LECTURE 1

What is cognition? = thinking, thought processes

The study of cognition has developed alongside the development of the modern computer therefore computer modelling has often been the key source of modelling human cognition. Computation is an analogy of the human mind and thinking.

"By the end of the century…one will be able to speak of machines thinking without expecting to be contradicted" Alan Turing

Alan Turning was a brilliant British mathematician involved in the development of computer science (and in cracking the Nazi Enigma code during WWII, among other things). 2012 marked the 100th anniversary of his birth. The invention of the digital computer went hand in hand with the "cognitive revolution" in psychology, and computation became a powerful metaphor for cognitive processes. Turing's work inspired subsequent innovations in Artificial Intelligence (AI) – a research programme dedicated to developing intelligent machines, modelled on human cognitive processes. The approach to cognition that developed from this work in AI is referred to as Classical Cognition. In its strongest form, classical cognition implies that human cognition reflects the manipulation of symbols according to specified rules for combining those symbols (syntax) – given this, the 'programme' for a human mind could be implemented in a computer, just as it is implemented in a biological brain. Despite the early enthusiasm for this approach, no computer programme has yet come close to passing the so-called "Turing Test" , in which a human interrogator attempts to distinguish between the (text-based) responses of a computer and a human to his/her (text based) questions (compare with the "Cleverbot" AI online http://cleverbot.com/). The Turing Test equates cognition with disembodied linguistic output. For a machine to pass a strong version of the Turing test its programme would need to encode all of the knowledge a human has acquired over a lifetime and it would need to have a procedure for matching any text input with an appropriate response. The scenario raises questions about how such knowledge could be acquired, and how the knowledge stored in the programme could be meaningful to the computer (although Turing himself was not concerned with the latter question, he was interested in the first). The thought experiment has proved useful if only to highlight such questions, and has prompted cognitive scientists to develop artificial intelligences that attempt to provide answers to these questions. In this lecture we will explore the classical view of cognition and we will contrast it with alternative (complementary?) approaches in an attempt to understand the multifaceted nature of our cognitive processes.

Cognition is the activity of acquiring, organising and using information to enable adaptive, goal-directed behaviour

- Activity = something that is occurring at all times. Acquires and uses information
- Purpose: we think reason and plan in the service of reaching the goals that we have adapting to our environment in order to survive

The study of informational processing (computational language!!): includes mental processes such as learning, memory, attention, language, reasoning, decision making etc

"the mind is a system that creates representations of the world so that we can act within it to achieve our goals" What are these representations of the world?

- Thinking about things that are not present or at various points in time
- Represent what you previously learnt
- The way in which, how we represent information mentally so that we can re-present it to ourselves in our imagination
- Linguistic codes or narratives
- Imagery (also sound, smell, taste etc)
- Using this to help you think about things that could happen in the future – represent hypothetical possibilities in certain situations or when certain event occur together
- Memory and the ability to bring those memories to mind
- Coded in the brain and brought back to life with the use of certain cues and markers

Cognitive abilities = intelligence

- There is an assumption that only the brain performs cognition

We can define cognition as the activity of acquiring, organising and using **information** to enable adaptive, goal-directed (intelligent) behaviour. We can define information (loosely) as the detectable changes in stimuli that enable us to (1) **categorise** the entities and events that we encounter, and (2) **infer** the relationships between them.

Attention to behaviourally relevant aspects of the environment (i.e., selective attention) results in the development of a **conceptual structure** (i.e., mental model of the world) that enables the organism to **recognise** salient objects and events and to respond adaptively to them based on **knowledge** acquired from past experiences with similar objects or events. Cognitive scientists are particularly interested in understanding how knowledge is mentally represented in the nervous systems and brains of humans (and other animals) and how this knowledge is used to guide behaviour.

<u>What makes a thing cognitive?</u>

Cognitive agents (or cognisers):

- Sense and action on the environment
    - Detect and effect changes in the environment: detect salient changes in the environment and effect it – perform actions that generate consequence sin which they learn from and obtain information
    - Gain information
- Construct mental models to represent the causal structure of their environment
- Adapt their mental models in response to feedback from their behaviour: continual update of the mental model – conceptual understanding of the world along with individual models for different situations (e.g. being in a lecture), entail certain features that are unique to that situation.
- Use mental models to guide future behaviour
- Thinker of some sort

