Memory Mechanisms in Man & Machine

Simon Thorpe

Director of the Brain and Cognition Research Centre (CerCo)

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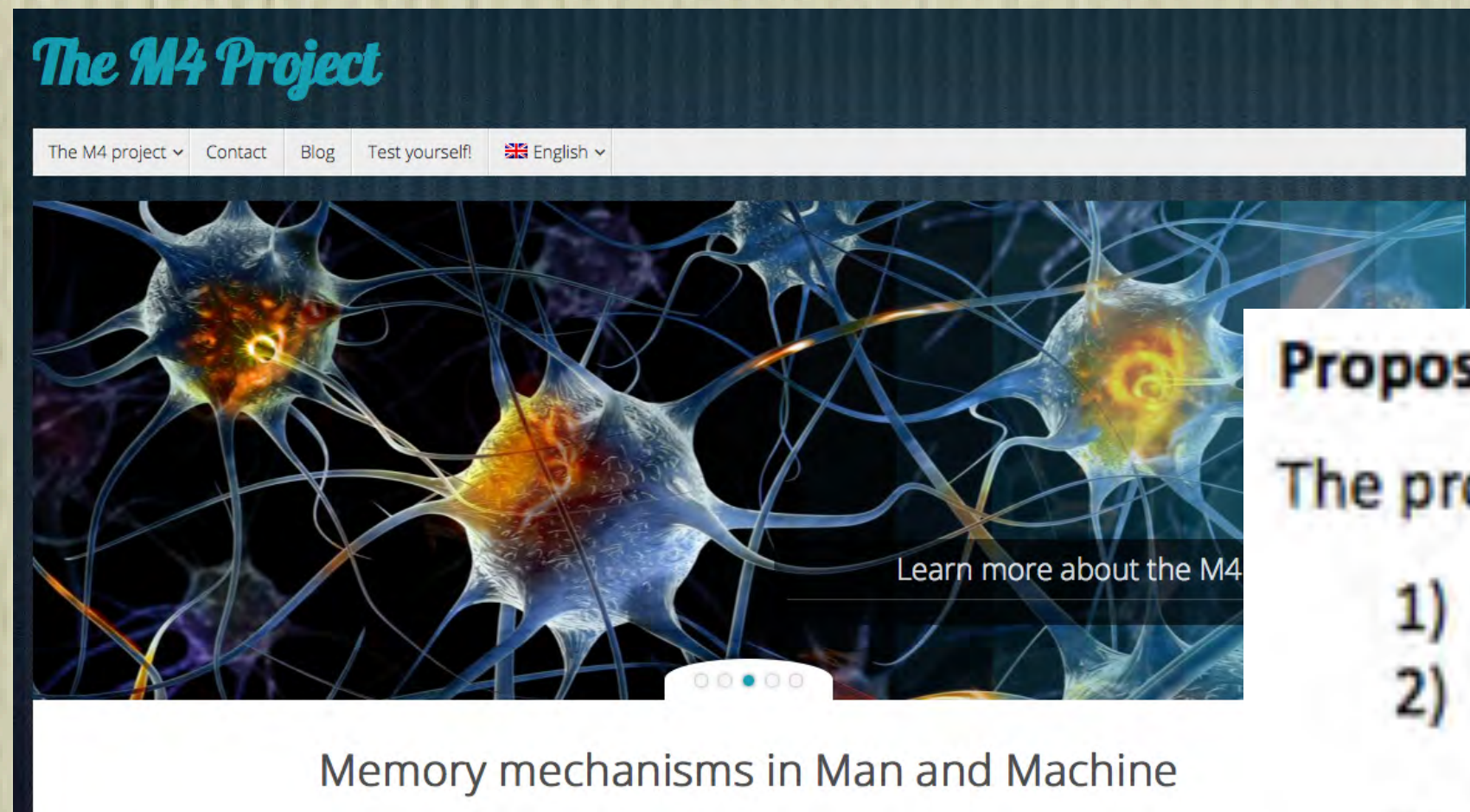
BrainChip Inc

Toulouse, France

CerCo
UMR5549

TOULOUSE MIND & BRAIN INSTITUTE

CNrS

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erc
European Research Council

brainchip*

The M4 Project : ERC Grant (2013-19)

The M4 Project

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Memory mechanisms in Man and Machine

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Proposal summary

The project aims to validate a set of 10 provocative claims.

1) Humans can recognise visual and auditory stimuli that they have not experienced for decades.
2) Recognition after very long delays is possible without ever reactivating the memory trace in the intervening period.
3) These very long term memories require an initial memorisation phase, during which memory strength increases roughly linearly with the number of presentations
4) A few tens of presentations can be enough to form a memory that can last a lifetime.
5) Attention-related oscillatory brain activity can help store memories efficiently and rapidly
6) Storing such very long-term memories involves the creation of highly selective "Grandmother Cells" that only fire if the original training stimulus is experienced again.
7) The neocortex contains large numbers of totally silent cells ("Neocortical Dark Matter") that constitute the long-term memory store.
8) Grandmother Cells can be produced using simple spiking neural network models with Spike-Time Dependent Plasticity (STDP) and competitive inhibitory lateral connections.
9) This selectivity only requires binary synaptic weights that are either "on" or "off", greatly simplifying the problem of maintaining the memory over long periods.
10) Artificial systems using memristor-like devices can implement the same principles, allowing the development of powerful new processing architectures that could replace conventional computing hardware.

1. Humans can recognise visual and auditory stimuli that they have not experienced for decades
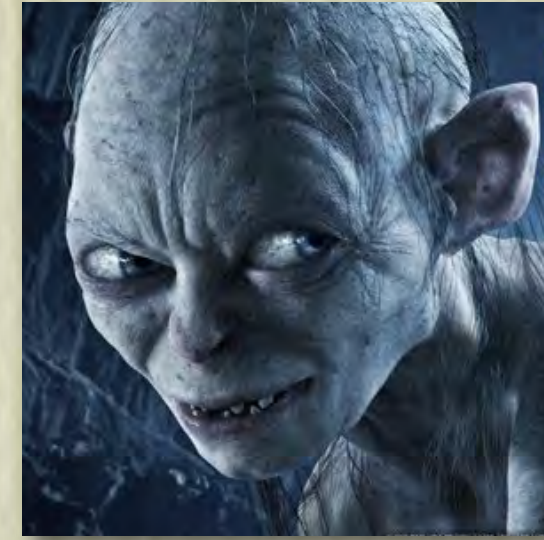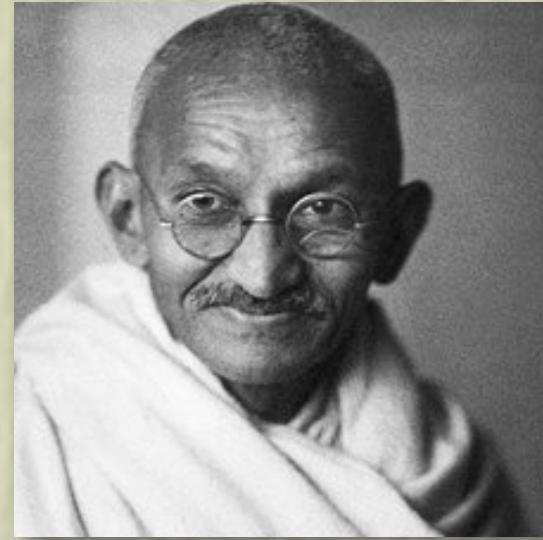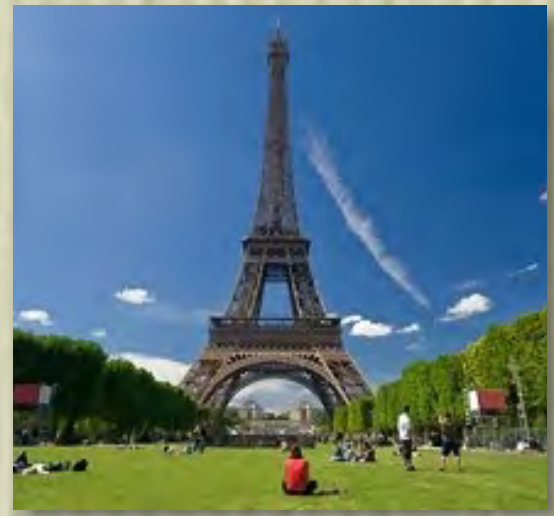
# 1. Humans can recognise visual and auditory stimuli that they have not experienced for decades
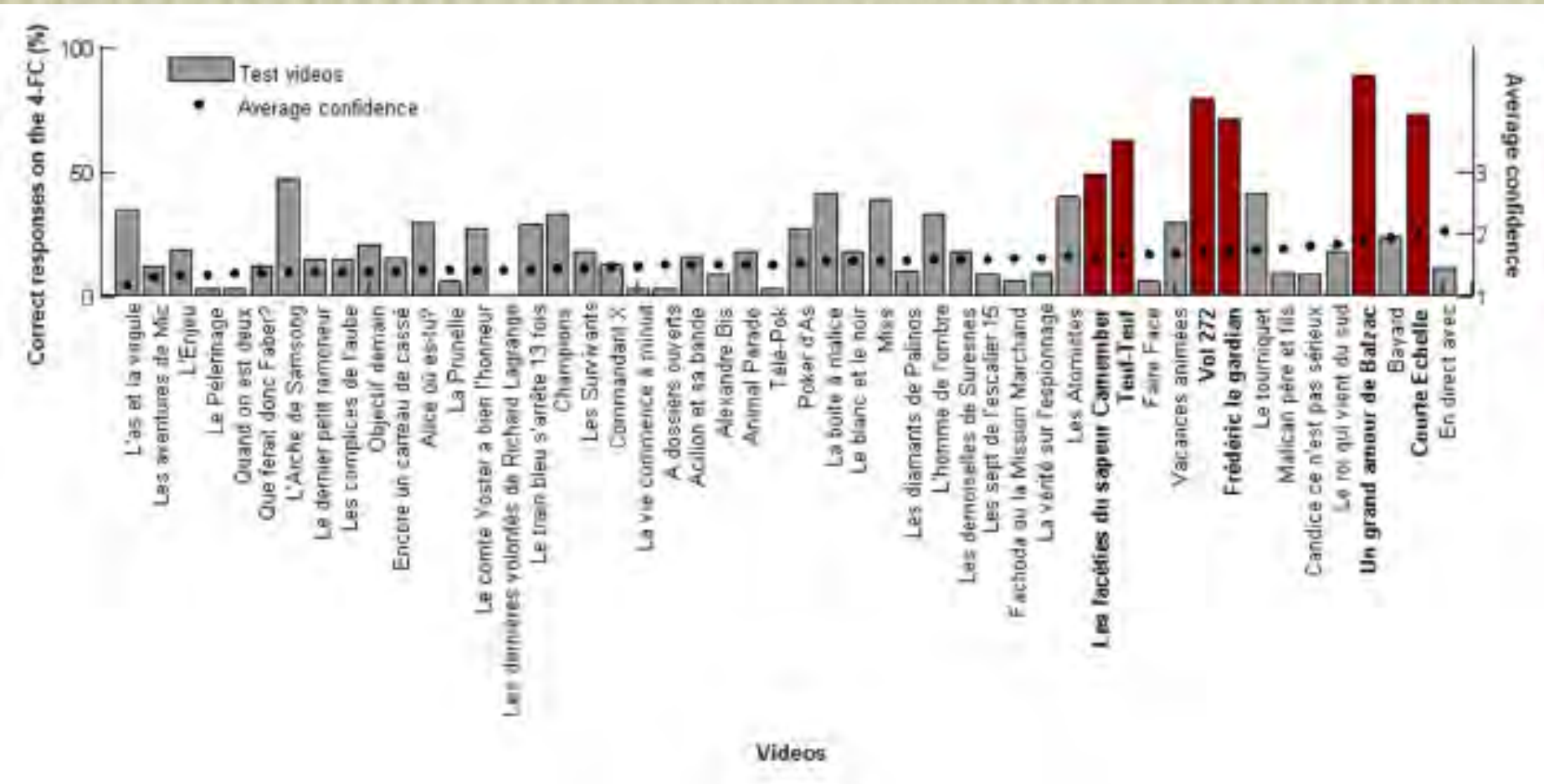
Waking Up Buried Memories of Old TV Programs

