The Relevance of Mathematics to Brain Functioning

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How does the brain:

- *process language*
- *do science and maths*
- *control rock-climbing*

etc.?

(brain = neurons + modifiable synapses)

basic concepts used:

- hyperstructure theory (N A Baas)
- relational methods (A Ehresmann)
- specialisation and ‘representational redescription’ (A Karmiloff-Smith)

Some standard answers:

1. look at the architecture of the nervous system, discover what each part does

Problem: the approach is a qualitative one, accounts for performance but not good performance

2. neural network models account for skill acquisition

Problem: doesn’t work for complicated skills

This approach:

1. theory of specialisations and their combination

2. ‘reference’ accounts for higher level skills such as planning, thought and language.

Specialisations

1. Assume we have circuitry specialised to deal with a large range of types of situation, including creation of new types.

2. Generate everything from this.

Note: this is how the body works, so this is less implausible than it may seem. But how can this work?

1. consider a particular type of entity (e.g. a physical object or a step forwards)

2. this can be abstracted out as some fixed collection of variables (e.g. the size and direction of a step, the force that needs to be applied).

3. from these we can create a theoretical model that is universal for the type of situation concerned (e.g. the process of moving an object)

4. this implies the possibility of a general solution to problems of the given type (e.g. how to keep balance).

5. we assume that nature has evolved mechanisms that do this for a range of different types of situation (e.g. balance, taking steps, controlling direction).
[computers provide illustrations, e.g. ‘login’ situation]

Relationships

hypothesis:

1. learning in a given type of situation is essentially learning specific relationships pertinent to the desired outcome

2. to do this the hardware needs to do things like make links between active systems, or adjust parameters of active systems

3. this argues for very specific architectures with particular connections being ready to be made on command in specific circumstances (thus lots of evolved special circuitry)

Illustrations of the relationship theme

1. motor output for turning is related to amount of turn needed

2. the position of a fixed object is related to the object

3. in a given context, the thought behind a word is related to the word that expresses it

4. in an X-bar construction, the position of a word relative to the head word indicates its role

Making this realistic

1. A given model may have only a restricted range of validity. Hence create a collection of modules each with its own domain of validity (paradigm), discovered by trial and error (e.g. one module for ordinary walking, and a different one for walking on ice).

2. The whole possibility of there being a universal model for situations of a given type is a function of prior learning. Example: the appropriate model of walking for someone who can't stay up very well or control direction very well (e.g. through excessive ingestion of C_2H_5OH) is a lot more complicated than for someone who has such control. The way to express this idea formally is to say that earlier developmental processes make certain facts true which make simplified models for other processes valid (Baas hyperstructure concept).

3. Even then, many problems may be encountered, so we need additional specialised devices to handle typical problems so mature, wide-ranging capacities can develop.

NB: an interrupt mechanism is needed to ensure that an interrupted process is resumed when the interruption has been handled. This could be handled by creating a new context consisting of an anticipated future state defined by the interruption being dealt with and the original task being resumed.

The 'life cycle' of a module

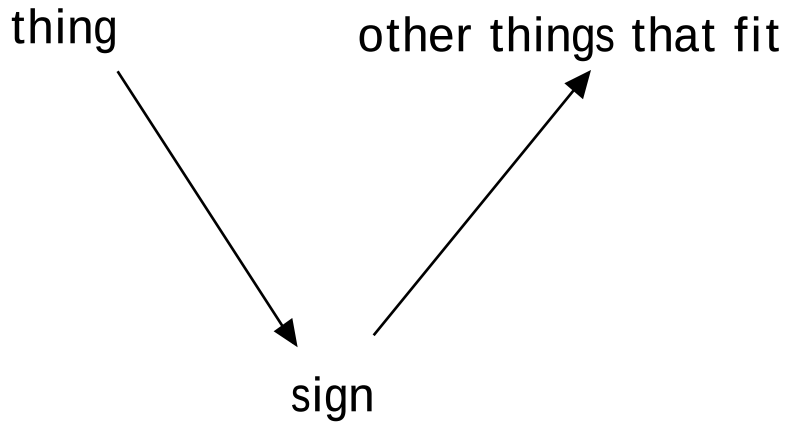
◇ *activation*
◇ *investigation*
◇ *learning*
◇ *confirmation 1*
◇ *paradigm establishment*
◇ *utilisation*
◇ *confirmation 2*
◇ *life benefit*

Where we have got so far:

lots of special devices that nature has discovered for getting good at particular things, all linked together in such a way that when one skill has been acquired another can exploit the possibilities it allows

but what tricks can make something like <u>language</u> work?

