

A photograph of a family of four running on a sandy beach at sunset. In the foreground, a woman in a red long-sleeved shirt and blue shorts runs towards the left, smiling. Next to her, a young girl in a light blue long-sleeved shirt and white shorts runs towards the right, also smiling. In the background, a woman in a teal top and white pants and a man in a purple shirt and khaki pants are walking away from the camera, holding hands. The ocean waves are visible in the distance under a clear sky.

Phylogeny and Ontogeny of the Theory of Mind

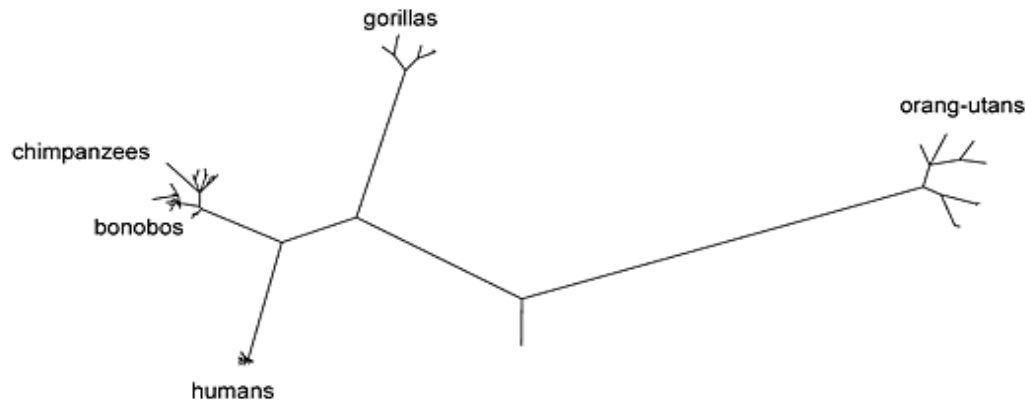
Theory of Mind during Lifespan Development and Evolution

- The term “theory of mind” (ToM) was originally proposed by primatologists Premack and Woodruff (1978) to suggest that chimpanzees may be capable of inferring mental states of conspecifics;
- It was later adapted to the ontogenetic development of mental perspective taking in infants and young children (Towner, 2010).



Evolutionary Roots

- The evolutionary origins of ToM can be traced back in extant non-human primates: ToM probably emerged as an adaptive response to increasingly complex primate social interaction;
- This sophisticated metacognitive ability comes at an evolutionary cost, reflected in a broad spectrum of psychopathological conditions (Brune & Brune-Cohrs, 2006)



Evolutionary Origins

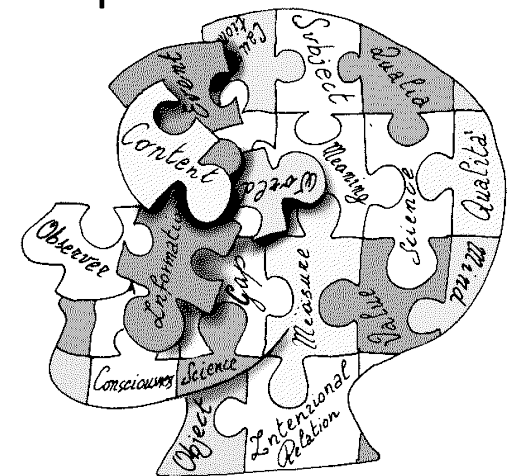
- Primates are essentially gregarious animals, and group living certainly confers adaptive advantages to the individual but it also incurs the cost of directly competing for resources, sexual partners and having to avoid deception from others;
- This situation may have created specific selective pressures in primates to evolve “social intelligence”, occurring an evolutionary arms race between as well within species;
- The study of animal behavior as well when ToM develops in humans has identified certain precursory behaviors to a full-fledged ToM, as understanding attention, understanding others’ intentions and imitative experience (Brune & Brune-Cohrs, 2006).

- Having a ToM may convey numerous advantages to a species and facilitate abilities such as learning and communication;
- Higher social cognition requires more brain capacity, which explains the additional brain volumes among the primates relative to other species (Towner, 2010);
- In humans the neocortex is 3 times greater and much more convoluted than expected for a primate of our size (Brune & Brune-Cohrs, 2006).
- The social environment may provide both pressure and context for the evolution of a higher social intelligence, so it's not surprising that it's in the great apes, which have more complex social systems, that we find the most evidence for ToM (Towner, 2010).

