Tigers and teapots: what does it mean to be alive?

Jennifer M. Rodd, Peter Bright and Helen E. Moss

The Symposium entitled 'Conceptual Knowledge: Developmental, Biological, Functional and Computational Accounts' was held at the British Academy, London, UK on 24–26 June 2002. It was funded by the British Academy with support from the Novartis Foundation, and organized by Lorraine Tyler (University of Cambridge, UK) and Tim Shallice (University College London, UK).

What do you know about tigers? You would certainly recognize one if it appeared at your desk, and you'd know what to do (run away!). You know what behaviour you'd expect from a tiger and what it's made of. You know it's quite like a cat but nothing like a teapot. Now consider some abstract concepts such as 'freedom', 'love' and 'animacy'. We know what we mean by these, although it is harder to put into words.

The nature of conceptual knowledge

We draw on concepts such as 'tigers', 'teapots', and 'animacy' to recognize, reason, predict, remember and communicate. The nature of conceptual knowledge is a fundamental and extraordinarily wide-ranging area of research in cognitive neuroscience. Key issues such as what constitutes a concept, how concepts are represented in the minds of humans and other species, their cognitive, biological, social and cultural foundations, how they are acquired by infants and break down following brain damage, are studied in a range of disciplines, but often in isolation. This symposium brought together leading researchers from many fields, including cognitive, comparative and developmental psychology, neuroscience, anthropology and neuropsychology, to discuss these issues in an interdisciplinary forum.

One major theme was that our conceptual knowledge about animals (and other living things) might be special compared with other objects. Neuropsychological studies show that brain damage can produce a selective deficit for knowledge about living things compared with artefacts such as tools and vehicles. Alfonso Caramazza (Harvard University, USA) distinguished two classes of explanation for why living things might be special. The first, and the one he supports, is that specialized neural mechanisms have evolved for particular categories, such as animals, for which rapid and accurate classification provides an evolutionary advantage. Brain lesions can affect these dedicated systems independently.

Features and properties

Tim Shallice (University College London, UK) and Alex Martin (NIMH Bethesda, USA) also claimed that neural structure constrains conceptual organization, but argued for specificity as a function of *type* of attribute rather than category of knowledge. Shallice proposed that sensory information allows us to distinguish a tiger from a lion (they look different, but behave in similar ways). By contrast, artefacts (such as teapots and jugs) are more variable in appearance, and are discriminated by their function. Thus damage to brain regions that store information about the visual properties of objects produces a greater deficit for animals. Martin presented neuroimaging evidence suggesting that the organization of the conceptual system parallels the neural organization of sensory and motor systems. The sensory/motor theme was taken up by Larry Barsalou (Emory University, USA) who argued that reactivating the sensory and motor features associated with objects is a critical aspect of their conceptual representations.

The second class of account is that essentially homogenous cortical systems are structured by learned correlations among properties of objects. Within this framework, Tyler proposed that animals typically have many shared correlated properties (they can walk, breathe, have eyes). These properties are robust to damage because they support each other with mutual activation. However, the more distinctive properties of living things are only weakly correlated with each other (objects with stripes are not necessarily fierce). Such weakly correlated properties are highly vulnerable to damage. By contrast, artefacts have robust 'form–function' correlations among distinctive properties, (e.g. objects with spouts are often used for pouring). This emphasis on the relationships between features within conceptual representations was extended by Jay McClelland (Carnegie Mellon University, USA) who presented a computational model in which the hierarchical clustering of living things emerges from the coherent covariation of the features of related concepts.

Animals and animacy

These ideas about the conceptual representations of objects in humans were complemented by research with non-human primates. Marc Hauser (Harvard University, USA) discussed whether the concept of a tool is present even in animals that are not natural tool users, and Herb Terrace (Columbia University, USA) described the ability of rhesus macaques to learn about the order in which objects appear. Daniel Amit (Universita di Roma, Italy) presented electrophysiological recording studies in which cells in the temporal cortex of monkeys appear to support delayed-matching-to-sample of geometrical images. He characterized the behaviour of these cells as a system of cortical attractors that allows the completion of incomplete patterns. Mechanisms of this sort could form the basis of classification systems for conceptual knowledge.

In addition to this work on object recognition, an important theme of the symposium was that conceptual knowledge is not simply the routines that allow us to classify objects, and predict their characteristics. One of the most salient properties that differentiates a tiger from a teapot is that the tiger is alive – it is an animate entity that can act as an independent agent. Jean Mandler (University of California, USA) and Susan Carey (New York University, USA) argued that the concept of animacy is acquired very early in development (whether it is innate or emerges on the basis of salient cues such as self-initiated motion, has not been resolved). Mandler reported that 14-month-olds respect the animate/artefact distinction; actions such as drinking and sleeping are generalized appropriately to animals but not to vehicles, even when the objects are visually similar (e.g. birds and aeroplanes). She emphasized the distinction between perceptual knowledge and conceptual knowledge;

http://tics.trends.com 1364-6613/02/$ – see front matter PII: S1364-6613(02)01981-2

perceptual knowledge allows recognition, whereas conceptual knowledge allows inductive inference.