<u>Classical cognition: the computational metaphor of cognition</u>

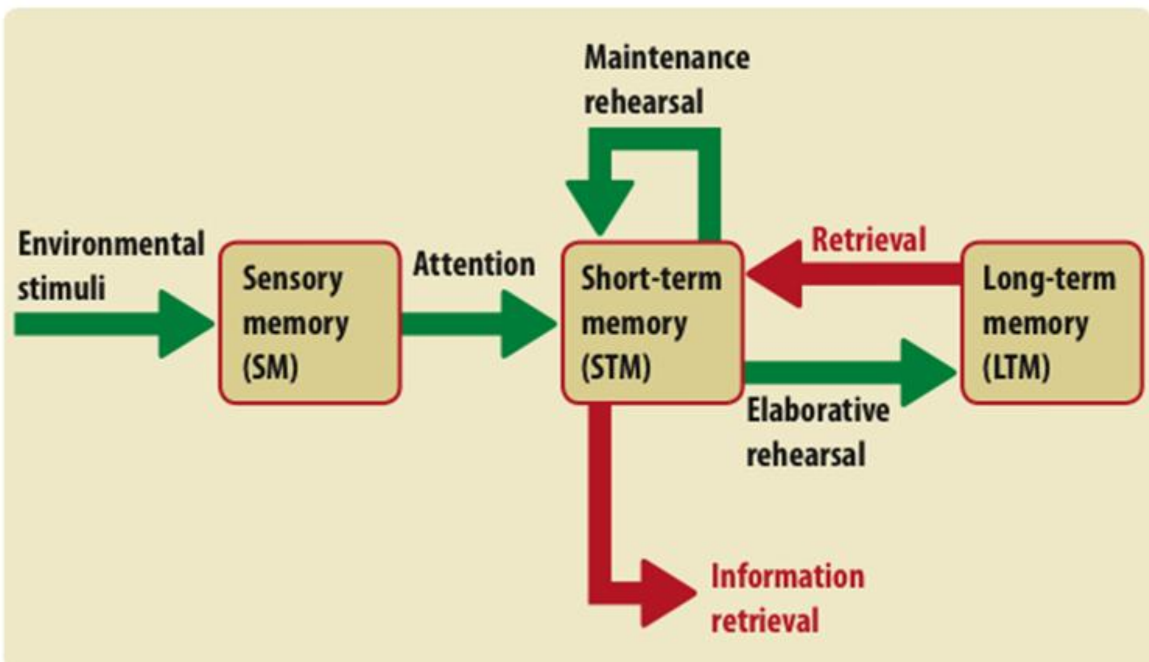
Symbolic representations – 0s and 1s in a computer are symbols that represent some form of information, in human this is a physical symbol of some kind.

The brain is the hardware and the mind is the software – in a sense the brain is irrelevant because there might be other ways that cognition could occur through other physical mediums. Number of different types of hardware that could work with the same software.

- Cognition as a flow of information through processing devices that encode, store and retrieve symbolic representations of knowledge
    - The brain is the hardware
    - The mind is the software (programme)
- Cognition analogous to the operation of a digital computer

EXAMPLE: AN INFROMATION PROCESSING MODEL OF MEMORY

- Sensory signals provide "input" to the system
- Transduction of sensory signals to a mental code for central processing
- Further processing (computation) in short-term/ working memory, informed by long term memory



The figure represents a typical classical information processing model described in the three stages shown in the diagram: Environmental input, Short-term memory, and Long-term Memory. This is the kind of memory model that will be familiar to you if you have done introductory psychology (e.g., Atkinson and Shiffrin's, 1968, modal model of memory). According to this classical view, stimuli are first encoded in sensory memory. The aspects of the input that are attended are then transformed into a mental code that is sent on to short term memory (or working memory), which serves as a metaphorical "workbench", where information can be examined, evaluated, and compared to other information from long-term memory. Short-term/working memory receives input from long-term memory, relating to previous experiences that bring meaning to a stimulus. Rehearsal increases the chances of storage in long-term memory. Long-term memory (LTM) is assumed to store large amounts of information for an indefinite amount of time. LTM has a number of different components representing information in a variety of formats including declarative (episodic, semantic, and linguistic knowledge) and non-declarative forms (conditioned learning, procedural skills, priming).

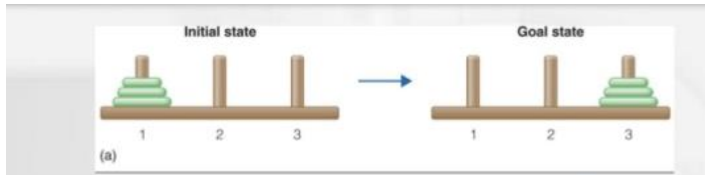
This account of human information processing and memory has been enormously influential, however, it has undergone significant challenges over the past three decades.