Cognitive Precursors of a Theory of Mind

- All great apes show recognition of the self and this may form the basis of the self-other distinction required for ToM;
- Mirror neurons (MN) found in humans and non-human primates have been suggested as the neural basis for this, which would facilitate imitation and teaching, both of which have been demonstrated in non-human primates (Towner, 2010).
- The discovery of MN demonstrated that a translation mechanism is present in the primate brain and is automatically elicited when viewing other's actions;
- This mirror system might underlie our ability to understand other people's intentions by providing us with an automatic simulation of their actions, goals and intentions (Singer, 2006) and offers an explanation of how the ability to imitate others has evolved into the capacity to simulate the mental states of other individuals (Brune & Brune-Cohrs, 2006).

- It has been found in non-human primate brains certain structures that have undergone adaptive modifications to constitute in humans a neural network of ToM (Brune & Brune-Cohrs, 2006):
 - Middle portion of the temporal lobe (specially the superior temporal sulcus) which is linked to observation of intentional movements;
 - Anterior cingulated cortex, that works as an important mediator of motor control, cognition and arousal regulation;
 - Mirror-neurons, that may have an important role in understanding action-goal states;

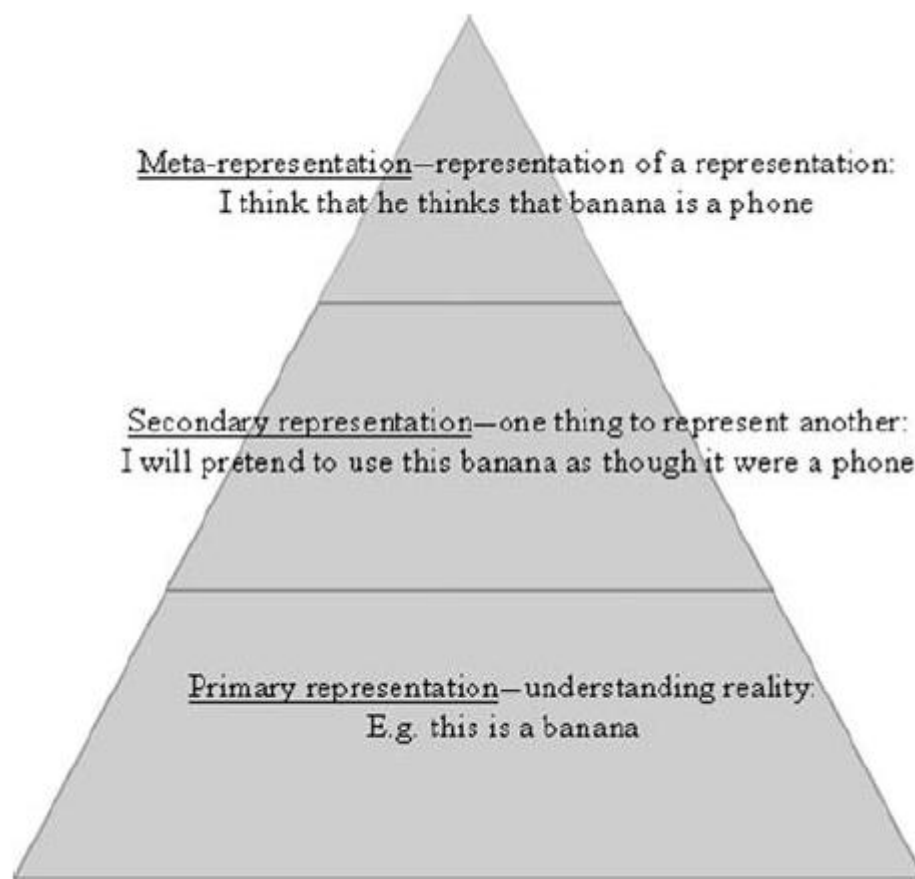


Emergence of ToM abilities

- Initially behaviors themselves evolved under the control of “low-level” psychological structures;
- As some lineages evolved increasingly complicated social brains interactions, brain systems dedicated to processing information about the regularities of the behaviors of others became increasingly sophisticated;
- About 4 million years ago, the human lineage began to evolve the additional ability to interpret these behaviors in terms of mental states. This psychological interpretation of behavior was applied to already-existing behaviors;
- The initial evolutionary advantage of this new psychological system (ToM) was that it allowed already-existing behaviors (such as deception and gaze following) to be used in more flexible and proactive ways, without discarding the low-level ancestral psychological systems (Povinelli & Giambrone, 2001).