Christelle Larzabal[1,2*], Nadège Bacon-Macé[1,2], Sophie Muratot[1,2] and Simon J. Thorpe[1,2]

[1] Centre de Recherche Cerveau et Cognition, Université de Toulouse, Université Paul Sabatier, Toulouse, France, [2] Centre National de la Recherche Scientifique, CerCo, Toulouse, France
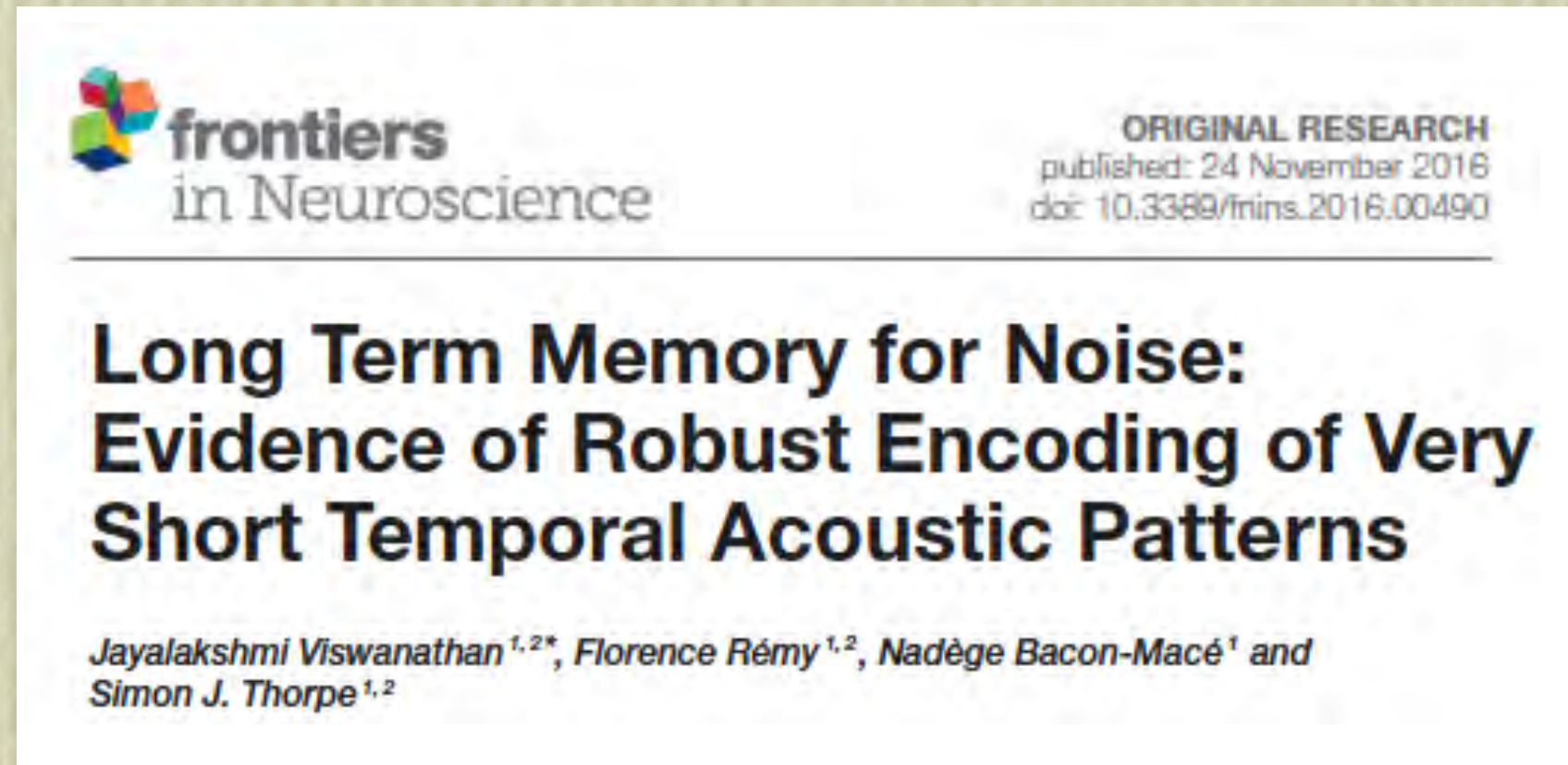
- 70 TV themes never rebroadcast for several decades
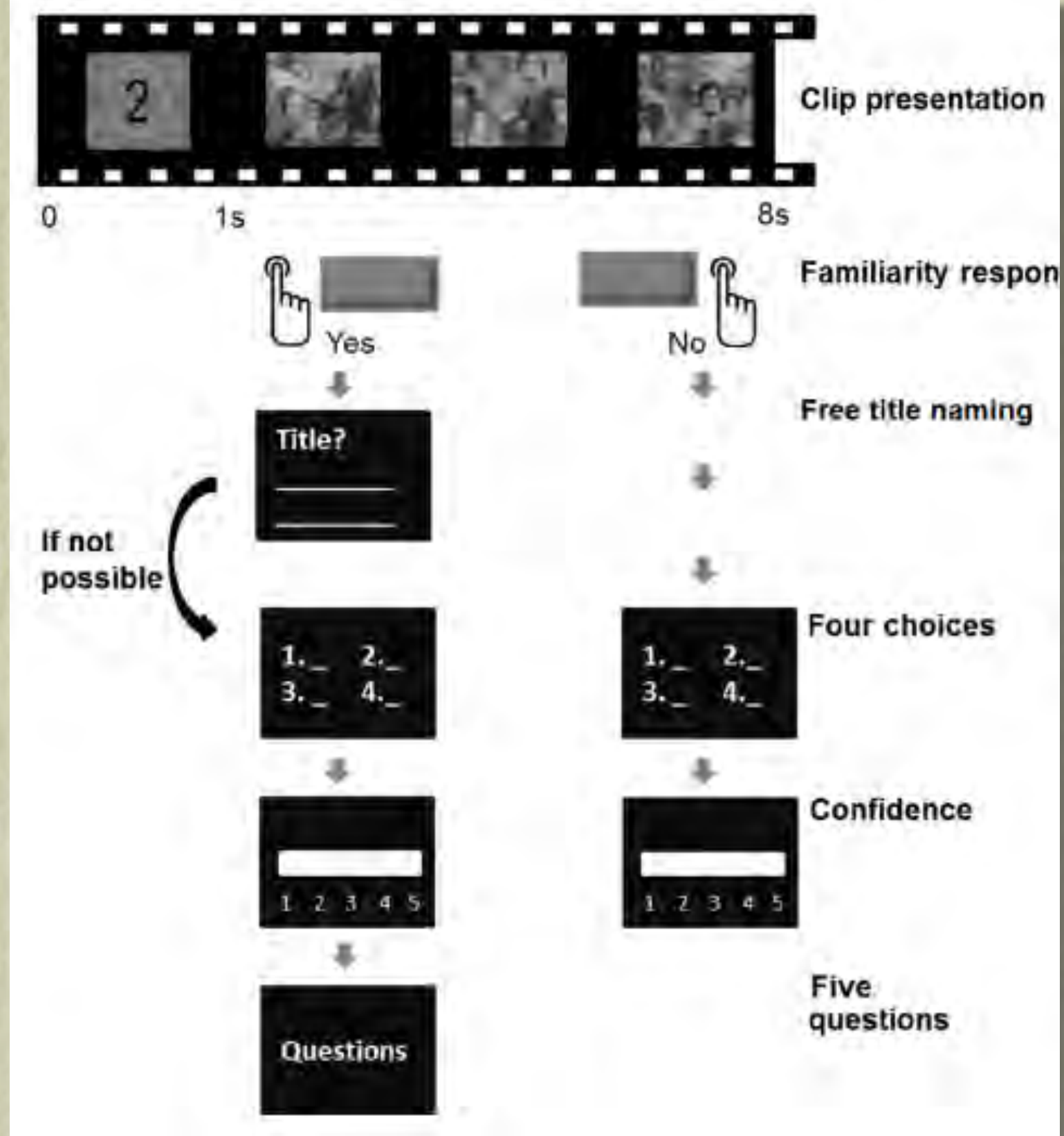
- Two cases of free identification
  - 90 year old woman who said "Balsac" for "Un amour de Balsac"
  - 77 year old man who said "Camember" for "Les faciétés du sapeur Camember"

six titles were particularly well identified by the older participants when they used the 4-FC, namely: "Les Facéties du Sapeur Camember" (16 participants out of 33), "Teuf-Teuf" (20 participants out of 32), "Vol 272" (26 participants out of 33), "Frédéric le Gardian" (24 participants out of 34), "Un Grand Amour de Balzac" (29 participants out of 33) and "Courte Echelle" (24 participants out of 33).

2. Recognition after very long delays is possible without ever reactivating the memory trace in the intervening period

Long Term Memory for Noise: Evidence of Robust Encoding of Very Short Temporal Acoustic Patterns

