Shape up, baby!

Perception, image schemas, and shapes in concept formation

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Abstract. Embodied cognition has emphasised the importance of sensorimotor processes for concept formation. According to this theory, image schemas are suggested to be a cognitive representation of certain basic spatial relationships. At the same time, the shape of objects is essential for categorisation and understanding. While information on both shapes and image schemas are primarily obtained through visual perception, their cognitive nature differs. Shape is an attribute of an object, whereas an image schema is a basic spatial relationship between (several) objects in a particular environment and context. We here discuss interdependencies between these two modes of perception with regard to their roles in concept formation.

Keywords. concept formation, image schemas

1. Introduction

When a child is born, it is immediately exposed to a complex world and, as a result, cognitive and conceptual processes start to take form. Eventually, the child becomes so familiar with objects and their behaviour in the environment that it successfully learns to categorise perceived objects and understands their purposes, roles, and affordances (in the sense of Affordance Theory [6]). Exactly how this process of concept formation occurs remains controversial.

Embodied and grounded cognition theory identify the sensory/motor system as the prime source for cognitive development [1, 24]. The theories argue that it is through an agent's experience with the environment that her concepts and understanding emerge. This theory has been corroborated by findings in cognitive linguistics, psychology and neuroscience (e.g. [25, 5, 4, 26, 12]).

2. Concept formation

Developmental psychologist Jean Mandler [15] investigates cognitive development and concept formation in the 'sensorimotor period' (as introduced by Piaget [21]) during early infancy. In the paper series *How to build a baby I, II & III* [13, 14, 16], the author

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studies how perceptual information gives rise to conceptual understanding. Mandler points out that while shape is important for categorisation, it (typically) does not explain in itself what the object *is* (i.e. a particular shape might be a typical but not an essential property of an exemplar). This discrepancy between perception and conceptualisation is further developed in [18], where she distinguishes two cognitive processes that take place during concept formation: perceptual and conceptual processes.

2.1. The perceptual process

The first, the *perceptual process*, is seen to be responsible for *object categorisation* based on similarity. As pointed out above, the shape of objects plays a central role here. For example, infants can early on distinguish between animals such as dogs and birds, but it takes much longer before they consistently and correctly categorise and distinguish between animals exhibiting greater similarity such as cats and dogs [20].

There are a few theories that aim to explain perceptual categorisation. One of these is the *Prototype theory*, which hypothesizes that all object categories are build from prototypes derived from experience [23]. Perceptions are categorised into a particular group if they sufficiently resemble the prototype. An example is 'dog'. There are many dog breeds that often greatly differ visually from each other. Still, (in most cases) people can intuitively relate instances they encounter, to the abstract version of their 'prototypical dog'.

Similarly, an influential theory explaining *object recognition* is the *Recognition by components* theory [3]. Here, all (concrete) objects can be taken apart into a limited set of simple geometric shapes, called *geons*[2], and it is the combination of these shapes that defines the object. An example is how a coffee cup could be defined as a hollow *cylinder* with *handle* on one side. This can be extended to more complex objects. E.g., the 'prototypical dog' from above might be a particular construction of a *cylinder* for a torso, four *expanding cones* representing legs, an *expanding handle* for a tail and an *ellipsoid* for a head. Each of these parts can be divided to capture more details, e.g. *cones* for ears, creating a more detailed spatial description and/or ontology based on geons.

However, the visual description does not, as Mandler pointed out, in itself carry the nature of the object. To ascertain affordances of an object, such as a coffee cup, where the capability to *contain* liquids is paramount, a different approach is required.

2.2. The conceptual process

The second component of Mandler's notion of concept formation is the *conceptual process*, during which the purpose and usage of objects are established [18]. Here, the role of shape and visual characteristics is less clear, and instead affordances of the objects play a central role.

While embodied cognition theory has found increased support, one remaining problem is the connection between the embodied experience and its mental representation.

Research on image schemas aims to address this problem, and to approach the conceptual process as a whole. It was introduced by Lakoff [11] and Johnson [9] in the late 1980s and has become an important field of enquiry in linguistics, psychology, and computational concept invention.

[2]Examples are cones, cubes and spheres.