- ToM is certainly most highly developed in humans but it comes with a cost: the evolution of big brains is energetically expensive and the ontogenetic acquisition of human-like ToM abilities are extremely time-consuming;
- ToM comprises an innate cognitive capacity represented in a dedicated neural network but the actual development of ToM is highly dependent on environmental input (Brune & Brune-Cohrs, 2006).
- High-level ToM is unique to our species and it's original function was to provide a more abstract level of describing ancient behavioral patterns (deception, reconciliation and gaze following), and those behaviors are shared by humans with many other species;
- The initial selective advantage of ToM may have been because it increased the flexibility of already-existing behaviors, not because it radically generated new ones (Povinelli & Giambrone, 2001).

- Since the conception of the term “ToM” the issue has evolved beyond if there is, or not, a ToM in non-human primates to a more sophisticated appreciation that the concept of mind has many facets and some of these may exist in non-human primates while others may not (Towner, 2010).



- In “real-life” situations, ToM is entrenched in a neural network that constitutes the 'social brain' of human and non-human primates (Dunbar, 2003 *in* Brune & Brune-Cohrs, 2006);
- ToM only represents one particular aspect of what is labeled as “social cognition”: the perception of social signals, motivation, emotion, attention, memory and decision-making, equally contribute to the actual behavioral output in social interaction (Brune & Brune-Cohrs, 2006);
- Early intention understanding, of the sort shared among primates, predict the ToM understanding of 4 years old children. That is, those early understandings provide a platform for the ontogenesis of further, deeper achievements in the human case;
- However we know very little of the ontogenesis of any such skills and understanding in primates (Wellman & Brandone, 2009).

Theory of Mind development during lifespan



6 months

- Distinguish between the motion of inanimate and animate objects

12 months

- Join attention

14-18
months

- Infants turn the head in the direction the gaze of an agent suggests an object to be

18-24
months

- Infants discover the difference between reality and pretence and start to recognize their-self in a mirror

3-4 years

- Sally-Ann's task and false beliefs

6-7 years

- Distinguish between jokes and lies
- Distinguish metaphor and irony

9-11 years

- Start to comprehend «faux pas»

- **«faux pas»**

- It requires a developmentally advanced representation of the second-person involved who commits the faux pas and the representation of the second-person involved who may feel hurt or irritated.



When and how ToM starts to change?

There are 2 lines of research:

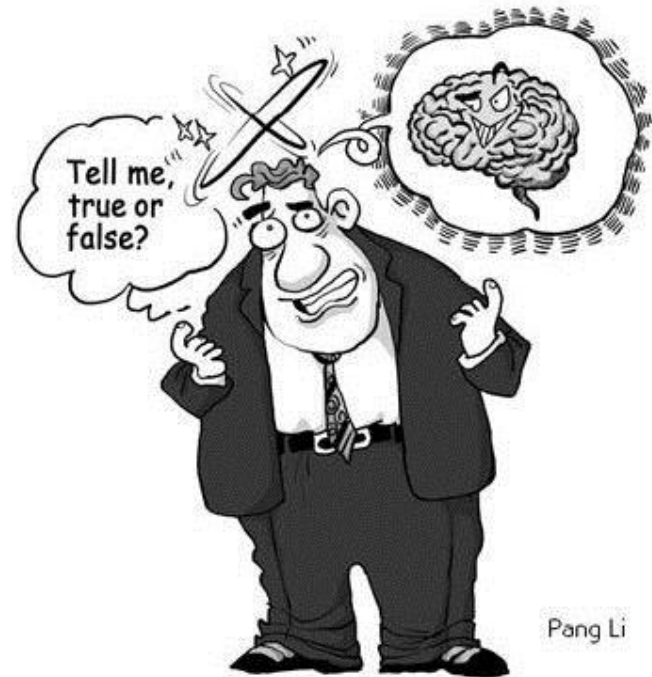
1. ToM in old age may even be characterized by lifelong improvements of social understanding - akin to the growth of wisdom (Happè *et al*, 1998)
2. Different form of ToM, namely the ascription of emotional states, sometimes called 'affective' or 'hot' ToM.
 - The ability to perceive and interpret emotional expressions from static and/or dynamic displays.
 - Several studies found evidence for age-related decline in the perception and interpretation of facial expressions of emotion (Maylor *et al*, 2002)