Classical conditioning

The Classical view of cognition tends to focus on pure, disembodied, thought processes that are expressed in a symbolic "language of thought" or "mentalese". Symbolic representations can be thought of as mental tokens that "stand in for" (i.e., represent) the things and events that they refer to; things and events that are not immediately available as environmental inputs. Under the Classical view, the mind is a rule-following device, analogous to a digital computer, where the mind is the software and the brain is the hardware – thoughts are based on symbolic representations of things and/or events that are combined and manipulated according to a set of rules (syntax). From this perspective, natural languages (like English, Spanish, Cantonese, etc.) merely translate this abstract inner mental language into a publically expressible format. Cognition is conceived of as a flow of information through information processing devices that encode, store and retrieve symbolic representations of knowledge.

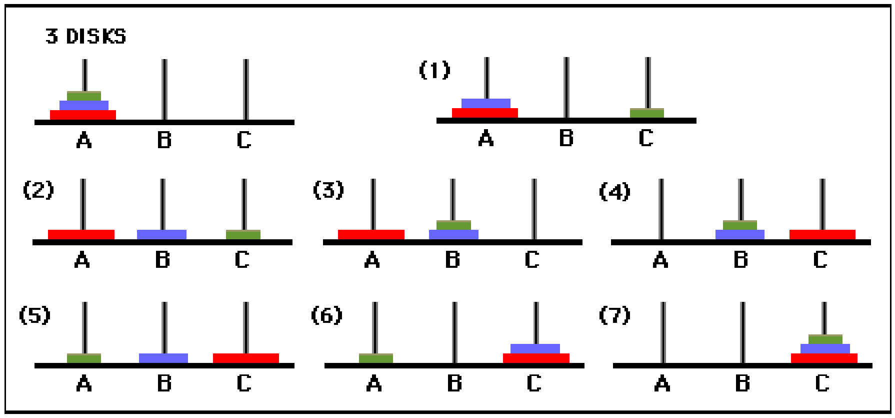
- Thought processes reflect the mental manipulation of **symbols** according to **syntactic rules** for combining those symbols
- Symbols represent our knowledge of things and events (concepts) and our knowledge of the way concepts can relate to one another. Symbols according to rules that allow us to think.
  - Words and numerals are examples of symbols
    - Concept <dog>
    - Properties and relationships <in> <has a…> <not> <and> <or>
    - 1,2,3,
- Syntax = the rules that underlie how symbols can be combined to produce some form of behaviour
- Syntactic rules are the 'program' of the mind expressed in "mentalese" – the language of thought e.g. spoken language is a translation of this underlying symbolic language of the mind
- Natural languages translate mentalese into a publically expressible format
- Is thought possible if I don't have language??? Language is a tool or medium for representing thought. We can have thought without the use of language however, what is this thought like and what are the symbols?
- Classical cognition can be used to model intelligent behaviour
  - Problem solving
  - Reasoning
- The steps we go through to solve a problem can be represented in an explicit symbolic code
  - A series of "if….then…." commands
- Good for formal problems and logical reasoning. These are the kinds of problems that we can programs a computer to do that demonstrate a kind of intelligence in the computer. Is a somewhat limited representation of cognition.
- Bad for perception, action, recognising patterns etc.

Tower of Hanoi Problem



Initial state: Three discs on left peg, placed largest on bottom to smallest on top

Goal state: Move the discs from the left peg to the right peg so that they are arranged in the same way



Rules:

1. Discs are moved one at a time
2. A disc can be moved only when there are no discs on top of it
3. A larger disc can never be placed on a smaller disc

You move through a series of intermediate states as you go from the initial state to the goal state.

The initial state, intermediate states and the goal state make up the 'problem space'.

The best solution requires only 7 moves.

Classical cognition: symbolic representations

Propositional representations – a symbolic code to express the meaning of a particular relationship among concepts

- "the cat is under the table"
- "the table is above the cat"
- UNDER (CAT, TABLE)
- [relationship between the elements] ([subject element],[object element])

The propositional representation provides the basic element (building block) for symbolic representations of knowledge and comprehension processes. The advantage of the propositional approach is that the propositional framework can be used to represent the relationships among semantic elements independently of the specific surface details of a specific utterance, written sentence, or the specific perceptual details of a witnessed event. That is, the propositional framework provides a means to represent the underlying meaning structures, independent of the specific details of the surface structure – and this is said to provide an approximation to the "language of thought" itself.

Propositions:

- Derived from propositional logic
- Express underlying meaning, independent of the specific surface details of an utterance, written sentence, image, or witnessed object/ event

- Abstract, symbolic code, like a mathematical formula
    - Neither words nor images

Composed of the **predicate** and a number of **arguments** (semantic elements)

- Predicate expresses the relationship between elements
- Argument expresses the subject and object elements

Propositions take the form of a predicate-argument schema:

- PREDICATE (argument, argument, argument)
- RELATIONSHIP/PROPERTIES (SUBJECT, OBJECT etc)
- UNDER (CAT, TABLE)
- P (x,y)

Propositions are composed of a ***predicate*** and a number of ***arguments** (or **semantic elements**)*.

