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Research article

A narrative in three acts: Using combinations of image schemas to model events

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ABSTRACT

Image schemas have been proposed as conceptual building blocks corresponding to the hypothesised most fundamental embodied experiences. We formally investigate how combinations of image schemas (or 'image schematic profiles') can model essential aspects of events, and discuss benefits for artificial intelligence and cognitive systems research, in particular concerning the role of such basic events in concept formation. More specifically, as exemplary illustrations and proof of concept the image schemas Object, Contact, and Path are combined to form the events Blockage, Bouncing, and Caused_Movement. Additionally, an outline of a proposed conceptual hierarchy of levels of modelling for image schemas and similar cognitive theories is given.

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Introduction

Already remarkably early during their cognitive development, children are able to reason about cause and effect on object relations and can also conceptualise simple events (Sobel & Kirkham, 2006). This capacity comes about long before the development of language, and before both social or mathematical understanding becomes part of the individual's capacities. Even in the first stages of cognitive development humans are capable to predict the outcome of objects' interactions in simple events. For example, a child early on registers that dropped objects will fall to the floor. It seems absurd that this realisation might be based on a sufficiently complete mathematical understanding of the physics behind gravity (the presence of which is quite doubtful even in grown adults). Instead, the prediction is more likely rooted in a simplified conceptualisation of gravity, or rather, the experienceable effects of gravity learned by some form of 'statistical inference' conducted over the child's sensorimotor experiences and relevant observations from the environment.

Embodied theories of cognition aim to explain how this type of conceptualisation comes about, emphasising sensorimotor processes as a crucial foundation of cognitive development and concept formation (Shapiro, 2011). At present it remains largely unknown how this supposed embodied experience manifests in detail, for example whether as mental representations (Barsalou, 2008) or as neural activations in corresponding areas in the sensorimotor cortex (Gallese & Lakoff, 2005). Still, whilst there are conflicting views regarding to which degree cognition indeed is or has to be embodied, there is growing agreement that in practice the body's interaction with the environment is a determining factor in the development of an understanding of the world and in the emergence of concepts. This position receives increasing support by independent findings from several disciplines, including cognitive linguistics, psychology, and neuroscience (cf., for instance, the work by Feldman & Narayanan, 2004; Louwerse & Jeuniaux, 2010; Tettamanti et al., 2005; Wilson & Gibbs, 2007).

Already for reasons of reasoning and representation efficiency—as well as due to the expectable complexity of a theory formation process based on observations from the environment, rather than on experimentation in a scientific setup—it appears unlikely that embodied experiences would mentally manifest as full-fledged theories, in a mathematical sense modelling and explaining the underlying physics of object manipulation. Instead, it seems much more plausible to assume that embodied experiences are used as basis for an abstraction process into generic building blocks, discarding much of the instance-specific and fine-grained information. One approach that aims to capture these abstracted experiences is the theory of image schemas (see Hampe & Grady (2005) for an overview). It suggests that (part of) the embodied

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experience can be explained using a set of spatio-temporal object relations, with CONTAINMENT, SUPPORT, LINK and PATH-following serving as classical examples. These and similar image schemas are then investigated, amongst others, in how they manifest in psychological development (Mandler, 2004) and language constructions and acquisition (Hampe & Grady, 2005). Also, for Oakley (2010) 'image schematic profiles' represent how conceptualisations of events can be described using combinations of image schemas.

Starting out from a similar intuition, the present article constitutes a first step in the investigation of the process with which image schematic abstractions can, when combined with one another, actually model simple events (formally). This question is approached from a conceptual level, but also from a formal and computational level with the motivation that modelling image schematic combinations may aid the development of event comprehension in artificial intelligence (AI). For this purpose, the already mentioned PATH-following schema (hypothesised as one of the most basic image schemas) is combined with other basic image schemas to illustrate how a conceptualisation of events such as 'blockage', 'bouncing' and 'caused movement' may develop. In the next section, "Theoretical and conceptual foundations", we summarise essential parts of the theory of image schemas and clarify some basic concepts relevant in the context of this article, as well as in the study of image schemas in general. Building on these conceptual foundations, the section "Formally combining image schemas" then presents the main contribution, namely a (computationally usable) formal model of the combination of several primitive image schemas into a more complex schema. Also, and of equal importance, an initial proposal for a hierarchy of several different levels of models (corresponding to different granularities of conceptualisation and explanation) for notions from the context of cognitive theorising, such as image schemas and similar phenomena, is put forward. Section "Conclusions and future work" then concludes the article, summarising what has been achieved and outlining future work towards a comprehensive formal and computational theory of image schemas applicable also in AI and cognitive systems.