Lifespan and belief reasoning

- Phillips *et al* (2010) tested 129 adults aged between 18 and 86 on novel measures of ToM, which manipulated whether true or false belief reasoning was required.
 - Designed both verbal and video tasks to investigate the specificity of age differences in belief reasoning.

Researchers's prediction

- Age differences will be greater on false belief compared to true belief tasks, because false belief reasoning places high demands on social decoding inhibitory processes and updating skills.



Results

- On the Videos task true belief reasoning was stable across the age range, while false belief reasoning was impaired in older adults compared to their middle-aged and younger counterparts.
- On the Stories ToM task, middle-aged adults outperformed both younger and older adults on true belief reasoning, indicating that the ability to decode some aspects of mental states may improve into middle age.
- In contrast, younger and middle-aged adults were matched on performance in false belief reasoning in the Stories task, both groups outperforming the oldest adults.

Why?



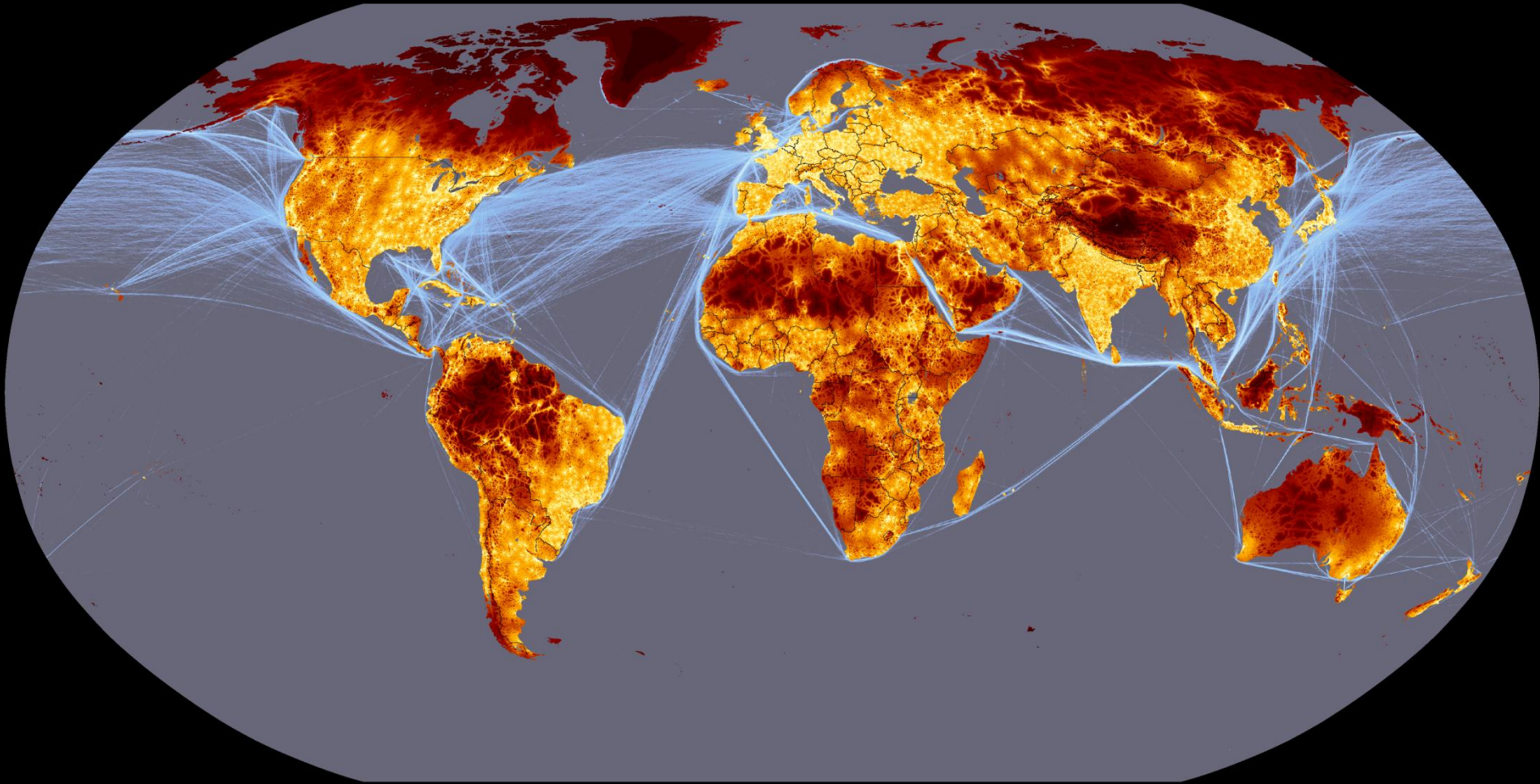
Evolutionary theory - a possible explanation