The predicate expresses the *relationship between* the elements, or a *property of* the element(s). The arguments represent the subject and object of the sentence.

Propositions take the form: PREDICATE(Argument, Argument, Argument)

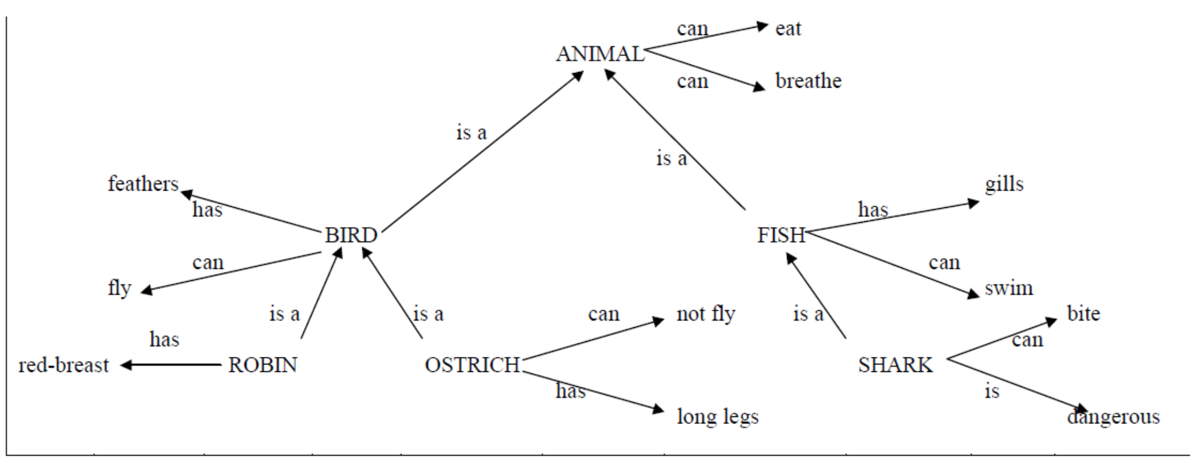
Propositions take the form of a predicate-argument schema - a template that describes a property of a semantic element (object, person, etc), or a relationship among semantic elements. For example, the sentences "The car Jane is driving is blue", "The sky is blue", and "The cover of this book is blue" come from the predicate template "is blue". Similarly the underlying meaning of the sentences "Mary gave the book to John“ and "Jane gave a loaf of bread to Mary“ can be expressed propositionally by substituting the appropriate subject, recipient and object elements for the arguments x, y, and z in the propositional template Gave(x, y, z).

- The same abstract propositional frame/schema can express many different surface forms
- Gave (agent, object, recipient)
    - John gave Mary the book
        - Gave (john, book, Mary)
    - The book was given to Mary by John
        - Gave (John, book, Mary)
    - Kevin gave Julia a kiss
        - Gave (Kevin, kiss, Julia)
- Propositions can be combined to represent more complex relationships

Consider the propositional account of knowledge representation and contrast it with the use of mental images.

The idea that the mind represents concepts and relations among concepts in propositional form is fundamental to the classical computational account of thought/cognition. Propositional statements (taking the form of a predicate and a series of arguments as described in the lecture) are derived from formal logic and mathematics and provide a means for representing concepts and relations among concepts symbolically so that they can be computed according to the rules (syntax) of a programme. In the classical computational account of the mind, propositions are proposed to be the basic elements of thought expressed in a formal language which underlies our natural language statements. This formal language is assumed to be universal to the human mind and to underlie all the variations in natural languages that are spoken by people. A basic proposition such as <happy(John)> (which represents the idea that 'John is happy') can be combined with other propositions according to rules to represent more complex relationships between concepts and their properties, just like words can be combined according to rules to represent/express complex thoughts in our natural spoken languages. Propositional representations are said to be 'symbolic representations' because the propositional statements "stand for" the things they represent in the same way that, for example, x and y are abstract tokens that can stand for numbers in a mathematical equation. According to the computational theory of mind, such propositions represent our understanding of the world symbolically in an abstract language of thought ('mentalese') and are used as the basis for all of our thought processes. The discussion about mental imagery followed this because it was raised in direct opposition to the propositional account of mental representation. Shepard and Metzler showed that the mind does not work exclusively with abstract symbols, but that it can represent objects in the world in a way that is much more directly analogous to the actual sensory experience. Hence the contrast between symbolic representations and analogue representations (think of a clock with hands as an analogue representation of time vs. a digital clock as a symbolic representation of time and this may help you get the contrast that is being drawn between propositions and imagery as symbolic and analogue forms of representation, respectively). According to opponents of the computational account of cognition, thinking about a cat under a table (as in the example used in the lecture) would be achieved via a mental image of the concepts and their spatial relations to each other, rather than by some more abstract formal representation (i.e., a propositional representation) in a language of thought.