Image schemas are defined as conceptual building blocks and capture abstracted patterns of spatial relationships learned from sensorimotor experiences. Often mentioned examples of image schemas are: CONTAINMENT, the notion that objects can be within borders or inside other objects; SUPPORT, the notion that objects can rest on other objects; and PATH, the notion of movement, often implying directed movement along a particular path.

One of the most important aspects of image schemas is how they can be seen as 'abstractions that model affordances' [10]. To illustrate this point, Kuhn demonstrated how (some) concepts could be broken down to their core by using image schemas. For example, the concept of 'transportation' may be described as a combination of PATH and SUPPORT (alternatively CONTAINMENT). In a similar fashion, Mandler proposed that 'marriage' could be viewed as a LINKED_PATH—the combination of the image schemas LINK and PATH [15]. Naturally these concept contain more information, but the image schemas model the conceptual skeleton.

Returning to the coffee cup. The most prominent and important image schema involved for a cup is the CONTAINMENT schema. If the cup is leaking, or for any other reason does not have the CONTAINMENT schema, the 'cup' is useless. Naturally, it is important that the cup has the prototypical 'coffee cup' shape for it to be classified as a coffee cup; otherwise objects such as 'glasses', 'houses' and 'cars', also capable of CONTAINMENT, could be classified as a cup. Clearly, visual characteristics are important alongside CONTAINMENT. However, in a situation where there are not enough coffee cups for all guests, a container such as a glass or a bowl, would be a better substitute, than an object without the CONTAINMENT capability. Arguably, both glasses and bowls visually resemble coffee cups, but so do flower pots. While flower pots also are capable of CONTAINMENT, as their purpose is to contain soil and plants, they are constructed to let excess water flow through. Serving coffee in such an object, becomes, if not impossible, inconvenient for the guest.

Clearly both visual characteristics and affordances play an important role for the nature of concepts.

3. Image schemas

Looking a bit closer at image schemas, they offer a tool to pin down cognitive phenomena, such as language, understanding, and reasoning, in the embodied experience. They offer a connection between externally experienced relationships of physical objects in time and space with the internal conceptual world of an agent. In natural language, they often constitute the conceptual components for metaphorical and abstract thought.

The cognitive benefit of image schemas lies in their generalised nature. Via analogical transfer, abstract information can be used in order to explain unknown objects and processes. Moreover, they can function as a conceptual framework when forming new concepts (discussed in more detail in [8]). For example, if the notion of CONTAINMENT has been learnt by observing water in a glass, an infant can also infer that coffee can be in a cup, and from this build a concept of 'container for liquids'.

It is through such analogical inferences that abstract concepts are thought to be explained. Expressions such as "life is a journey" conceptualize the passing of time as movement along a PATH, and "to fall into a deep sleep" illustrate how the mental state of unconscious rest is conceptualised as a form of CONTAINMENT.

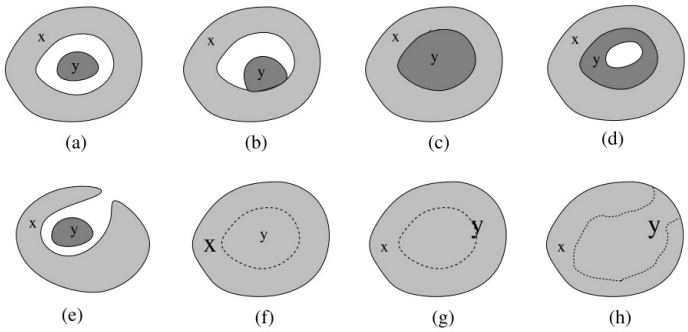

Figure 1. The eight variations of Containment discussed by Bennett and Cialone.