- Testing after a month
- Impossible to rehearse
- Looped sounds also work
  - It's not just the start
- Scrambled sounds also work
  - The learning must work on tiny snippets only 10-20 ms long
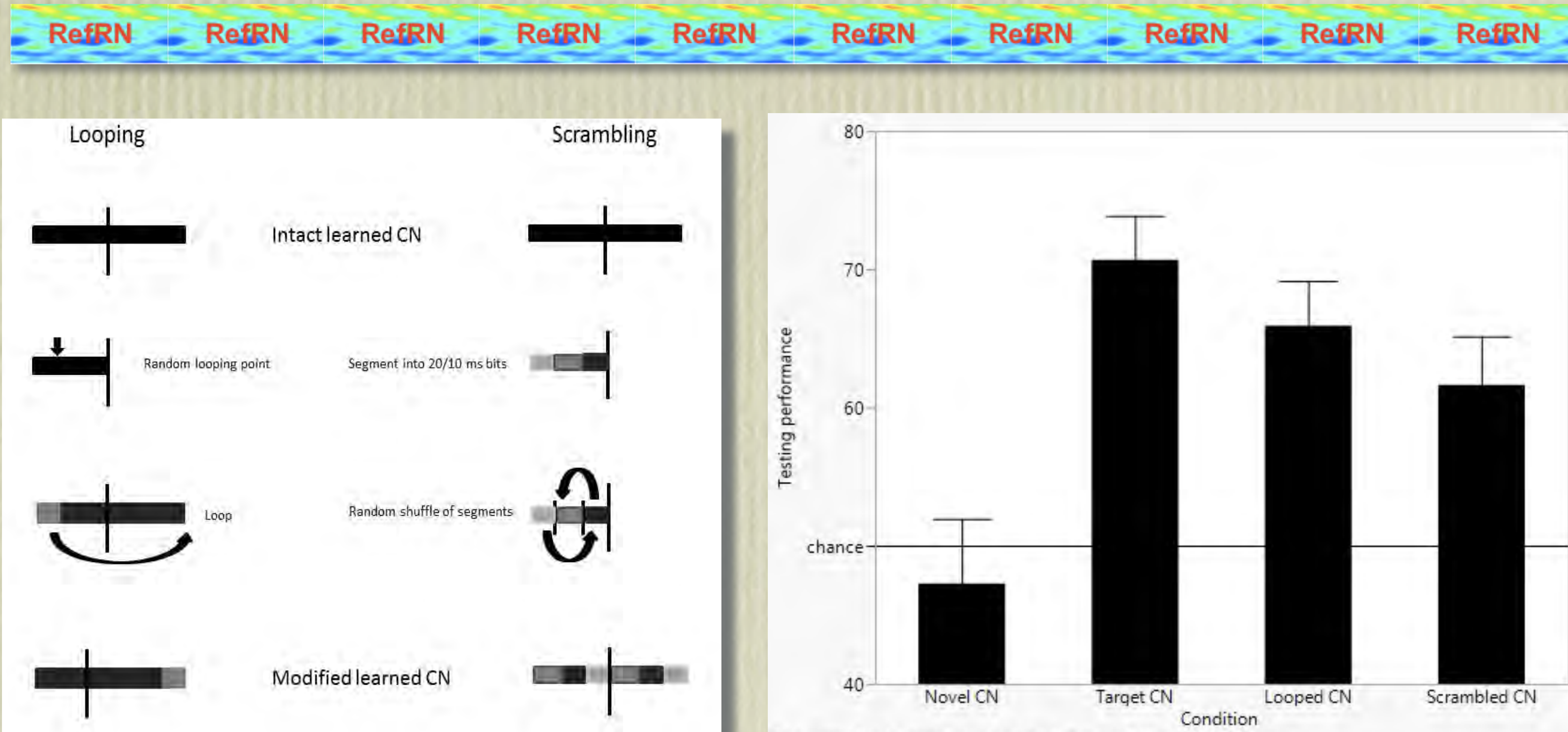
3. These very long term memories require an initial memorisation phase, during which memory strength increases roughly linearly with the number of presentations

BrainSpotting
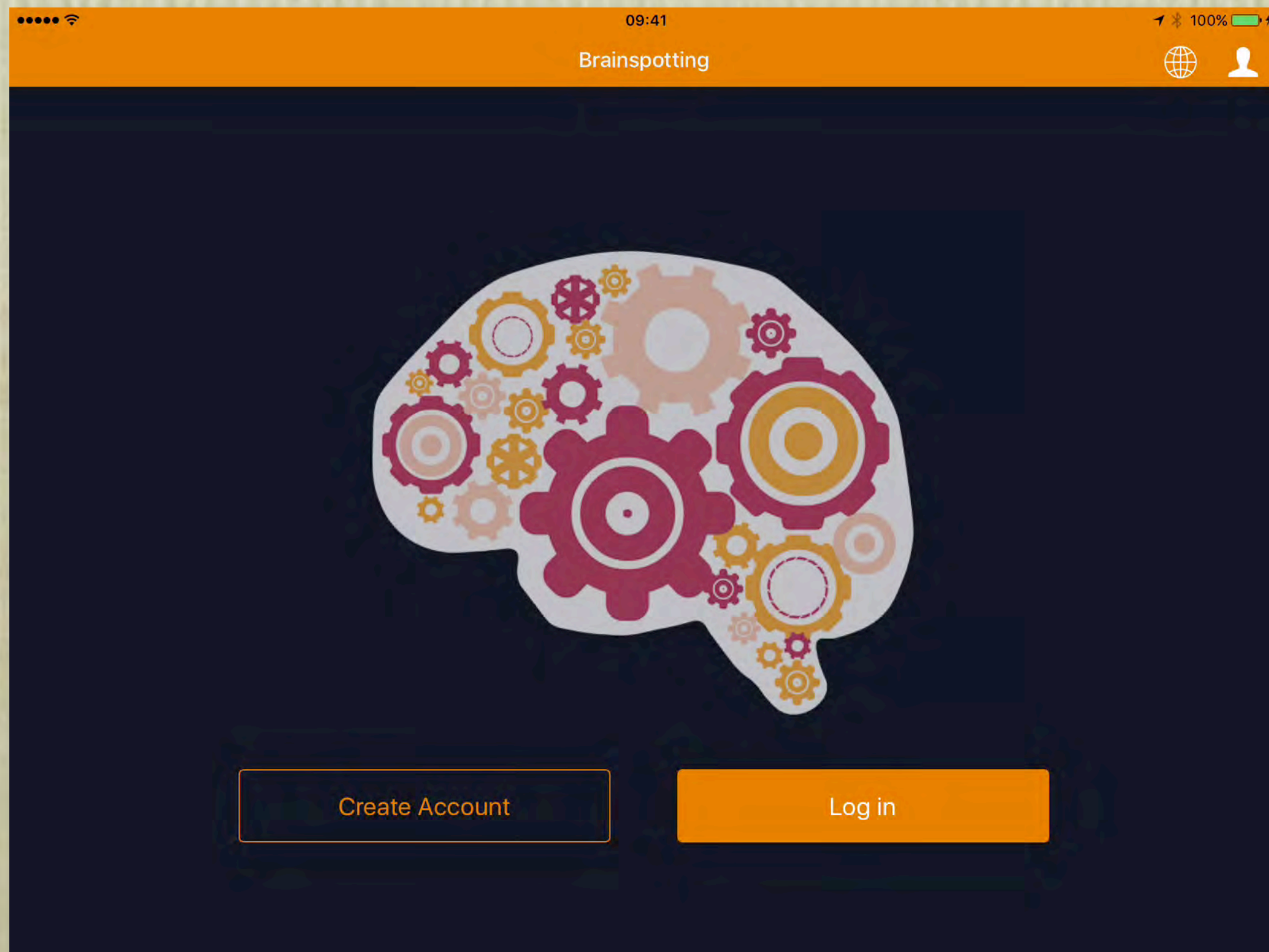
- Frame Rate : 2, 4, 6, 9, 10, 12, 15, 20, 30, 60…

- Repetitions : 1, 2, 3, 4, 5, 6, 7, 8…

- Distractors between targets : 1, 2, 3, 4, 5….
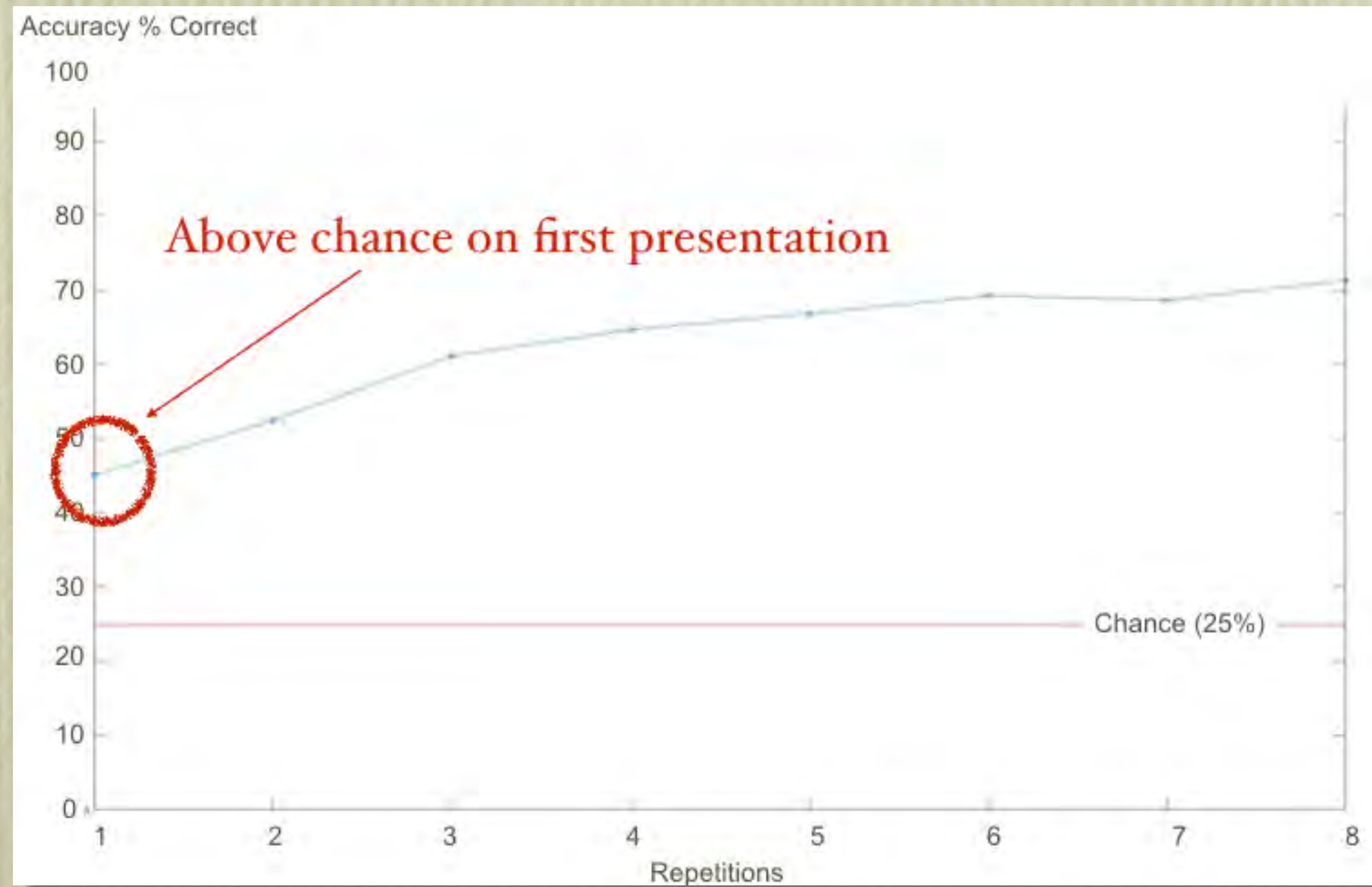
- 556 different conditions!

3. These very long term memories require an initial memorisation phase, during which memory strength increases roughly linearly with the number of presentations

- Roughly linear increase from 1 to 5 repeats

- But - only a short interval between training and testing

- Would this also apply for Long Term Memories?