Animacy is just one aspect of conceptual knowledge that is more abstract than objects' perceptual and functional features. Other such 'high-level' concepts that seem to be important include cause and intentionality. Carey also discussed how knowledge about integer numbers might develop during infancy, by the integration of systems that represent analogue magnitudes and individual object files.

Lastly, focussing on cultural aspects of conceptualization, Scott Atran (University of Michigan, USA) observed that current theories are largely based on research in industrialized societies. He noted that in the domain of living things, our reduced contact with the natural world has produced impoverished knowledge, compared with societies such as the Mexican Maya. Despite such variation, it appears that the classification of living things into hierarchical groups, and representation of animals as animate agents is stable across different cultures.

Jennifer M. Rodd*
Peter Bright
Helen E. Moss
Dept of Experimental Psychology, University of Cambridge, Downing Street, Cambridge, UK CB3 3EB
*jrodd@csl.psychol.cam.ac.uk

On Enigmas and Oracles: looking back to the future

Christof Teuscher and Ursina Teuscher

The Turing Day was held at the Swiss Federal Institute of Technology (EPFL) in Lausanne, Switzerland, on 28 June 2002.

The Turing Day was an initiative to commemorate the anniversary of Alan Mathison Turing's 90th birthday and to revisit his many contributions to computer science, biology, philosophy and cryptography. The goal was not only to look back in history but also to determine the importance of Turing's fundamental work for contemporary and future trends. The workshop consisted of a series of invited talks given by internationally renowned experts in each the various fields. The Turing Day demonstrated that a number of research programs lead or inspired by Turing continue to feed passionate scientific debates, and that a number of questions remain unsolved.

An Oscar Wilde of computer science

Alan Mathison Turing, born in London on June 23rd 1912, is widely considered to be one of the most creative thinkers of the 20th century. Not only was he one of the great pioneers of computer science, laying much of the theoretical groundwork for modern computing, but his wide interests, from computing and the mind, to information science and biology, spanned many of the emerging themes of the postmodern society.

His concept of the 'universal Turing machine' (dating from 1936) was revolutionary for a time when most computers were designed for a specific purpose. During World War II, Turing worked as chief cryptanalyst at Bletchley Park, where he succeeded in cracking the code of the German *Enigma* cipher machine. After the war, he worked at the National Physical Laboratory in London, where he developed a design of an electronic computer, the 'Automatic Computing Engine' (ACE), and investigated connectionist models.

Turing spent the last few years of his life working on computer simulations of plant growth. He developed a morphogenetic theory for biological pattern formation and introduced a central concept of mathematical biology with his 'Turing instability'. Alan Turing died on June 7th 1954, of cyanide poisoning, almost certainly by his own hand.

Hypercomputation: hype or computation?

Does a universal Turing machine really capture the essence of any and all forms of computing? Or are there hypercomputers (Turing called them 'oracles') – super-Turing machines capable of going beyond the Turing limit? This was the subject of Martin Davis' (New York University, NY; and University of California, Berkley, CA, USA) talk entitled 'Beyond the Church–Turing Consensus'. Davis made clear that any physically realizable process – including a Turing machine with random elements and the quantum computer – computes in the domain of the Turing machine. It has been shown by Hava Siegelmann [1] that certain theoretical neural networks having real weights (i.e. infinite precision, so in fact physically impossible) would be able to compute beyond the Turing limit. Davis pointed out rather sarcastically that it is not astonishing that a theoretical device could compute all languages if all languages (i.e. infinite precision) were put into it. According to Davis, no meaningful and serious research is going on around hypercomputers and Turing had nothing in mind himself. All he said in his 1939 doctoral thesis was that 'oracles' compute uncomputable functions and that they cannot be machines. In conclusion, the strong version of the Church–Turing thesis (that no realizable physical device can be more powerful than a Turing machine) is still valid and the much disputed question of whether non-Turing computation is relevant to human-like artificial intelligence remains unsolved.

Key conference outcomes

- Turing was undoubtedly one of the most important thinkers of the 20th century.
- A number of research programs lead or inspired by Turing continue to feed passionate scientific debates.
- Practical hypercomputation remains a dream. So far, no physically realizable machine has been able to compute beyond the Turing limit.
- Does the brain perform functions not computable by a Turing machine? Is thinking more than computing, or does thinking amount to hypercomputation?
- It remains unclear whether machines will ever be able to do as much as the human mind.

Mind, AI, and computation

Undoubtedly, the central question for Turing was always whether machines can do as much as minds. After World War II, Turing paved the way to what would later become known as artificial intelligence (AI). Christof Teuscher (Swiss Federal Institute of Technology, Lausanne, CH) focused in

  PII: S1364-6613(02)01988-5