Theoretical and conceptual foundations

In this section, we introduce the necessary concepts from basic image schema theory as developed in previous studies on image schemas, and also clarify the intended meaning of several central notions relevant in this context. Before focusing on image schemas proper, we therefore start with a working definition of the notion of "event".

Conceptualising "events" in the context of image schemas

Throughout this article, events are to be understood as defined, for instance, by Galton (2012). For our purposes an event therefore "*(...) is a temporally bounded occurrence typically involving one or more material participants undergoing motion or change, usually with the result that at least one partipant [sic!] is in a different state at the end of the event from the beginning*".[1] This notion of event is also well-suited to an embedding in the context of narratives (which are to be understood as reports of connected events presented in a sequential manner as mental images, written or spoken words, visual scenes, and/or similar), particularly when allowing for participants that only exhibit a 'derived materiality'. Precluding the more detailed introduction of image schemas in the following section, this is of importance since in the context of cognitive development and concept formation, Mandler and Pagán Cánovas (2014) also conceptualise image schemas from a narrative perspective (and locate them within a conceptual hierarchy of increasingly complex mental constructs): "*Spatial primitives are the first conceptual building blocks, image schemas are simple spatial stories built from them, and schematic integrations use the first two types to build concepts that include non-spatial elements.*"

Introducing image schemas

Simply put image schemas are thought of as generic pre-conceptualisations that allow us to mentally structure our experiences and perceptions. Supposedly learned from embodied experiences they are often spoken of as object relations situated within a spatio-temporal dimension.

Important parts of the intuitions and conceptual ideas underlying image schemas can be traced back already to, amongst others, the notion of the Kantian 'schemata' (Kant, 1998). In Kant's theory of schemata, the idea of how non-empirical concepts could be associated with sensory input was introduced. In the first half of the 20th century, Piaget (1952) then looked at human development from infancy to adulthood. According to Piaget, cognitive development goes through four stages before reaching maturity. The first of these is the "sensorimotor period" in which cognitive understanding emerges from sensorimotor experiences. This research hypothesis lies at the foundation of embodied theories of cognition (Shapiro, 2011). In the 1970s, cognitive linguistics and psycholinguistics gained influence in the cognitive sciences and became increasingly connected to theories of embodied cognition as the spatial nature of language was brought to light. During the last decades, eventually research methods from neuroscience became increasingly important in answering questions regarding cognitive phenomena, amongst others further supporting the main ideas of embodied theories of cognition (cf. Aziz-Zadeh & Damasio, 2008; Feldman & Narayanan, 2004; Gallese & Lakoff, 2005, amongst others).

Against this backdrop, the theory of image schemas was developed and introduced by Lakoff (1987) and Johnson (1987) simultaneously. Tying back into Piaget's aforementioned theories about development during the sensorimotor period, image schemas are thought to develop in early infancy, as the body physically interacts with and perceives its surroundings. A paradigmatic example is the VERTICALITY (or the UPDOWN) image schema. It is thought to develop as a result of the body's own vertical axis (Johnson, 1987). Still, as already stated previously, whilst children quickly learn to predict that objects will fall when dropped—a process spatially unfolding mostly in the vertical dimension—, it is unlikely that they have gained understanding of the physics behind gravity in any mathematical sense (i.e., having developed a mathematical theory of gravity and corresponding force dynamics). Instead it is suggested that the abstracted information presented in image schemas is the cognitive component with which infants make predictions about the world.

Image schemas are often confused to be abstract visual representations, partly due to the (somewhat unfortunate) terminology and partly due to the proportionally high representation of vision in our perception. However, as Oakley (2010) points out, "*image schemas are neither images nor schemas in the familiar sense of each term as used in philosophy, cognitive psychology or anthropology*". Instead, in the same way that embodied experiences are multimodal, so are image schemas. For instance, auditory experiences appear more abstract and have therefore a distinct logic and different expressions than the ones found solely in vision and more

[1] The precise ontological nature and status of events has for a long time been, and still is, an open question and lies outside the focus of the present article. We direct the reader, for instance, to Bach (1986) for a classic account on the classification of events and their internal structure. Alternative proposals have also been made by Mourelatos (1981), Mani, Pustejovsky, and Gaizauskas (2005), and van Lambalgen and Hamm (2005), amongst others.

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