3. These very long term memories require an initial memorisation phase, during which memory strength increases roughly linearly with the number of presentations
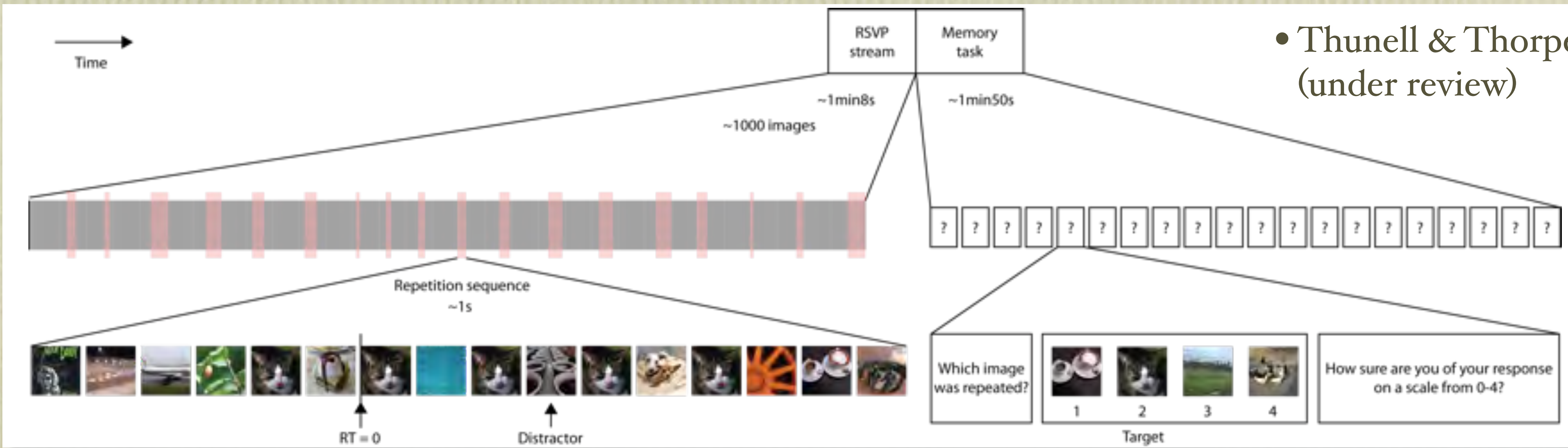
- Thunell & Thorpe (under review)

- Performance doesn't decrease with testing delay!
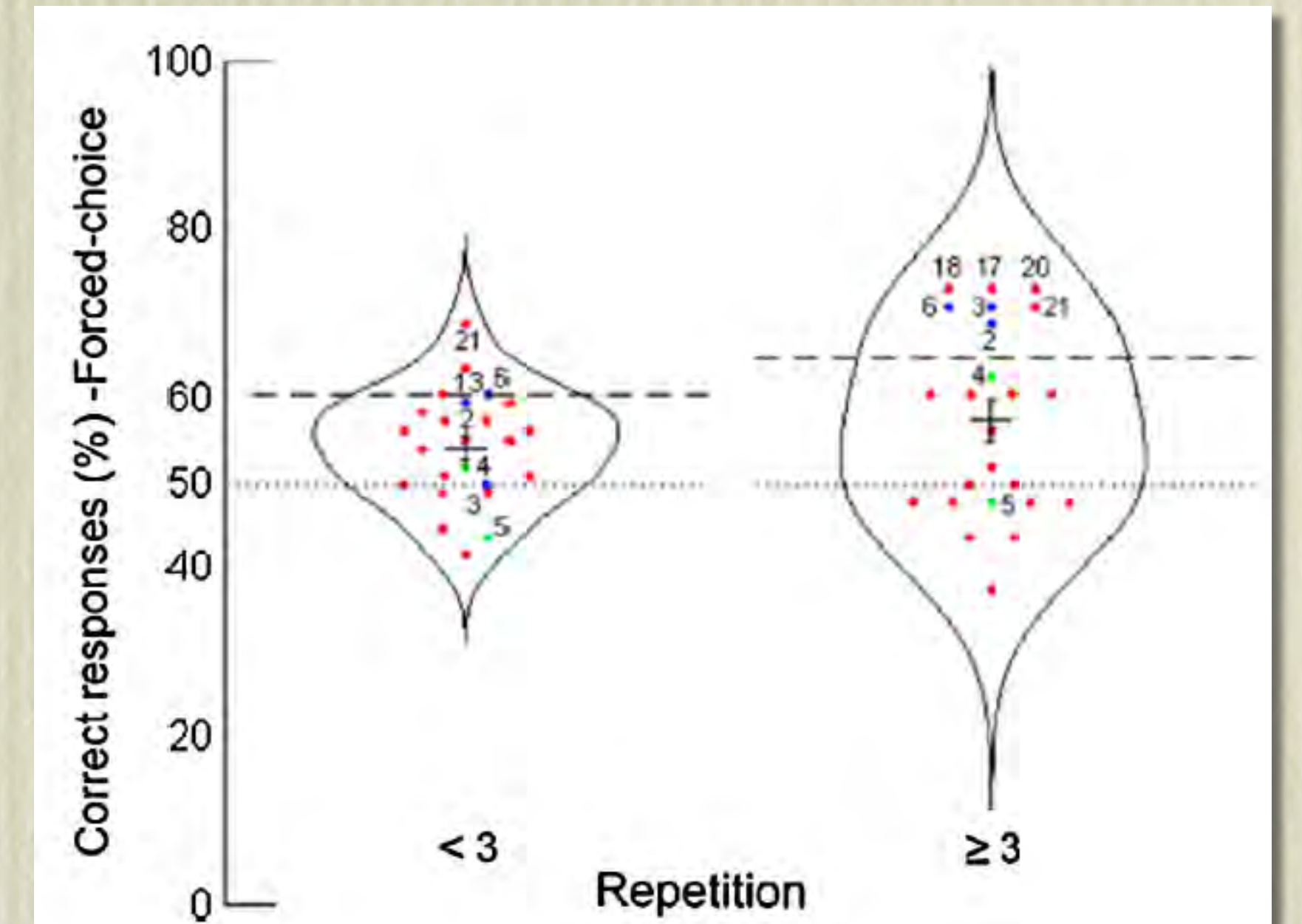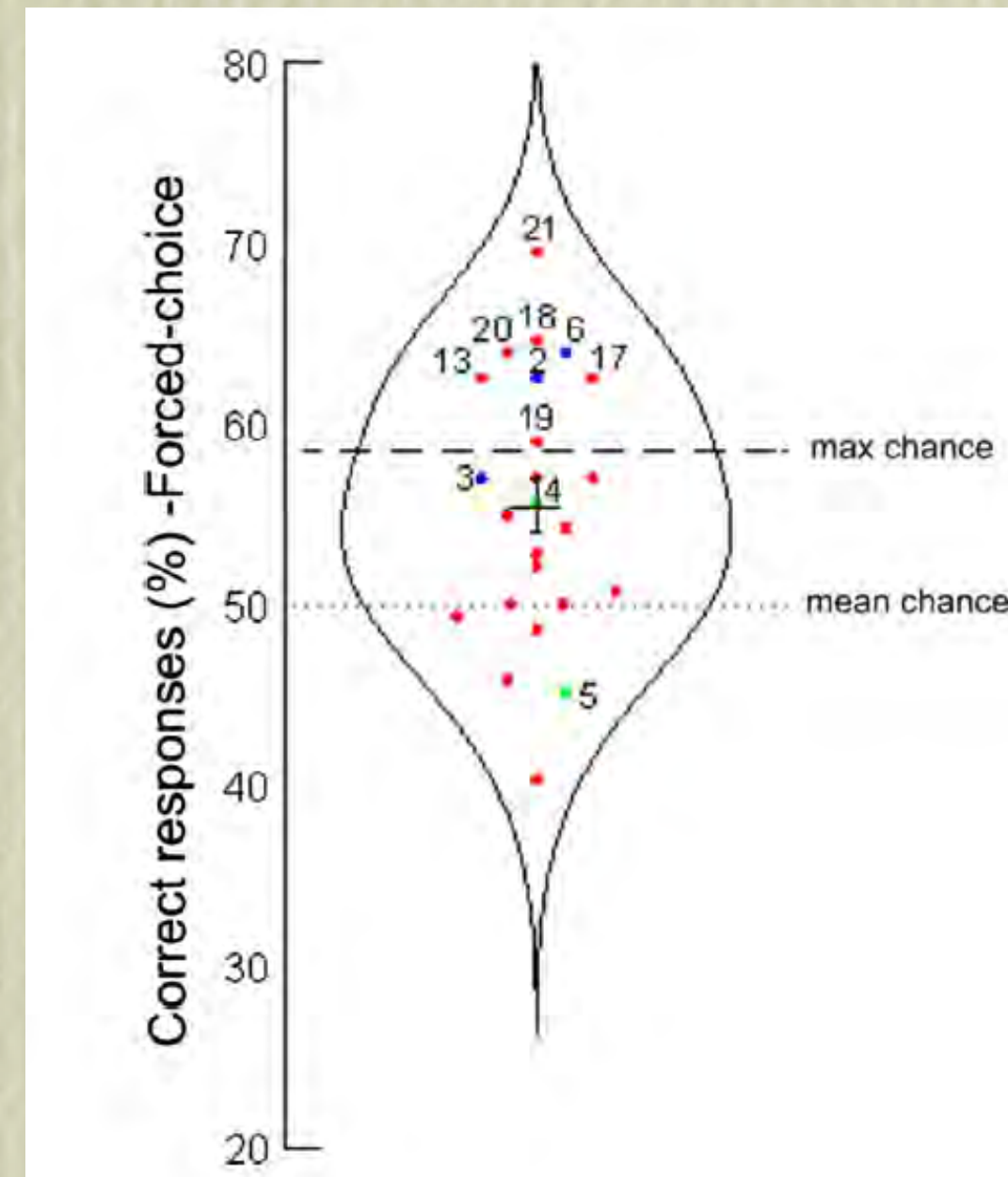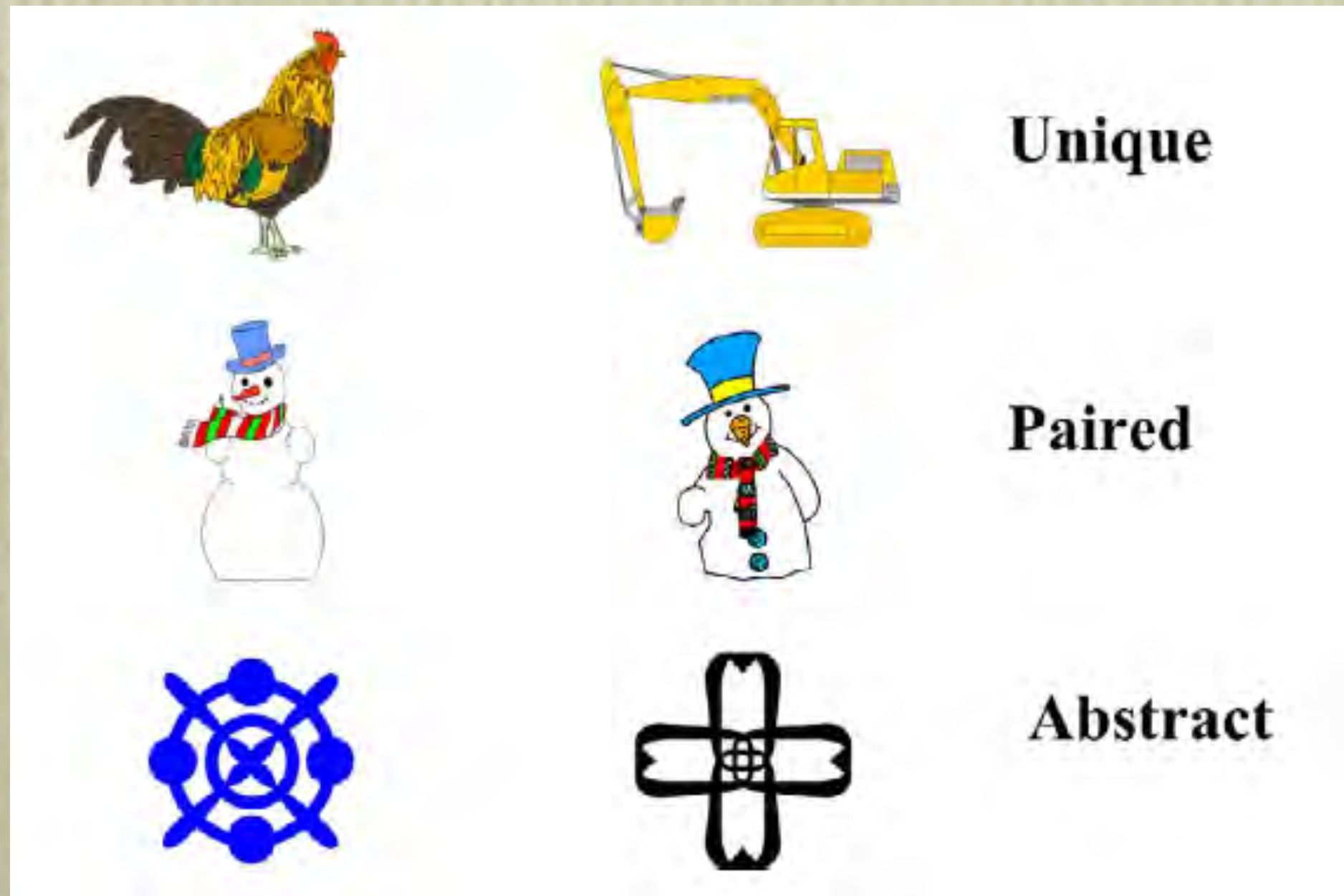
- At least for a few minutes....