According to Darwinism, the most important thing for humans is to pass on its genes to the next generation. In old age, humans stop to be fertile so they don't need to socialize and to find a partner, and that could be the reason for the decline of ToM and the Executive Functions related to it.

How to prove this argument?

- In the future, we will need studies that focalized the differences between genders in Tom decreasing.
- Since menopause arrives before andropause in a typical human-lifespam, if the hypothesis is right we will find that women's decreasing will start before to men's decreasing.

Cultural influence in Theory of Mind development



During the preschooler age, children longitudinally progress through the five tasks in this Theory of Mind Scale in a standard order:

Diverse Desires (DD)



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graph TD; DD[Diverse Desires (DD)] --> DB[Diverse Beliefs (DB)]; DB --> FB[False Beliefs (FB)]; FB --> KA[Knowledge Access (KA)]; KA --> HE[Hidden Emotions (HE)];
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Diverse Beliefs (DB)

False Beliefs (FB)

Knowledge Access (KA)

Hidden Emotions (HE)

However, these scales aren't always fixed.

- Wellman *et al* (2006) found that USA and Australian preschooler children follow this developmental scale, but Chinese children have some differences:
 - They performed all the steps
 - But the order differed:
 - DD → **KA** → **DB** → FB → HE
- The same pattern has been discovered by Shahaieian *et al* (2011) in Iranian children.

How do we explain this?

The socio-cultural context must have shaped these differences (Shahaeian *et al*, 2011) :

Australia

- Individualistic society (like USA)
- Encouraging their children's assertiveness and skills of reasoned argument:
 - **Exposure to diverse beliefs make earlier to understand that people have diverse beliefs (DB).**

Iran

- Collectivist society (like China)
- Emphasis on teaching intercollective values and valorize children's knowledge acquisition
 - **More exposure to experiences of understanding knowledge and distinguished it from ignorance (KA).**

Socialization is a key process for acquiring theory of mind.

The family size, specifically the number of siblings, was also proposed to explain these differences. Siblings provide:

- Opportunities for family discussions about thought
- Disputes and/or disagreement

Australia:

- Children with siblings outperform in all steps only-children.
- Faster acquisition of theory of mind.



Iran:

- The number of siblings have no effect in theory of mind performance.
- Iranian children may not gain as much conversational exposure as Australians with siblings to benefit ToM development.
- Iranian children interact so frequently with cousins that compensate the lack of a sibling.



- A lot of studies have been made in order to understand what is different between western and non-western societies in the development of a theory of mind.
- Lecce and Hugdes (2010) emphasises that this differences occur even between different countries in western society.
- Italy and Britain are geographically close but parental and social expectations are clearly distinctive.



Britain

- Great value on independence and promotion of children development.
- Quickly understand the division between private and public spheres of life.
- Caregivers talk more often with their toddlers, are more likely to ask genuine questions and less likely to ask test questions.
- British government promotes book reading.