Answer: <u>reference and dereference</u>



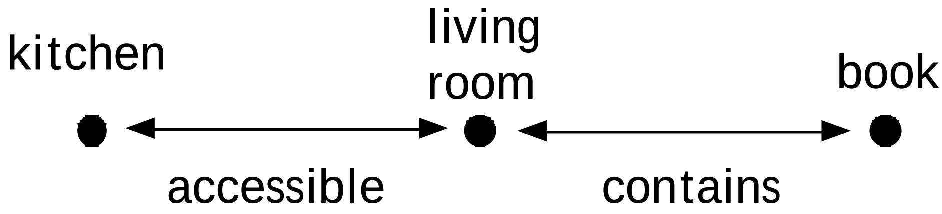
By referring to situations, signs are able to create situations

the conditions (paradigm) over which a creative process will work are investigated, making available a paradigm for its use

(where ‘that’ translates into a sign for some object; ‘get’ etc. are ‘native’ signs capable of activating a corresponding activity)

combinations of signs, e.g. ‘get that’, ‘avoid that’, ‘move that over there’ ‘the book is on the table’ referring to actions or information that might be relevant in the circumstances, are generated naturally. They can be evaluated, acted upon, bound to a context and so retrievable later …

in other words, there is some ability to ‘think’, which can be tried out by exploring the potentialities of the resulting thoughts. Storing the information as links creates a ‘cognitive atlas’ built up out of a set of individual cognitive maps. A map (or semantic network) is a set of links referring to what can be done in a given context; these can be tested for their validity (confirmation 1). The maps can then be used. After this has been achieved the maps can be used ‘out of context’, i.e. for planning.



(i) on going from kitchen to living room we create an ‘accessible’ link
(ii) on seeing that the book is in the living room we create a ‘contains’ link
(iii) when we want the book we run a mechanism that sees that the living room is a container for the book, and then one that sees that the living room is accessible
(iv) the thought ‘go to living room’ is then created and executed
(v) in more complex situations, that thought would create further thoughts and we’d get a recursive situation

This requires a certain amount of neural circuitry, but it seems necessary for sensible behaviour to emerge. One needs basic thinking apparatus, i.e. a system that can represent and use ideas, to achieve human intelligence.

One assumes that such planning operations can be cascaded: what stops this process from going to far is the process that prefers processes that deal with real problems, so that planning (like computers) is primarily a tool rather than a toy.

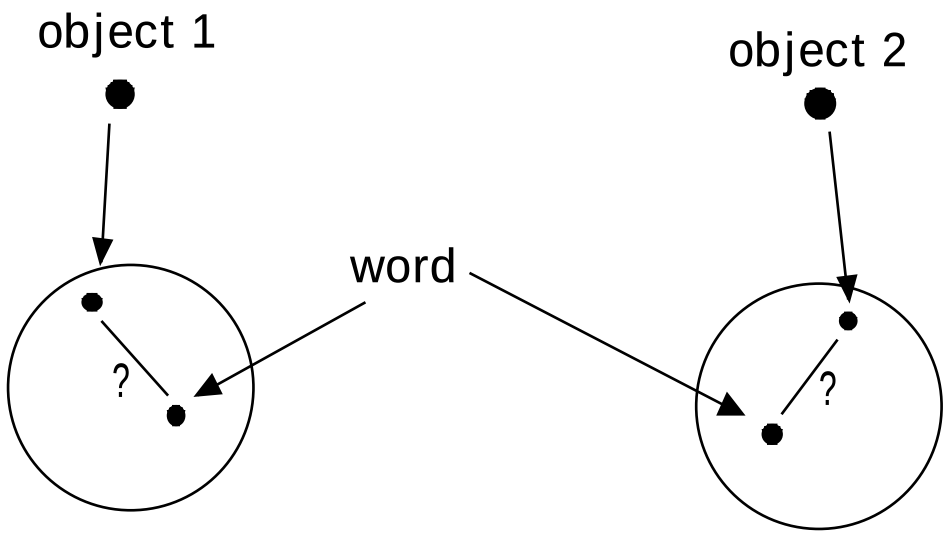
We learn what thoughts make sense, and are useful, and then make use of them.

Language can pin down useful thoughts and the most useful of these get transferred through the culture.

Thoughts get elaborated just because we keep encountering situations where more thoughts are needed, and store them in relation to a context which is itself evoked by thought.

Language is now treated as a further coding mechanism with systematic relationships created between word-like entities and thoughts, and with the things that the thoughts refer to.

1. The inventor/instructor uses a word or word sequence linked to some thoughts. The listener has the task of determining what thoughts are linked to the words and how, which can be done in stages, and taking advantage of other indicators of what the thoughts are (types and content). If the connections made correspond, the communication is successful and the relationships employed are stored as links.



If object 1 = object 2, communication is successful and we strengthen the links, otherwise we let them fade away.

With groups, position in group is linked to role.

2. the links are then <u>used</u> and more elaborate possibilities developed, largely by paradigm expansion, i.e. existing lexical items and structures have new possibilities assimilated to them. The possibility of a complex idea being treated as a single thought leads to hierarchical structures.

3. grammatical types help the listener's parsing process, which is essentially collapsing sign clusters into a single entity. The construct in the theory that accounts for this is the concept of 'recognising where one is an a linguistic process', or in other words being somewhere in the part of the cognitive atlas relating to language activity. With linguistic activity two dimensions of location are involved, where one is in the context of using language and where one is in the context of what is being referred to. The combination is used to direct the comprehension process.

How to make a brain?

1. Decide which types of things are going to be dealt with
2. Create circuitry adapted to these types and designed to create outcomes relevant to other type
3. Link all the circuits together in an appropriate manner
4. Set up arrangements relating to the 'life cycle'
5. Set up reasonable contexts for each process to occur
6. Start the system going and stand back!