4. A few ~~tens of~~ presentations can be enough to form a memory that can last a lifetime

- Images from the DMS-48 test
- 243 subjects tested between 2002 and 2006
- 63 tested in 2016

6. Storing such very long-term memories involves the creation of highly selective "Grandmother Cells" that only fire if the original training stimulus is experienced again

7. The neocortex contains large numbers of totally silent cells ("Neocortical Dark Matter") that constitute the long-term memory store

- Still just a theoretical hypothesis

- Single unit recording from cortical neurons in patients could be the ultimate test

8. Grandmother Cells can be produced using simple spiking neural network models with Spike– Time Dependent Plasticity (STDP) and competitive inhibitory lateral connections

9. This selectivity only requires binary synaptic weights that are either "on" or "off", greatly simplifying the problem of maintaining the memory over long periods
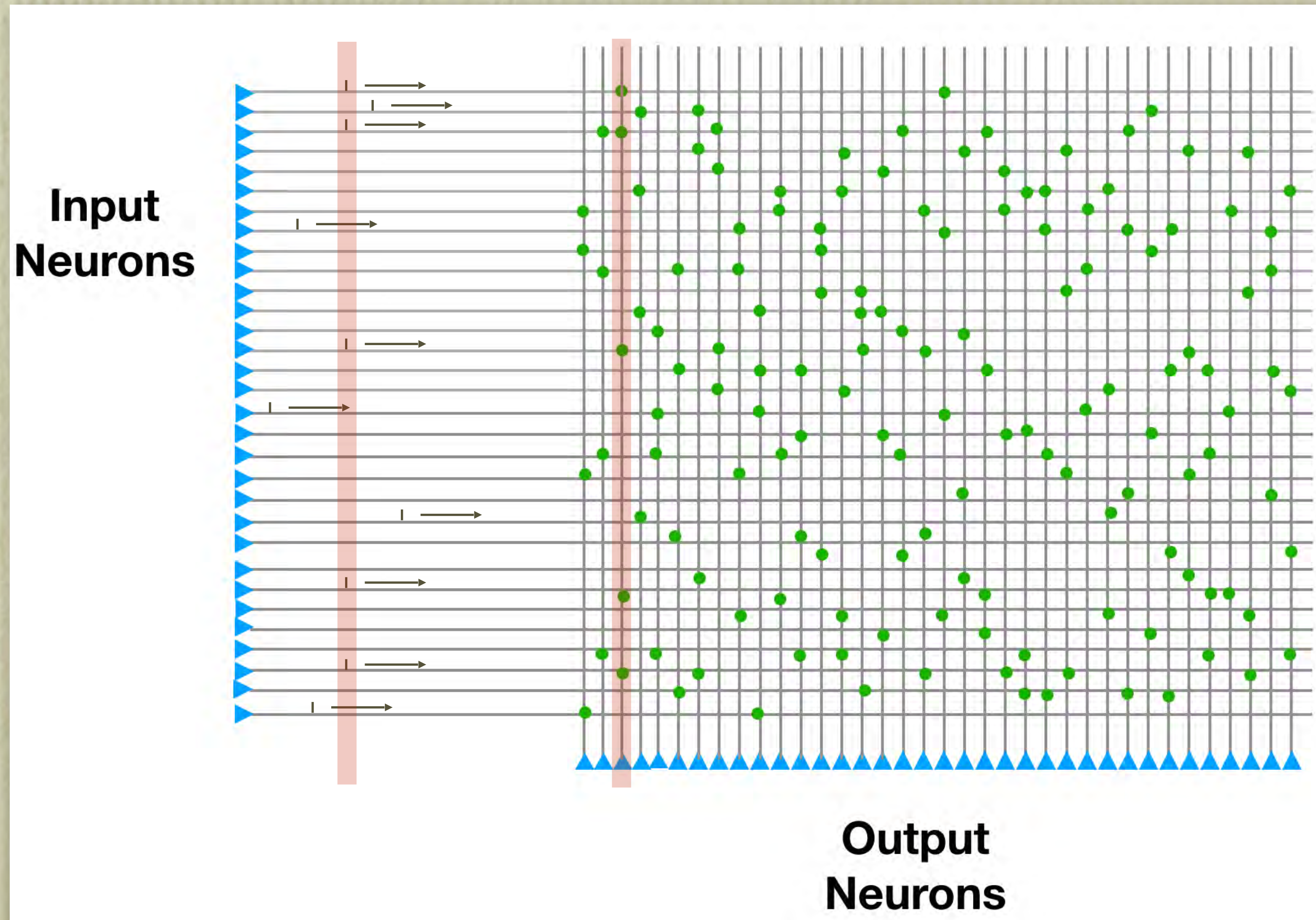
- A new highly efficient algorithm

- **JAST**

  - **J**ake, **A**mir, **S**imon & **T**im!

JAST

- System with Binary weights
- Input neurons fire spikes asynchronously
- Output neurons function as synchrony detectors
- Learning rule adjusts the weights to match incoming spike patterns

10. Artificial systems ~~using memristor-like devices~~ can implement the same principles, allowing the development of powerful new processing architectures that could replace conventional computing hardware

## Unsupervised detection of repeating patterns in a series of events

Abstract

A method of performing unsupervised detection of repeating patterns in a series (TS) of events (E21, E12, E5 ...), comprising the steps of:
a) Providing a plurality of neurons (NR1 - NRP), each neuron being representative of W event types;
b) Acquiring an input packet (IV) comprising N successive events of the series;
c) Attributing to at least some neurons a potential value (PT1 - PTP), representative of the number of common events between the input packet and the neuron;
d) Modify the event types of neurons having a potential value exceeding a first threshold T_L; and
e) generating a first output signal (OS1 - OSP) for all neurons having a potential value exceeding a second threshold T_F, and a second output signal, different from the first one, for all other neurons.
A digital integrated circuit configured for carrying out such a method.

Images (3)
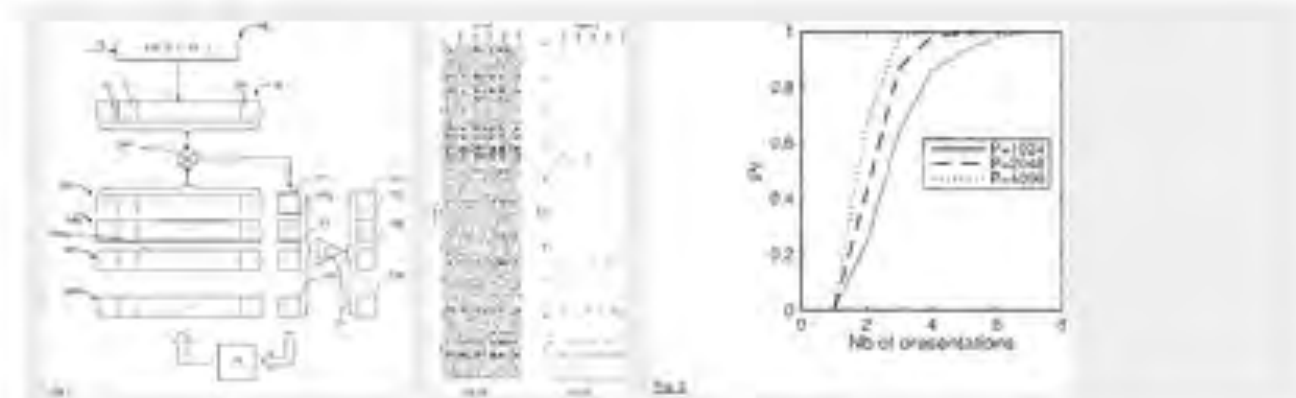
EP3324343A1
EP Application

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Other languages: German, French

Inventor: Simon Thorpe, Timothée MASQUELIER, Jacob Martin, Amir Reza YOUSEFZADEH

Current Assignee : Consejo Superior de Investigaciones Cientificas (CSIC) , Centre National de la Recherche Scientifique CNRS

Original Assignee: Consejo Superior de Investigaciones Cientificas (CSIC), Centre National de la Recherche Scientifique CNRS

Priority date : 2016-11-21

Family: EP (2) WO (1)

Date   App/Pub Number   Status

2016-11-21 EP20160306525   Pending

Digital electronic circuit and system implementing a spiking neural network for performing unsupervised detection of patterns

Abstract

A digital electronic circuit (SNN) implementing a spiking neural network comprising: an input unit, (IU) for receiving a series of digital signals (ES) representing respective events and for generating a data packet (PK) representative of N contiguous signals of the series, with $1 \leq N \leq M$;
- a memory (NM) storing data defining a plurality of neurons, comprising for each neuron a set of binary weights (BWV);
- a match calculating unit (MCU), connected to said input unit and said memory, configured for computing, for at least some of the neurons, a potential value (PT) representative of a match between said data packet and said binary weights; and for generating a series of output signals (OS) indicative of neurons having a potential value exceeding a threshold TF, called firing threshold; and
- a learning unit (LU), for modifying the set of binary weights of neurons having a potential value exceeding a threshold TL, called learning threshold.