Italy

- Development as natural and inevitable
- Encouraged to participate in groups that extend beyond their immediate families
- Engage in affectionate interactions
- Italian children begin formal schooling at 6, a year later than British.

British children outperformed Italian on false beliefs tests.

➔ **Favored "Social Goals" model**

- Group differences remained significant even when the number of siblings for each child was entered as a covariate.
- Correlations between family size and false-belief performance were small and negative.
- Caregiver's social goals are related to individual differences in children's social understanding.

Other explanations:

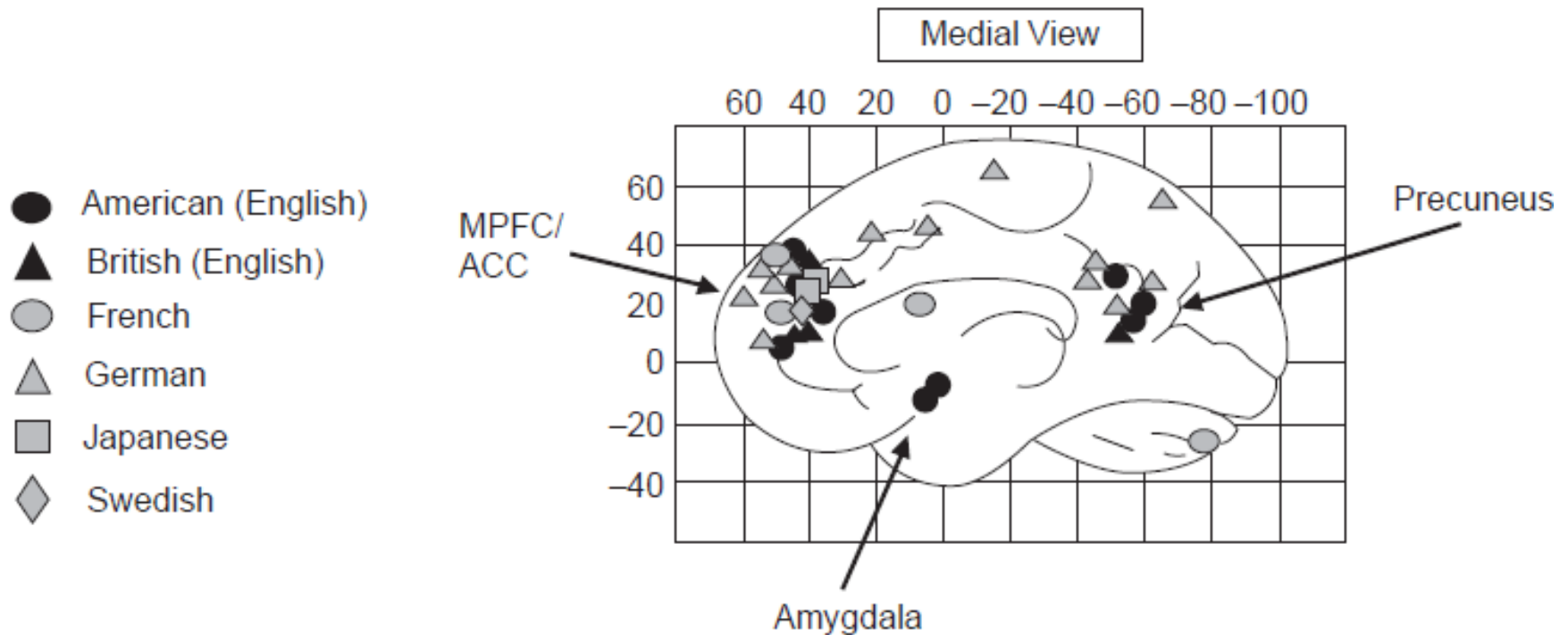
- The earlier school and the government book promotion could be also involved.



Cross-cultural differences are very well studied in children, but in adulthood and old age they are poorly documented.

- Frank and Temple (2009) analysed brain imaging during ToM tasks and discovered:
 - **Some aspects of theory of mind are not universal, but culturally dependent.**
 - **mPFC:** Consistently implicated region in a variety of theory of mind tasks across cultures, involved in a self-referential component of theory of mind
 - Show evidence for possibly being **culture independent.**

- **TPJ**: may be involved in distinguishing self-agency from other agency
- If one culture has a more self–other distinction of theory of mind perhaps the TPJ would be more involved in their processing
 - Seems to be related to ToM just in Anglo-Americans.



