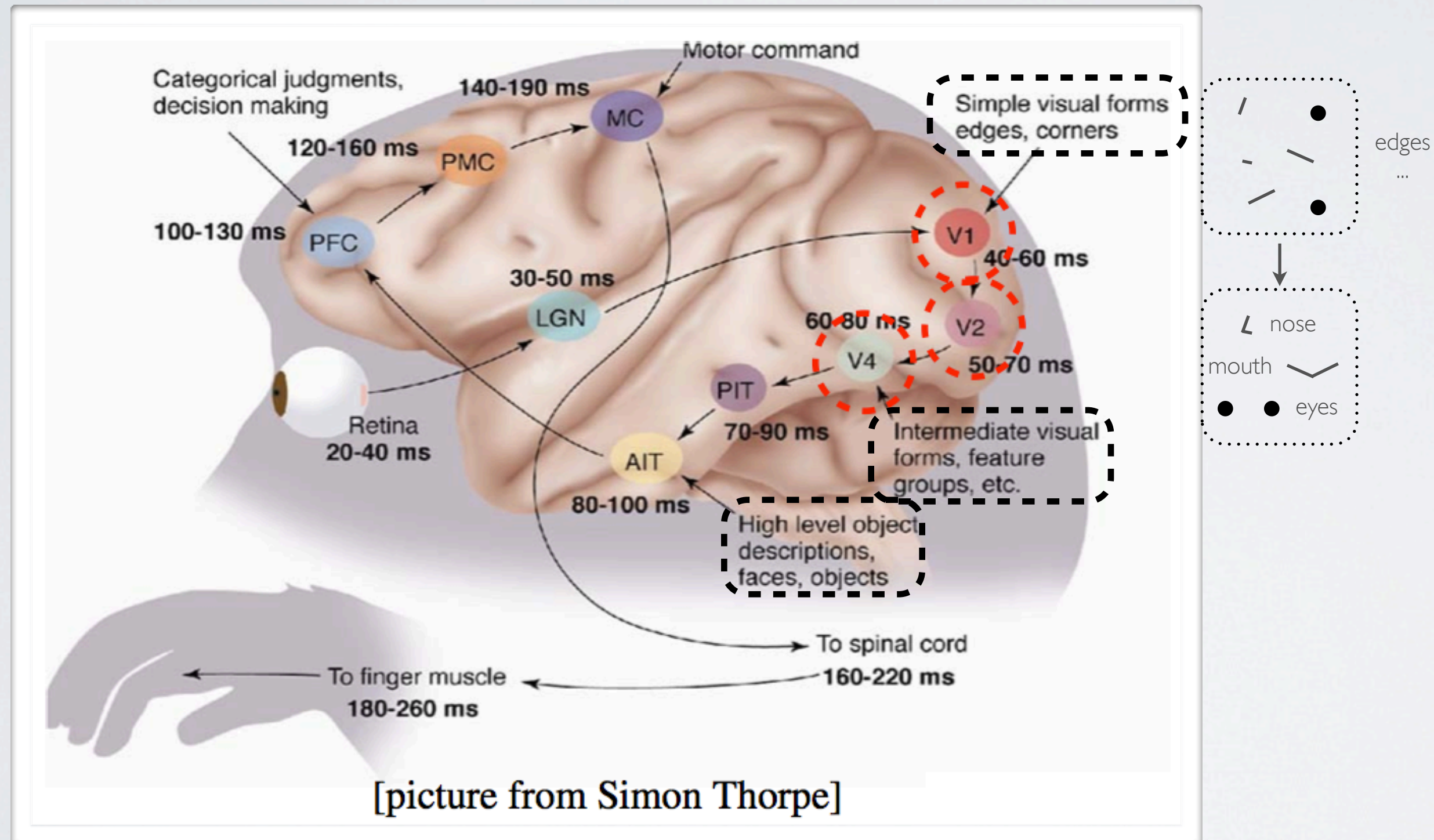
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Topics: inspiration from visual cortex