Images (6)
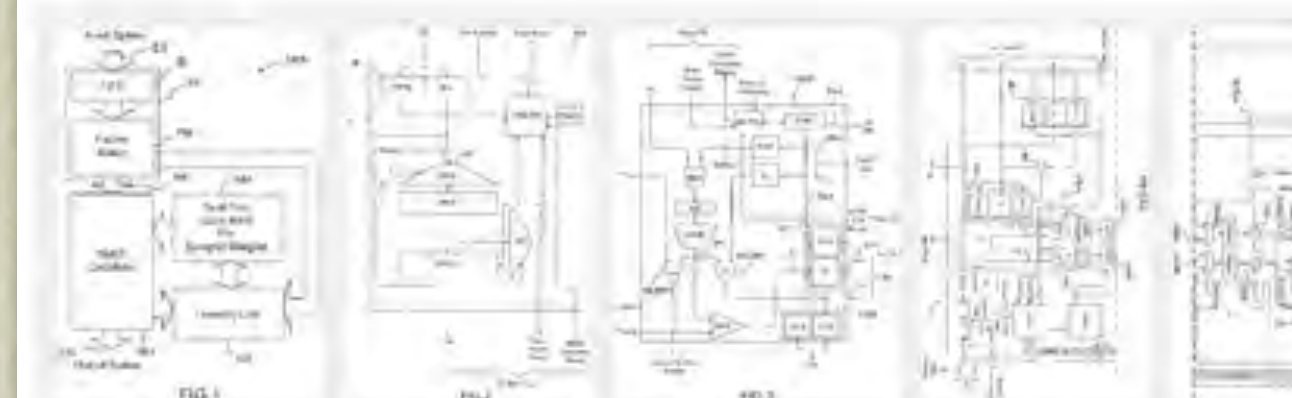
EP3324344A1
EP Application

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Other languages: German, French

Inventor: Simon Thorpe, Timothée MASQUELIER, Jacob Martin, Amir Reza YOUSEFZADEH, Bernabe LINARES-BARRANCO

Current Assignee : Consejo Superior de Investigaciones Cientificas (CSIC) , Centre National de la Recherche Scientifique CNRS
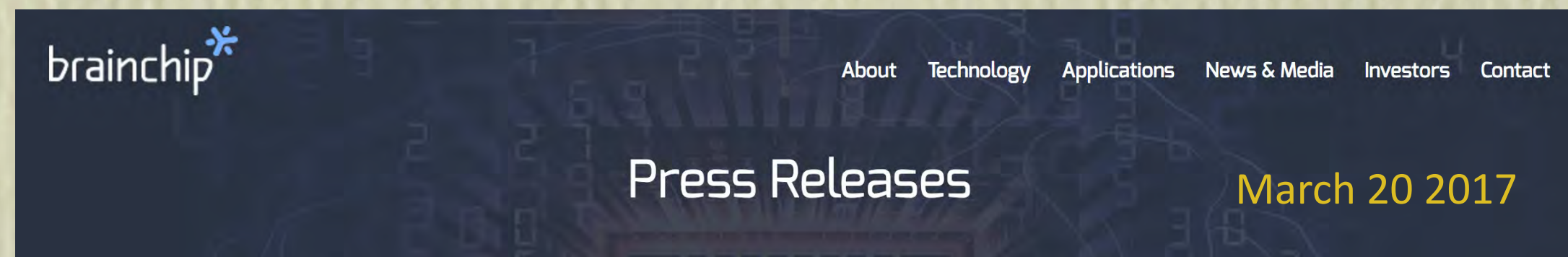
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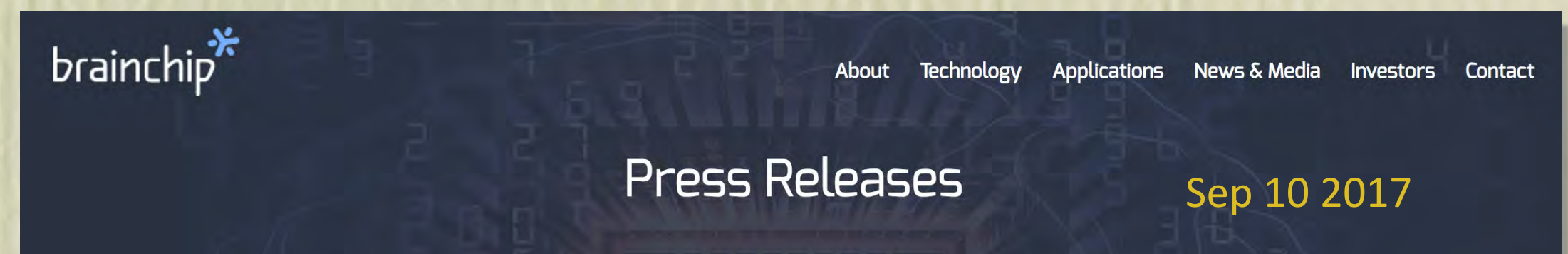
Press Releases

March 20 2017

BrainChip Advances its Position as a Leading Artificial Intelligence Provider with an Exclusive License for Next-Generation Neural Network Technology

MARCH 20, 2017   DOWNLOAD AS PDF

Highlights:

- Agreement with Toulouse Tech Transfer and the CERCO research center to license the exclusive rights to the JAST learning rules;

- JAST technology will be implemented on BrainChip's proprietary SNAP technology;

- License further solidifies BrainChip's position as a leader in the field of Neural Networking and Artificial Intelligence technology and solutions.

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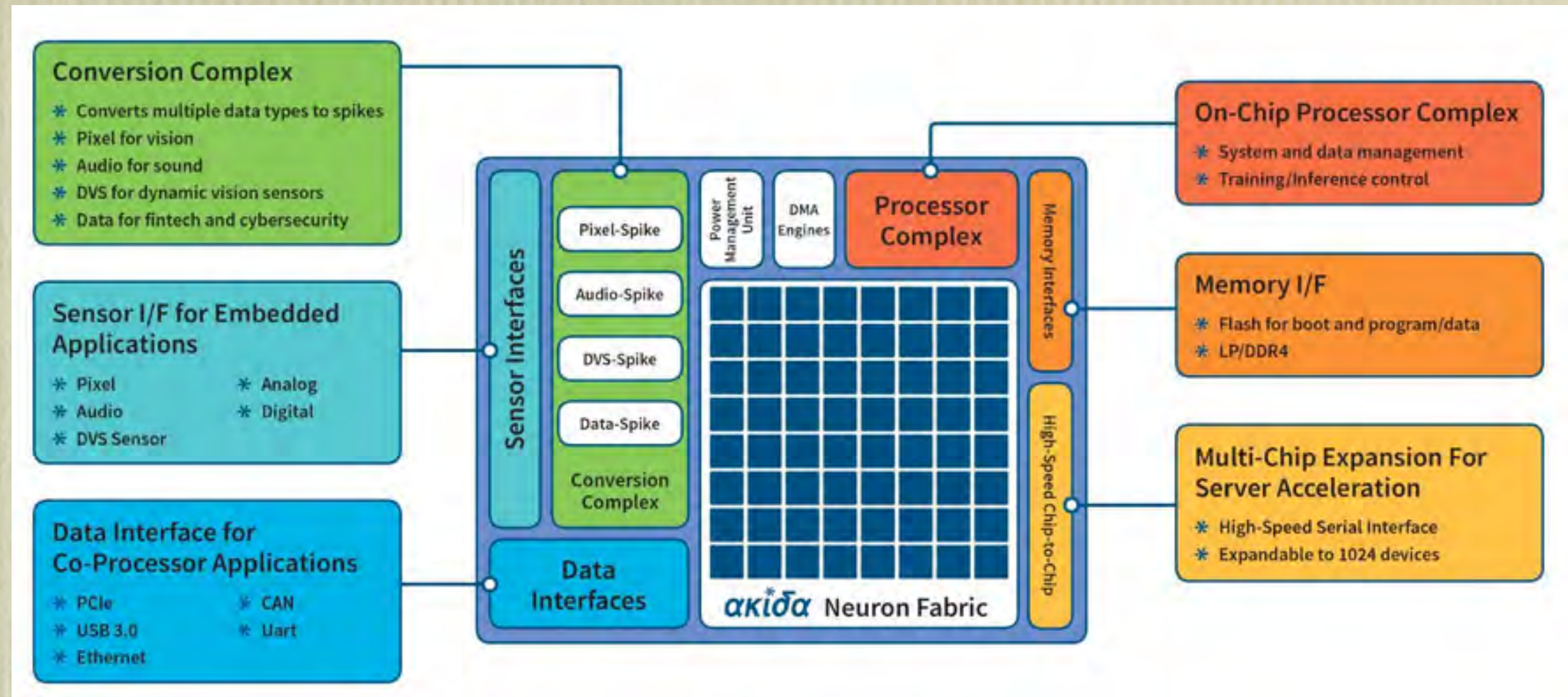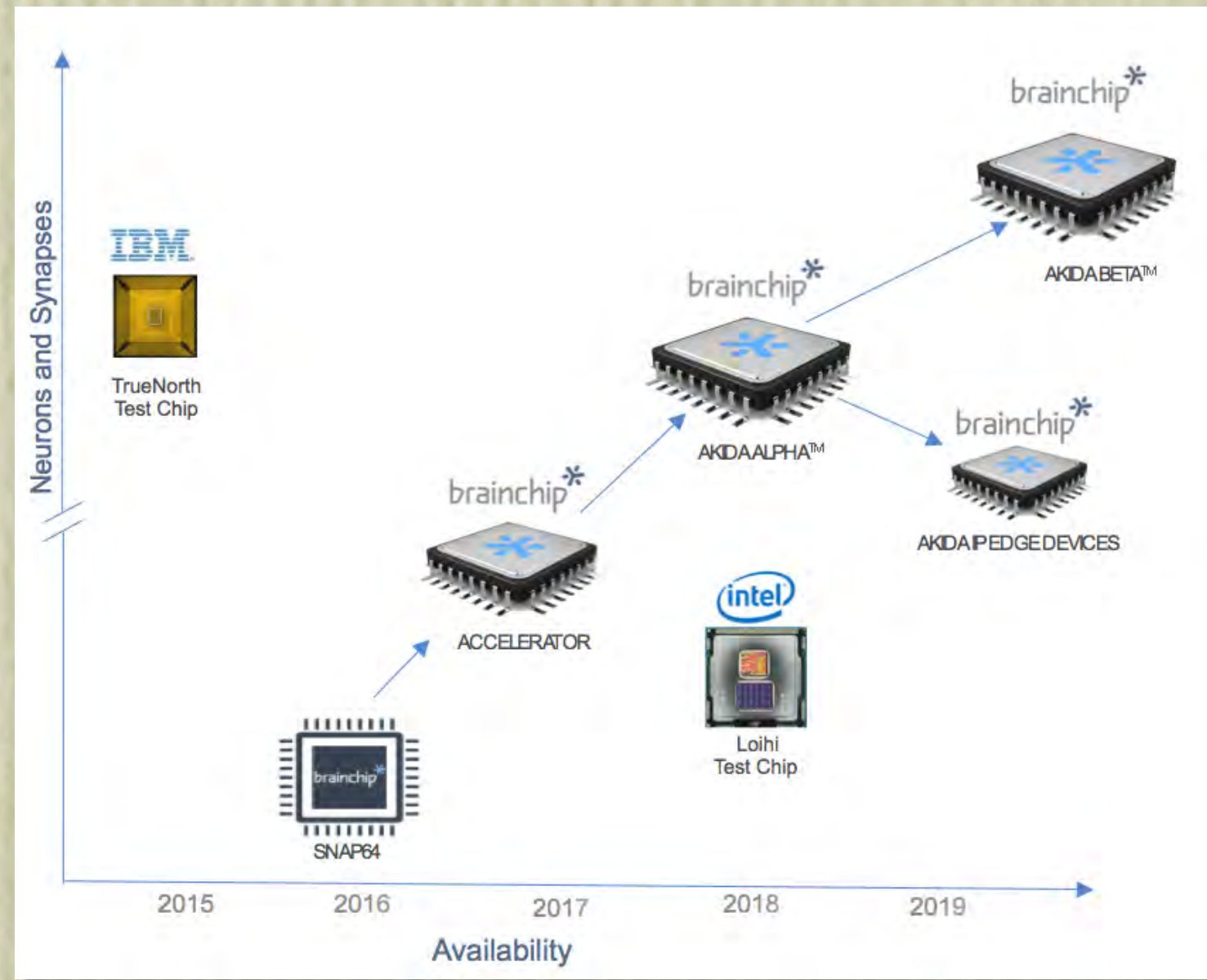## Press Releases