3.1. The shape of image schema

Image schemas are abstract in nature and are therefore 'shapeless' in essence. Yet they are learnt through perceiving shapes and relationships between objects. For

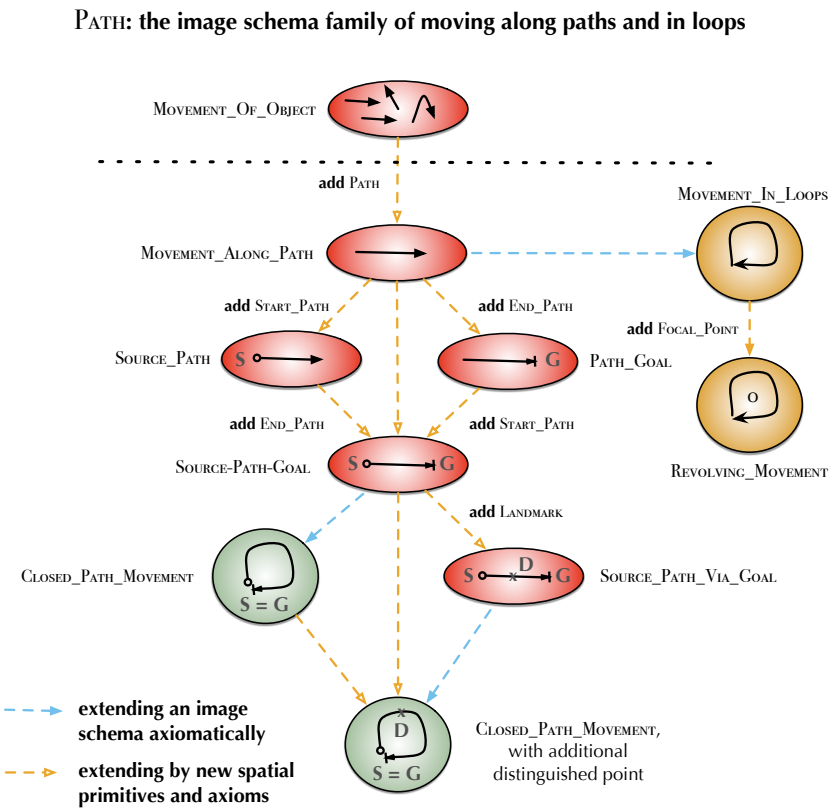

Figure 2. A portion of the Path-following family, presented as a DOL, Distributed Ontology Language, graph.

example, infants appear to learn CONTAINMENT by focusing on objects that enter and exit containers [19], rather than by directly perceiving an 'outside-border-inside' relationships [11]. This image schematic generalisation is made instead by merging a multitude of different CONTAINMENTS: 'liquid in a glass' implies a tightly fitted container, 'being inside a house' demonstrates a loosely fitted container, 'eating food' displays a seemingly bottomless container and object such as flower pots and colanders illustrate containers that intentionally leak liquids. Obviously, there is a multitude of different kinds of CONTAINMENT, yet, the 'shapes' of these are often disregarded in image schema research.

Bennett and Cialone performed a linguistic corpus analysis on the image schema CONTAINMENT in order to investigating the shapes of image schemas in a reverse engineering fashion, i.e. from language to generalised image schema notions [2]. They distinguished no less than eight different CONTAINMENT schemas from natural language (see Figure 3).

Similarly, Hedblom et al. visualised image schemas as a series of theories of increasing complexity [7] (see Figure 3). They aimed to explain how image schemas become more fine-tuned in cognitive development as a result of a complex environment [17, 22], by using the PATH-following image schema as evidence.

4. Outlook

This short contribution aimed to discuss the relationship between perceptual and conceptual processes in concept invention, in particular regarding shapes and image schemas.

Shape appears to occupy a central role during concept formation [18]. In the perceptual processes of concept formation, shape is of great importance for the categorisation of objects, but regarding conceptual processes, has often been neglected. However, image schemas have been suggested to play a pivotal role as the conceptual components that model affordances.

While image schemas are abstract and 'shapeless' in essence, they are still drawn from perception and embodied experiences, where shape is important. Additionally, one kind of image schema appears to exist in different constructions. Therefore, it follows that the shape of image schemas needs to be considered when speaking of the conceptual processes in concept formation.

The concluding remark for future research is that while performing research on concept formation, in particular the conceptual side thereof, shape considerations should play a more important role than previously considered.

Acknowledgements.

The project COINVENT acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the Seventh Framework Programme for Research of the European Commission, under FET-Open Grant number: 611553.

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