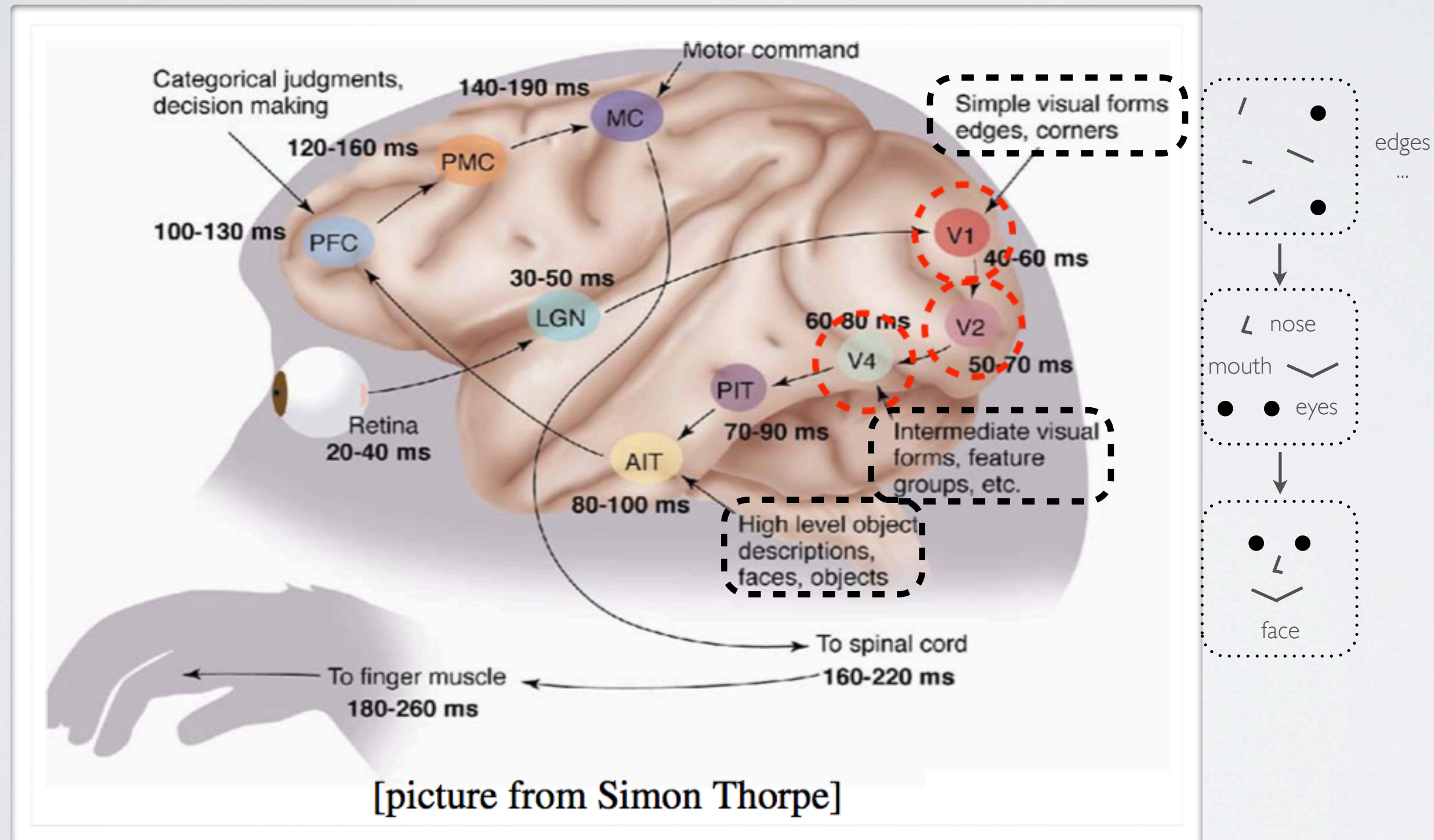
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Topics: inspiration from visual cortex



DEEP LEARNING

Topics: inspiration from visual cortex



DEEP LEARNING

Topics: theoretical justification

- A deep architecture can represent certain functions (exponentially) more compactly
- Example: Boolean functions
 - ▶ a Boolean circuit is a sort of feed-forward network where hidden units are logic gates (i.e. AND, OR or NOT functions of their arguments)
 - ▶ any Boolean function can be represented by a “single hidden layer” Boolean circuit
 - however, it might require an exponential number of hidden units
 - ▶ it can be shown that there are Boolean functions which
 - require an exponential number of hidden units in the single layer case
 - require a polynomial number of hidden units if we can adapt the number of layers
 - ▶ See “Exploring Strategies for Training Deep Neural Networks” for a discussion

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Topics: success stories (Microsoft Research)



The screenshot shows the Microsoft Research website. At the top left is the 'Microsoft Research' logo. To its right is a search bar with the placeholder text 'Search Microsoft Research'. Below the logo and search bar is a navigation menu with links: 'Home', 'Our Research', 'Connections', 'Careers', 'Hub', 'About Us', 'News', 'Media Resources', 'Events', and 'Community'. The 'News' link is highlighted. Below the navigation menu is a breadcrumb trail: 'Home > News > Speech Recognition Leaps Forward'. The main heading of the article is 'Speech Recognition Leaps Forward'. Below the heading is the author information: 'By Janie Chang' and the date 'August 29, 2011 12:01 AM PT'. The article text begins with 'During Interspeech 2011, the 12th annual Conference of the International Speech Communication Association being held in Florence, Italy, from Aug. 28 to 31, researchers from Microsoft Research will present work that dramatically improves the potential of real-time, speaker-independent, automatic speech recognition.' The text continues with 'Dong Yu, researcher at Microsoft Research Redmond, and Frank Seide, senior researcher and research manager with Microsoft Research Asia, have been spearheading this work, and their teams have collaborated on what has developed into a research breakthrough in the use of artificial neural networks for large-vocabulary speech recognition.' The article has a sub-heading 'The Holy Grail of Speech Recognition' and begins with the sentence 'Commercially available speech-recognition technology is behind applications such'.

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Speech Recognition Leaps Forward

By [Janie Chang](#)
August 29, 2011 12:01 AM PT

During [Interspeech 2011](#), the 12th annual Conference of the International Speech Communication Association being held in Florence, Italy, from Aug. 28 to 31, researchers from Microsoft Research will present work that dramatically improves the potential of real-time, speaker-independent, automatic speech recognition.

[Dong Yu](#), researcher at [Microsoft Research Redmond](#), and [Frank Seide](#), senior researcher and research manager with [Microsoft Research Asia](#), have been spearheading this work, and their teams have collaborated on what has developed into a research breakthrough in the use of artificial neural networks for large-vocabulary speech recognition.

The Holy Grail of Speech Recognition

Commercially available speech-recognition technology is behind applications such

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Topics: success stories (Google)

The New York Times

Business Day
Technology

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

How Many Computers to Identify a Cat? 16,000



Jim Wilson/The New York Times

An image of a cat that a neural network taught itself to recognize.