Sep 10 2017

BrainChip Announces the Akida™ Architecture, a Neuromorphic System-on-Chip

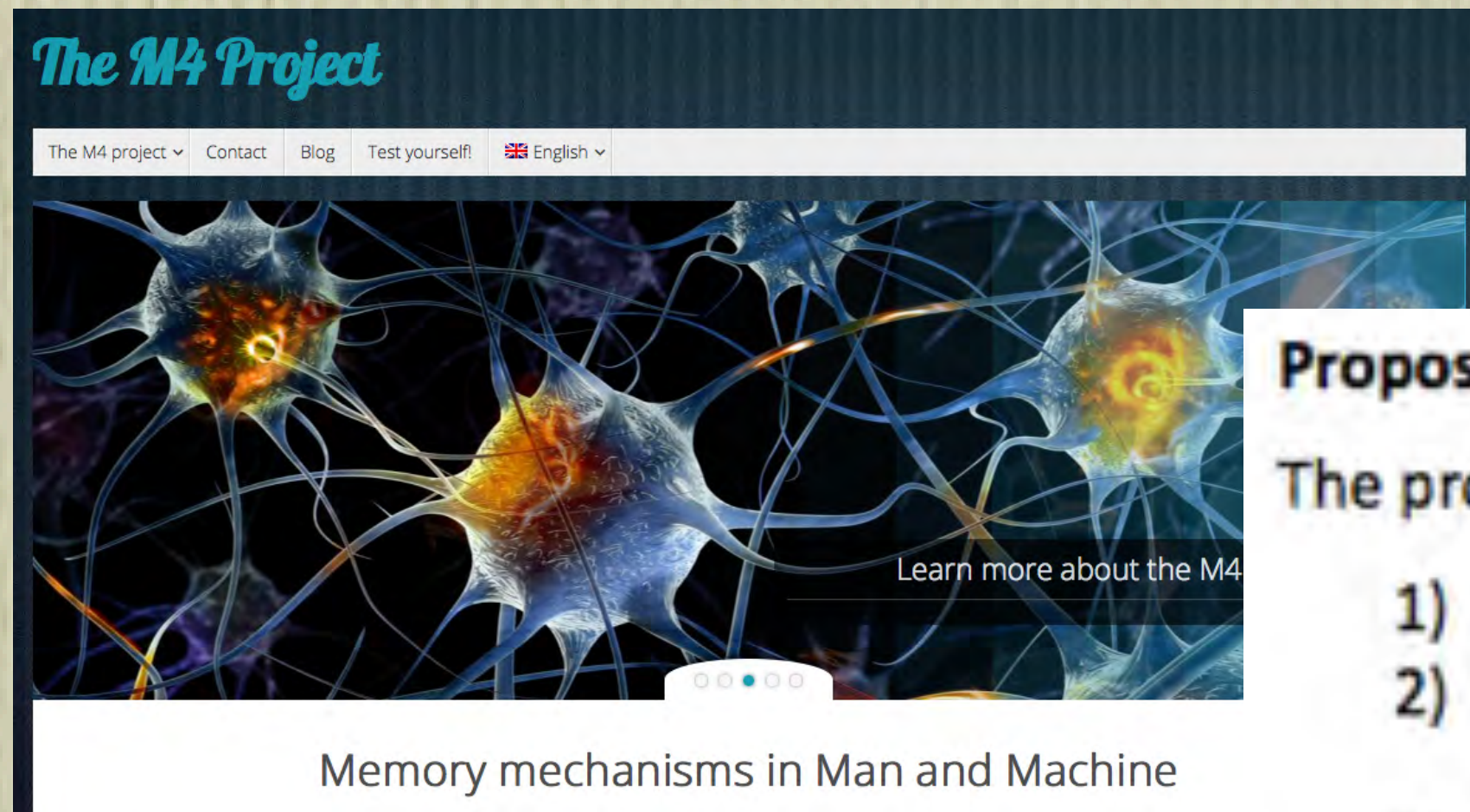SEPTEMBER 10, 2018   DOWNLOAD AS PDF

Company introduces the architecture of the first in a new breed of neural network acceleration SoCs that puts artificial intelligence at the edge and the enterprise

AKIDA

- 1.2 million neurons
- 10 billion connections
- 7 mm chip
- On-chip learning using JAST
- $10 fabrication cost

The M4 Project : ERC Grant (2013-19)

The M4 Project

The M4 project ⌄   Contact   Blog   Test yourself!   🇬🇧 English ⌄

Learn more about the M4

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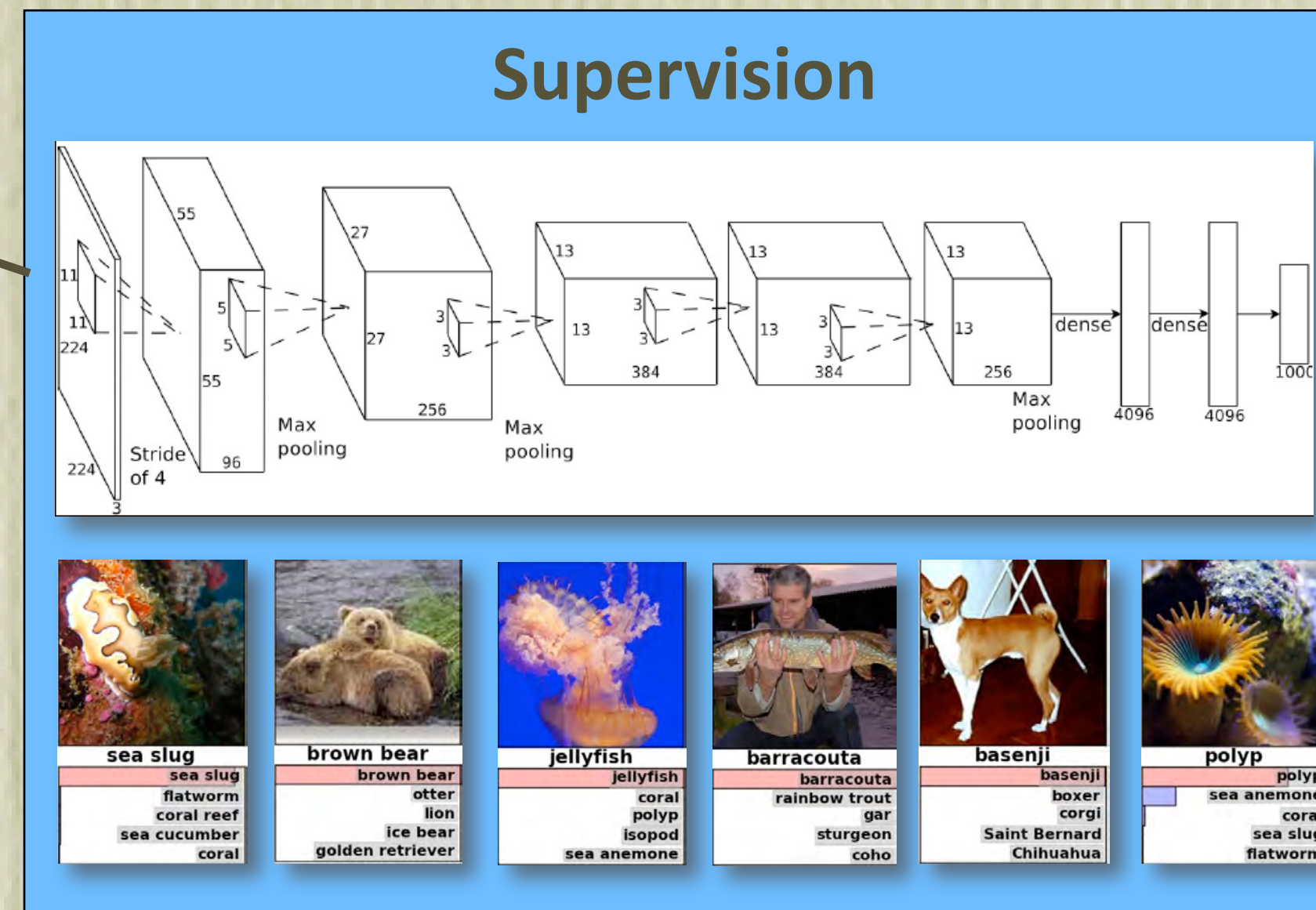
Why is this important?

- The Deep Learning Revolution
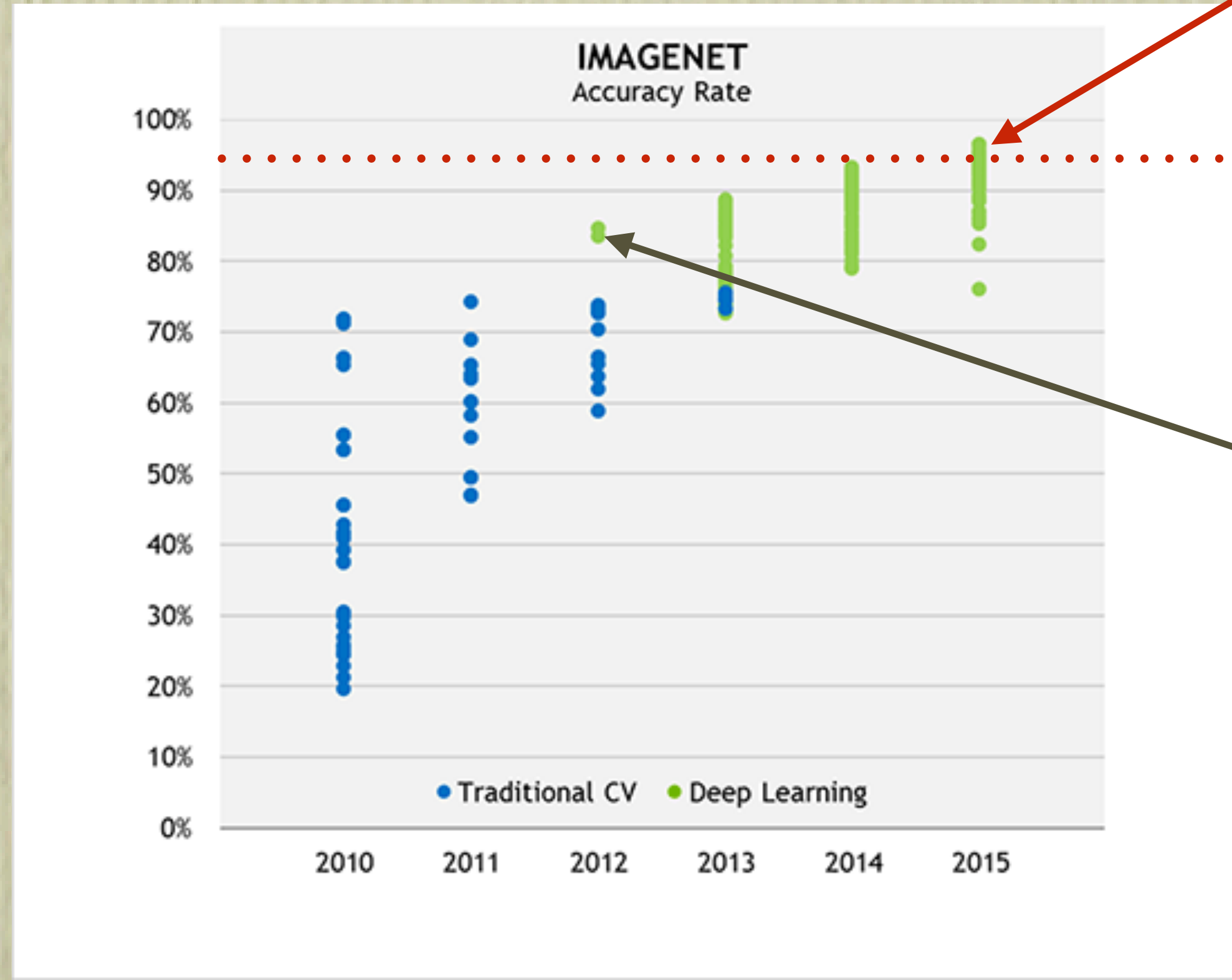
Superhuman performance