“Early language ability predicts later ToM performance”
(Kobayashi *et al*, 2008)

- Language is a crucial part of cultural development, shaping the culture itself.



Kobayashi *et al* (2008) investigates linguistic effects on the developmental neural bases of ToM in Japanese-English late bilingual adults and early bilingual children.

- Bilingual children showed an overlap in the mPFC area for both languages.
- In adults has found more divergence between languages and some convergence in the pSTG/TPJ area.
 - **This areas seems to be universally important for ToM development.**
- Early bilinguals may utilize more similar brain regions for processing ToM in different languages than late bilinguals.
- Adults, more than children, recruited different brain regions depending on the language used in the ToM task.
 - **People recruit different linguistic and cognitive resources depending upon the language used to process ToM, and that this difference may become greater as people age.**

Recapitulation: Genesis of ToM

- Species evolution
- Changes through Phylogeny
- Changes through Ontogeny

- Cultural factors (learning vs. simple exposure)

- Psychological correlations (Behavior)
- Neuroanatomy correlations (brain, CNS, PNS)

What kind of Scale is ToM? (what values can ToM achieve)

- Nominal – Children – have, doesn't have (False belief test)
- Ordinal – “autist” < “normal” < mind reader
- Interval, numerical scale? Can ToM be some kind of continuum?
- Scales and measurement (Stevenson, 1964)

Is Agreeableness related to Theory of Mind?

- In separate empirical studies, we find that Agreeableness is substantially correlated with socio-cognitive ToM performance, but uncorrelated with social-perceptual ToM performance (Nettle & Liddle, 2008)
- **Agreeableness:** warmth, friendliness, altruism and compliance to the needs of others
- **Social-perceptual component** of ToM is the ability to detect the mental states of others using immediately available cues such as facial expressions and bodily movements.
- **The social-cognitive component** of ToM is the ability to reason about the content of another's mental state, and use such reasoning to predict or explain their actions.

Is Agreeableness related to Theory of Mind?

- Differences between men and women
- Correlations to other personality traits:
 - Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism
- Social-perceptual component
 - Reading the Mind in the Eyes test;
<http://glennrowe.net/baroncohen/faces/eyetest.aspx>
- The social-cognitive component
 - 30 stories, level 2-9 of embedding

Differences between men and women

- **Social-perceptual component**
 - no significant sex difference on this task -> generalisation that the social-perceptual component of ToM is not sexually dimorphic
 - higher female scores on Agreeableness and Neuroticism, higher male scores on Openness
 - no significant relationships between ToM score and Agreeableness, or indeed any of the five personality factors
- **The social-cognitive component**
 - higher in females (mean 26.00, SD 1.75) than males (mean 24.80, SD 2.80). The sex difference was significant ($t(3.25)$, $p < 0.01$, $d(0.51)$).

Table 1. Correlations between ToM scores and personality factors, and amongst the personality factors. The social-cognitive component.

	ToM	O	C	E	A
Openness	0.16				
Conscientiousness	0.11	0.33*			
Extraversion	-0.11	-0.02	-0.25*		
Agreeableness	0.48*	0.11	0.20*	-0.05	
Neuroticism	0.40*	0.05	0.15	-0.11	0.23*

* $p < 0.05$.

ToM – What is there for psychologists?

- To what extent are mind-brain correlations important to us?
- How exactly does the idea of Mirror Neurons helps?
- How exactly does the idea of particular Brain part helps you?
- How exactly are you people skills improved when you know something about chimpanzees?

Old Questions

- Nature vs. Nurture
- Genes vs. Environment
- Determinism vs. Free Will (are we predestined or do we have a choice)
- How should humans behave towards animals, does the animals have personality or human-like emotions?
- Are we building human or animal-oriented psychology? What is our field or personal orientation?

Conclusion

- The phylogenetic and ontogenetic study of ToM in human and non-human primates allow us to better understand the highly complex inter-relations present in social intelligence;
- The research about the ontogenic development of ToM in humans reveal that there are differences between genders, age-groups but also in different cultural systems;
- More research is needed to clarify these differences.

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