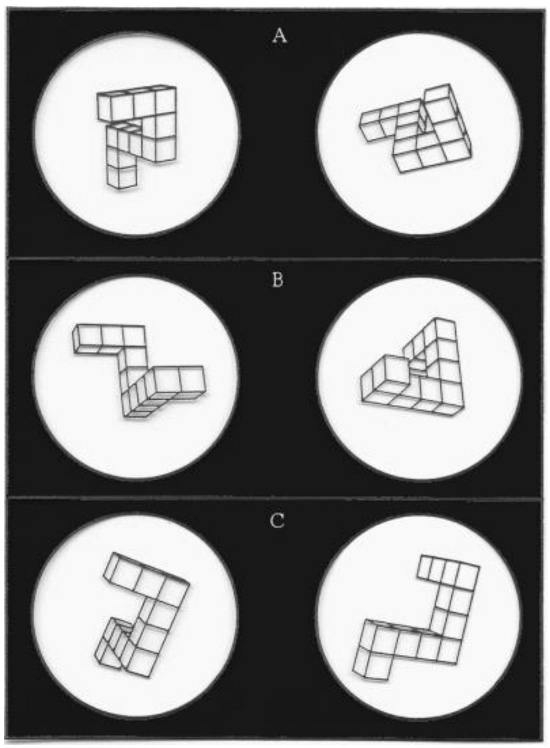
<u>Symbolic representations: Semantic networks</u>

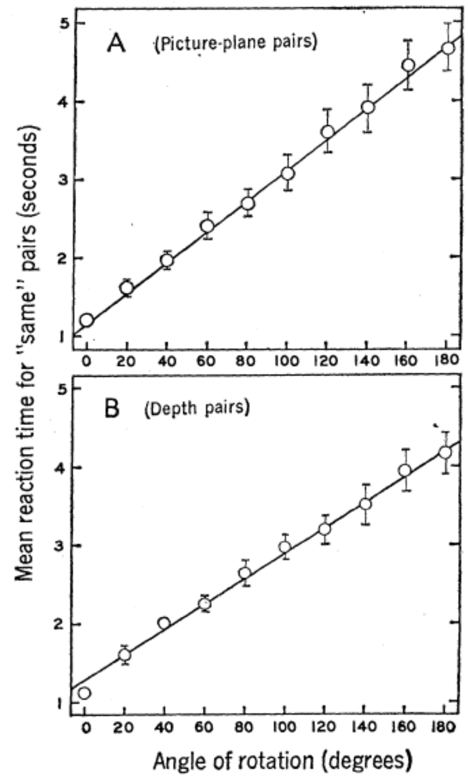


Collins and Quillian's (1969) model of the organisation of conceptual knowledge in the semantic memory system. According to this classical view of semantic knowledge, concepts are coded in propositional form expressing relationships and properties such as "is-a" or "has" or "can" (e.g., a canary "is-a" bird; a canary "has" wings; a canary "can" sing). The model indicates that living things "can breathe" ; that an animal "is a" living thing, that a bird "is a" kind of animal, and that a canary "is a" kind of bird. It follows from the hierarchical organisation of the network that that a canary "can" move around. The canary node inherits this property via its connection to the category of animals and to a still higher category of living things. From Figure 1.2 in Rogers & McClelland (2004). Is our semantic knowledge really represented in this format?

Analogue representations: Mental Imagery and Mental rotation

Shepard & Metzler (1971) presented their subjects with pairs of drawings of three-dimensional, asymmetrical assemblages of cubes, as shown in the figure on the slide. In each pair, the right-hand picture either showed an assemblage identical to that shown on the left, but rotated from the original position by a certain amount (figures A and B), or else it showed an assemblage that was not only rotated, but was also the mirror image of the one to the left (figure C). The experimental task was to indicate, as quickly as possible (by pressing a button), whether the two objects depicted were in fact identical (except for rotation), or were mirror images. The hypothesis was that the task would be done by forming a three-dimensional mental image of one of the depicted objects, and rotating this whole image, in the imagination, to see whether it could be brought into correspondence with the other picture. The experimental results (displayed on the right of the slide) clearly supported this idea, because it was found that the time taken to confirm that both objects of a pair were identical increased in direct proportion to the angular rotational difference between them. It was as if the subjects were rotating their mental image at a steady rate (although this might be different for each subject), so that the further they had to go to bring their image into correspondence with the reference picture, the longer it would take them.