Human performance

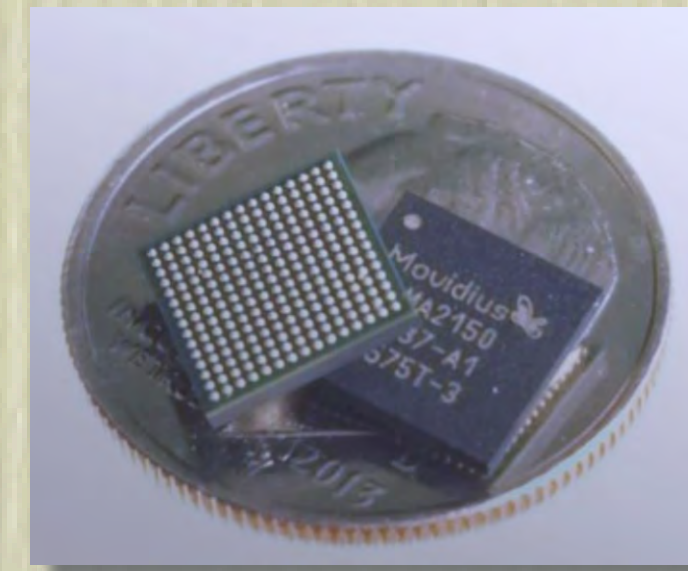**Supervision**

- Reinforcement Based Learning

  - Deep Mind's Chess system learned from scratch in 4 hours
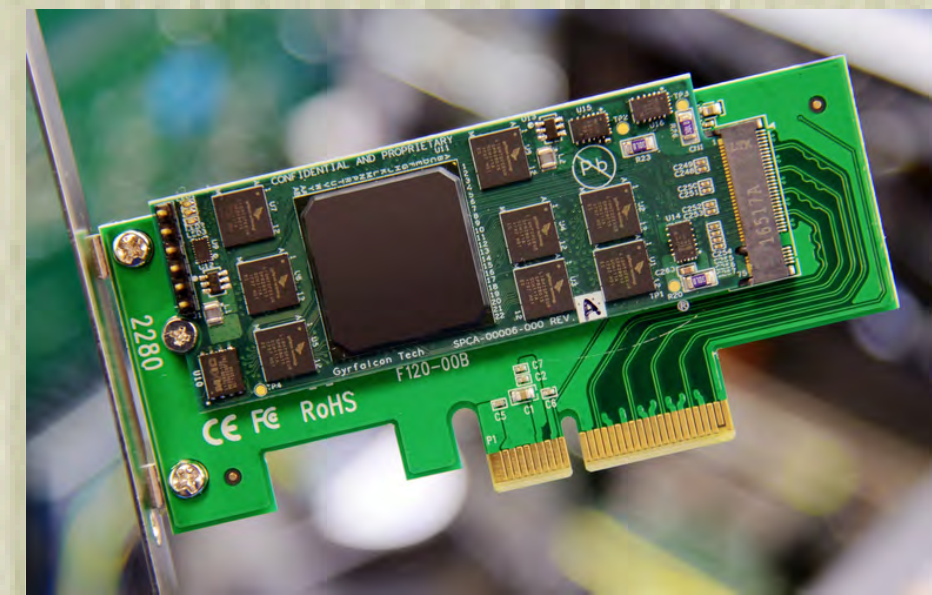
Deep Learning Chips

- Movidius

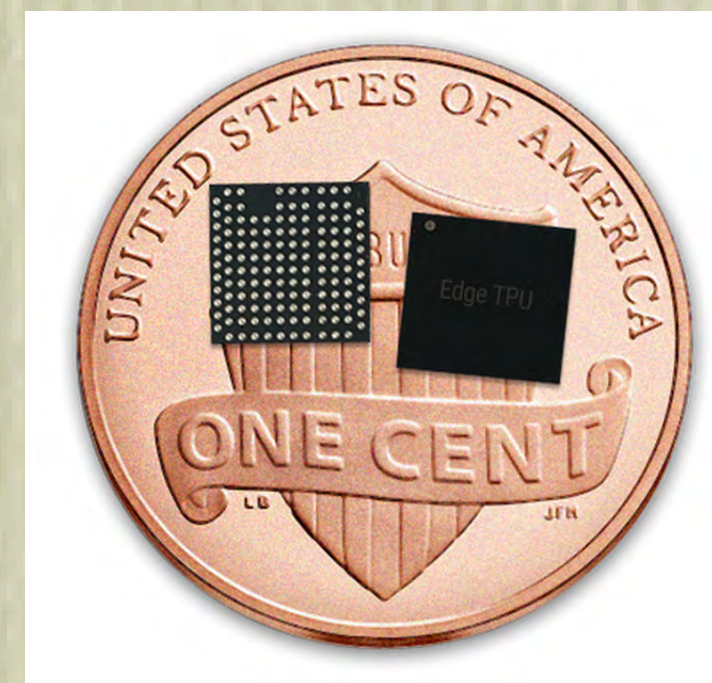 **Movidius: A stick for neural-networks from Intel for $79.**

  🕐 July 27, 2017 | 03:01

- Gyrfalcon Technology Inc

- Google's Edge TPU

- Plus
  - Apple
  - Microsoft
  - NVidia
  - Amazon
  - ARM
  - IBM
  - ....

- Plus
  - Graphcore
 - Anotherbrain.ai
  - GrAI Matter Labs

Natural Intelligence

- The implications of the M4 project

  - Humans don't learn like Deep Learning Systems

  - We don't need hundreds of millions of training cycles with labelled data

  - Humans learn in 2-5 repeats

    - Unsupervised learning

  - We now have learning rules that can do the same thing with relatively simple spiking neural networks

  - Implementation on inexpensive custom chips

  - Grandmother Cells and Neocortical Dark Matter are very important for power consumption

Implications for society

- Very powerful Deep Learning chips for $10 could replace many paid jobs

- AKIDA style intelligent chips are potentially an even greater threat!

- The resulting technological unemployment could prove catastrophic

- Calum Chace
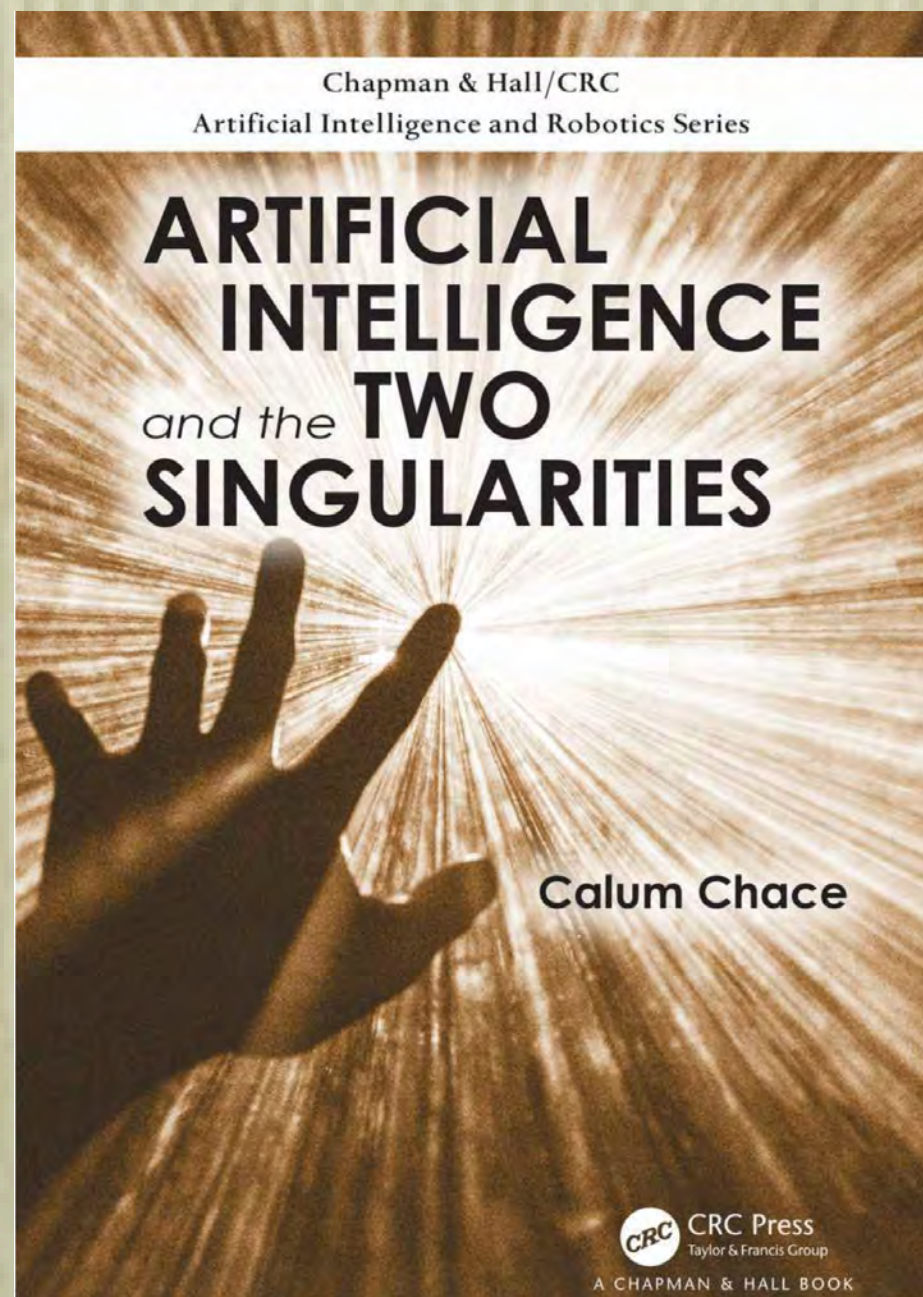
- Economic Singularity Club Think Tank

  - Forthcoming book

    - "Stories from 2045"

      - 24 positive stories

      - 13 negative ones

- My proposed solution

  - Universal Basic Income!

Chapman & Hall/CRC
Artificial Intelligence and Robotics Series

ARTIFICIAL INTELLIGENCE and the TWO SINGULARITIES

Calum Chace

CRC Press
Taylor & Francis Group

A CHAPMAN & HALL BOOK

AI, Neural Technology and Social Transformation

Simon Thorpe

Director of the Brain and Cognition Research Centre (CerCo)

Toulouse, France

0:11 / 17:02

Questions or Comments?