The image on the left of the slide shows some of the stimulus figure pairs used by Shepard & Metzler (1971).
A- Identical objects differing by a rotation in the plane of the page

B – Identical objects differing by a rotation in depth
C – Mirror-image objects (also rotated in depth)

The image on the right of the slide shows the mean response time to judge the objects as the "same".

- The data provide compelling evidence that at least some degree of our cognitive processes are carried out using **analogue representations**, rather than abstract symbols
- Mental images are analogous to what they represent
- We "manipulate" mental images in our minds in a manner analogous to the way in which we might physically manipulate a real object

Shepard and Metzler's data provide compelling evidence that at least some of our cognitive processes are carried out using representations that are based on images that are analogous to the thing they represent, and that we literally manipulate these images in our minds in a manner analogous to the way in which we might physically manipulate a real object.

The Shepard and Metlzer experiment has become one of the best-known experiments in cognitive science. The findings directly challenged the doctrine, still holding considerable sway amongst psychologists at the time, that thought processes depend entirely upon language-like symbolic processes. By suggesting that analogue representations have an important role to play in thinking, the findings raised difficulties for the (digital) computer model of the mind that lay at the heart of cognitive science.

DYNAMIC, EMBODIED, SITUATED COGNITION

Cognition if **dynamic**

- Unfolds over time and space
- Cognition inseparable from sensing, thinking, acting in real time

These relatively recent movements in Cognitive Science represent a strong challenge to the classical view. According to such accounts, Cognition is *situated* and *dynamic* in the sense that it unfolds in time and space and in active interaction with the world – this stands in contrast to the Classical view of cognition as a process of receiving and interpreting input from the world in a way analogous to input being provided to a computer programme.

More broadly, recent movements in Cognitive Science include in the study of psychological processes that have typically been considered to be "non-cognitive", and that have been studied separately from cognition. For example, it is now considered important to include in theories of cognition an understanding of how rewards and punishments, emotion (affect), social interactions, and development shape cognitive processes.

Spivey & Dale 2006

- “real-time cognition is best described not as a sequence of logical operations performed on discrete symbols but as a neuronal activity
- Between describable states of mind, mental activity does not lend itself to the linguistic labels relied on by much of psychology
- Using continuous online experimental measures such as eye-tracking and experimental computer-mouse-tracking (instead of outcome-based measures such as reaction time and accuracy), it is possible to see that mental activity is being conducted in between those seemingly discrete thoughts
- Thus, we argue that cognition is best analysed as a continuous dynamic biological process, not as a staccato series of abstract computer-like symbols”

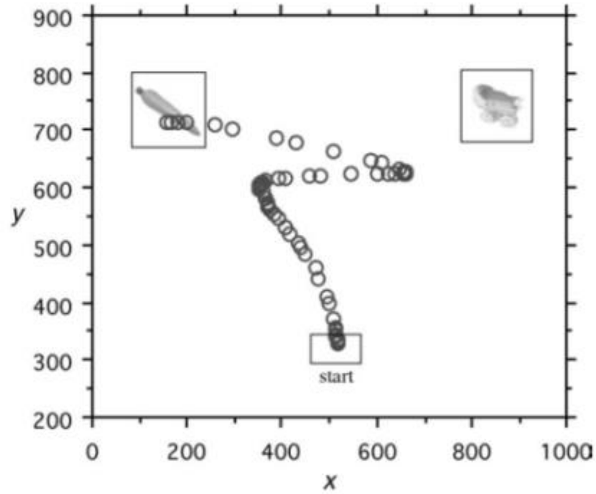


Figure 3.9. Mouse-movement trajectory (in pixels) for “Click the carrot,” with a carriage as the cohort competitor.

Situated, dynamic cognition. In this experiment Spivey et al. (2005) used real-time mouse-tracking to demonstrate categorical decision-making (identification) unfolding “dynamically” (i.e., over time) and inseparably from the perceptual and motor processes that accompanied it – sensing, thinking and acting in a perceptual-cognitive cycle. The image shows the trajectory of the participants responses as they moved the mouse towards the target image “carrot” in the context of a phonologically similar competitor “carriage” provided as a distracter. As the sound of the target item unfolded over time (“c_a –rr_o_t”), the participant’s response shows a diversion towards carriage before settling on a beeline for carrot.

From Spivey and Dale (2006). “Real-time cognition is best described not as a sequence of logical operations performed on discrete symbols but as a continuously changing pattern of neuronal activity. The continuity in these dynamics indicates that, in between describable states of mind, mental activity does not lend itself to the linguistic labels relied on by much of psychology. When the state of the system travels toward a frequently visited region of that space, the destination may constitute recognition of a particular word or a particular object; but on the way there, the majority of the mental trajectory is in intermediate regions of that space, revealing graded mixtures of mental states......However, when you look more closely, especially with continuous online experimental measures such as eye-tracking and computer-mouse-tracking (instead of outcome-based measures such as reaction time and accuracy), it is possible to see that mental activity is also being conducted in between those seemingly discrete thoughts. Thus, we argue that cognition is best analyzed as a continuously dynamic biological process, not as a staccato series of abstract computer-like symbols”

Cognition is **embodied**

- Our embodies interactions with the world provide the basis for higher level thought processes
- Our knowledge is grounded in physical interactions with the world

- Metaphors
    - E.g. to solve a problem in our minds we search through a mental problem space, as if searching a physical environment
    - Justice = balance; love = warmth

Cognition is *embodied* in the sense that it is our bodies and their relationship to the world that provide the information to be represented. That is, in the process of thinking about something, of perceiving something, we gain knowledge of ourselves in relation to the object of attention as well as knowledge about the thing itself. For a simple example, thinking about the concept <u>big</u> has meaning only in relation to <u>small</u>, and both concepts are defined relative to our own embodied and situated interactions with the world. Lakoff and Johnson have famously detailed the way in which our abstract concepts, such as justice and love, are grounded in physical metaphors. We talk of balance in relation to justice, and warmth and strength in relation to love.

Cognition is **situated**

- We structure the physical environment to support our cognitive processes
- E.g. we lay things out in physical spaces to help us think about how to organise our ideas
- Use lists to prompt memory etc

The DES approach to cognition also emphasises the role of development, social interactions and emotions in supporting higher level cognitive processes.

<u>Rodney Brooks</u>

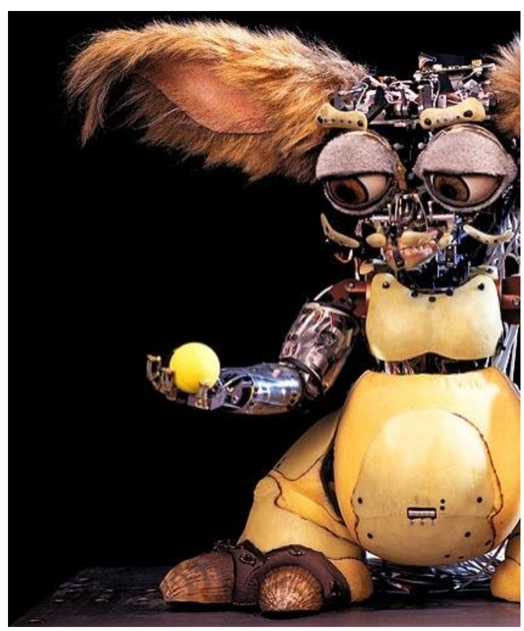
- Began his artificial intelligence projects with simple robotic systems designed to navigate environments
- These "mobots" were modelled on insects
- They sense their world and adapt to changes in their environment
    - These are the foundations of cognition

The robotics projects at Massachusetts Institute of Technology (MIT) provide a clear example of how our theories of cognition change when we take embodiment, situatedness, social interaction, emotion, and development seriously. The programme is headed by Professor Rodney Brooks. Brooks has been at the forefront of developing adaptive robots, where his basic approach is to "build cognition from the ground up". Rather than starting with representations inside the head that are encoded as explicit data structures in a pre-programmed memory, Brooks starts with basic sensory and motor systems, coupled with some sensitivity to social and emotional cues (such as tone of voice and facial expression) as a means to drive ongoing learning in real time

One of Brook's first mobile robots ('mobots'), Herbert, was designed to pick up empty drink cans lying around the lab. In this case, the drink-can-littered lab provided a "niche environment" to which Herbert was adapted as a simple artificial animal foraging for cans. The mobot had no central programme to guide its behaviour, just a set of on-board sensory devises (e.g., video camera, sonar, touch sensors), and three layers of "competing behaviours" that were triggered selectively by environmental inputs. For example, the mobot was equipped with a ring of ultrasonic sonar sensors that cause the mobot to stop if an object is detected in its path and then to reorientate. A second layer of it's architecture allows it to "wander". The wandering routine would be interrupted if a table-like outline was detected by its simple visual system (cameras). Once beside a table, Herbert then visually swept the table with a laser and a video camera. Once the basic outline of a can was detected it would rotate itself until the can was in the centre of its visual field and then the robot arm would activate. The arm, equipped with simple touch sensors, would then explore the table surface ahead. When a can shape was encountered it would close its grasp and then move on. The alternative classical approach to such a task would involve complex stored programmes for planning behaviour, represented as explicit production rules (i.e., "if-then" statements). All of the work would be done "in the head" first, and then executed. Herbert in contrast solves its problems "online" using its simple onboard sensors and its ongoing exploration of the environment. Robotics has to date addressed mainly very basic, low-level cognitive phenomena like sensory-motor coordination, perception, and navigation, and it is not clear how the current approach might scale up to explain high-level human cognition.

In a slightly more complex vein, the addition of an emotional/reward system and social interaction (as in the more complex social robots like Leonardo, see following slide) starts to provide us with a plausible insight into the cognitive processes of many animals. It is easy to imagine many other species managing goals, perceiving and categorizing the environment, generating simple inferences about what will happen next, performing actions based on previous rewards, and experiencing affect (emotion) in response to the outcomes of those actions. Understanding this particular set of coordinated processes may represent the core component of intelligence that evolved into human intelligence. Because of this, Brooks and his colleagues argue that rather than trying to understand the most advanced human abilities first, such as logic and mathematics, it might make more sense to understand how these advanced abilities are built upon more basic abilities that existed previously........The interesting question is how our advanced symbolic reasoning capacities evolved from and develop out of these more basic interactions.

LEONARDO THE SOCIAL ROBOT



The MIT lab's "social robots", Leonardo (named after Da Vinci). This is the work of Dr Cynthia Breazeal who works with Professor Rodney Brooks………Here is a description of what is happening with Leonardo, adapted from Barsalou, Breazeal & Smith (2007) "Cognition as Coordinated non-cognition." Cognitive Processing 8: 79-91. "When the robot encounters a novel object (the plush toy), **the robot's object appraisal mechanism tags the object as novel**, **which biases the emotion system to evoke a state of mild anxiety**. The robot's face expresses a state of heightened arousal as it looks upon the novel object. The robot also looks to the human's face to "soothe" itself. The human tends to react in naturally instructive ways. The human may notice the robot's initial reaction to the unknown object and decide to familiarize the robot with it. For example, the human may pick up the object and share her reaction to it with the robot. **The robot's attention system determines the robot's focus of attention, monitors the attentional focus of the human, and uses both to track of**

the referential focus (the object that the interaction is about). For instance, the robot looks to the human's face, thereby allowing the robot to witness her emotional response, and then looks back at the novel toy to share attention with her about the referent. The fact that the human is gazing and reacting toward the novel object draws the robot's attentional focus to it as well. As the robot's attentional focus shifts to the human (while maintaining the novel object as the referential focus), **the robot extracts the affective signal from the human's voice by analyzing her vocal prosody for arousal and valence levels**. The **empathic mechanism** (mimicking the human's facial expression to simulate the emotion in itself) enables the robot to also extract the affective meaning from the human's facial expression. **The resulting change in the robot's internal affective state triggers a remembering process that establishes a memory of the new object, tagged with the robot's affective state**. **Thus, the novel object is appraised with socially communicated affective information and committed to long-term memory".**

- Object appraisal mechanism tags objects as novel
- Triggers mild anxiety response and expressions
- Promotes a human response to emotion
- Attentional system monitors human facial expressions and looks back to object – sharing attention
- Picks up signals from tone and voice
- Empathic mechanism mirrors human facial expressions to simulate emotion in itself
- Change in emotional state triggers long-term memory response for object, tagged with socially referenced emotional information

Symbol grounding

- Conceptual abstract knowledge must be **grounded** in our perceptions and interactions with the world
- There is a fundamental relationship between cognition, sensation, perception and emotion
    - I ***feel/sense***, therefore I think

One of the strongest criticisms of the classical view is that it provides no account for how symbols are learned. We are not born knowing about all the different kinds of things that exist in the world and the relationships between them. Our conceptual knowledge must be "grounded" in our bodily interactions with the world and our perceptions – things that cause us to feel (sense and perceive). Cognition must also be grounded in developmental, bodily (sensory-motor), and social interactions. One of the challenges for the classical view is to provide an account for how symbolic representations are grounded in more basic perceptual and motor interactions with the world. The Dynamic, Embodied, Situated approach to cognition provides some solutions to this.

A hierarchy of representations

- Mental representations form a hierarchy:
    - Sensory-base representations (war, red)
    - Image-based representations (relations between elements)
    - Propositional/linguistic representations
- Representations become increasingly independent of the environmental stimuli they represent
- Symbolic representations are "grounded" in sensory, perceptual and emotional representations derived from experience with the world