Linking Image Schemas with Affordances: An Ontological Approach

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Abstract. Affordances and image schemas are two building blocks of cognitive and behavioral modeling. In this paper, we present initial steps towards an extension of our dispositional view of affordances and effectivities to image schemas. In particular, we consider image schemas as mental patterns that are, in most cases, about classes of affordances and effectivities.

Keywords. image schema, affordance, disposition, agency, cognition

1. Introduction

According to Kutz et al. [1], affordances and image schemas are the twin pillars on which a successful theory of cognition is built; and they have been intensively investigated in various fields for the last few decades. How affordances and image schemas are entwined has been less carefully investigated, though. Indeed, for instance, Kuhn [2] develops an image-schematic and algebraic account of affordances, which has been widely applied as in Cunha et al's [3] visual representation of concepts. However, an analysis of ontological nature of affordances, image schemas, and their relations is still lacking. We provided in former work a dispositional formalization [4, 5] of affordances and effectivities. This paper will provide an ontological analysis of some relation between image schemas on one hand, and affordances and effectivities on the other hand.

The remainder of the paper is structured as follows. After preliminaries on our general ontological framework, Section 2 synthetizes how we formalized affordances and effectivities in former work [5], and analyzes the connection of image schema with so-called "family-directed" affordances and effectivities. Section 3 discusses a few points, including how image schemas can be applied beyond their domain of origin, how our framework accounts for the dual nature (static and dynamic) of image schemas, and how image schemas might be combined. Section 4 concludes the paper with some remarks on future directions of research.

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2. From Affordances to Image Schemas

2.1. Preliminaries

For the sake of anchoring our work in a general ontological background, we postulate some basic categories and relations that are relatively widespread in upper ontologies. Entities fall into two kinds: universals (aka types, classes) and particulars (aka tokens, instances). Particulars (e.g., Mary) bear the instance-of relation to universals (e.g., *Human*). Particulars (resp. universals) fall into two categories: continuants (aka endurants) and occurrents (aka perdurants). Continuants exist fully at each time when they exist; whereas occurrents (including processes) extend through time and have temporal parts. Note that discussion on occurrents in formal ontology is complicated by significantly diverse usages of the term "process" (as well as the terms "event" and "state", which we will not discuss for simplicity). In this paper the term "process" refers to occurrents in which continuants can participate (such as the process of an organism sleeping). Continuants can be further divided into independent continuants (including objects) and dependent continuants (properties such as qualities or dispositions, which can be seen as tropes). Independent continuants, especially objects (e.g., stones), can be bearers of dependent continuants (e.g., hardness).

2.2. Affordances, Effectivities and Image Schemas

The term "affordance" was coined by Gibson [6] to pin down precisely the interaction between animals and the environment: "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill" [6, p. 119]. For instance, a gap affords hiding when it is of a certain size relative to the size of a person and a stair affords climbing when it is a certain proportion of a person's leg length. Our recent conceptualization of affordances [4, 5] builds upon both Turvey's [7] dispositional view of affordances and a state-of-the-art formal-ontological characterization of dispositions [8, 9]. A disposition is a property that is linked to a realization, namely to a specific possible behavior of an independent continuant (typically an object) that is the bearer of the disposition. To be realized in a process, a disposition needs to be triggered by some other process. Typical examples include fragility (the disposition of a glass to break when pressed with a certain force) and solubility (the disposition of salt to dissolve when put in a certain solvent). The crux of Turvey's argument is that: "An affordance is a particular kind of disposition, one whose complement is a dispositional property of an organism" [7, p. 179]. He also calls this complement an "effectivity". For instance, the affordance of the stairs is their disposition to move an organism upward and its complement is the disposition (effectivity) of an organism to move upward when using stairs.

Image schemas, on which we put a primary focus in this paper, are used in a number of different domains, ranging from cognitive linguistics and developmental psychology to artificial intelligence. They are usually attributed originally to Lakoff [10] and Johnson [11]. Roughly speaking, image schemas are mental patterns or "conceptual building blocks" that are extracted from the sensory and motile experiences.[3] They are presumed

[3] For instance, Johnson [11, p. xiv] initially defines image schemas as follows: "An image schema is a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience." Oakley [12, p. 215] explains image schemas from the viewpoint of cognitive

to be learnt during the early infancy [14]; and a complete understanding of them requires considering carefully prelinguistic conceptual development [13]. Image schemas are derived from embodied experiences deriving themselves from sensorimotor inputs, which are multimodal. Quite often, image schemas are nonetheless associated practically to generic spatiotemporal relationships that are learnt from the repetitive interactions with the environment (and the objects therein), especially in formal studies.[4]

One of the most intensively studied image schemas is CONTAINMENT: broadly, the recognition that objects can be inside other objects or (container-shaped) sites.[5] CONTAINMENT is most basically defined as the relationship between an inside, an outside, and the border between them [11]. Seen dynamically, however, CONTAINMENT could be characterized in terms of more "fine-grained" image schemas INTO and OUT OF [13]. Other paradigmatic examples of image schemas include SUPPORT (which denotes a relationship between two objects in which one provides support to the other), PATH (which represents movement of objects from one point to another), and LINK (an enforced connection between objects where the linked object reacts to the stimuli of the other).

2.3. The Connection between Image Schemas and Effectivities

As has been already alluded to in [5], Galton [17, p. 1] would serve as a useful starting point for the extension of our dispositional construal of affordances to image schemas: "Examples of image schemas include CONTAINER and PATH: the link with affordances is obvious, since to be a container is precisely to *afford containment*, while to be a path is to *afford passage*. Thus at least in many cases image schemas may be characterized in terms of the affordances of actual exemplars of those schemas."

We agree with Galton that there is a strong connection between image schemas and affordances. We will characterize image schemas in terms of what we call "family-directed" affordances and effectivities. To explain what those are, we need to remind our model [5] of Turvey's [7] idea of affordances and effectivities as reciprocal dispositions.

2.3.1. Categorical Bases and Reciprocal Dispositions

First, let us introduce the notion of "categorical basis" of a disposition as a quality (or a sum of qualities) of the disposition bearer that underlies this disposition. The categorical basis of $\mathbf{glass_0}$'s fragility is the sum of individual qualities of $\mathbf{glass_0}$ that make it fragile, and the categorical basis of its electrical resistivity is the sum of its individual qualities that make it electrically resistive [8,9].[6]

Let us now turn to the notion of reciprocal dispositions. Classical examples of reciprocal dispositions include a key and a lock such that the former opens the latter: $\mathbf{key_1}$ has the disposition $\mathbf{d_1}$ to open $\mathbf{lock_2}$, and $\mathbf{lock_2}$ has the disposition $\mathbf{d_2}$ to be opened

linguistics: "an image schema is a condensed redescription of perceptual experience for the purpose of mapping spatial structure onto conceptual structure." Mandler and Cánovas [13, p. 526] also critically state: "Image schemas are generally viewed as redescriptions of perceptual events, or even more broadly as generalizations over perceived similarities."

[4] For example, Kuhn [2] characterizes image schemas merely as "patterns abstracting from spatio-temporal experiences."

[5] For details on CONTAINMENT, see Davis, Marcus and Frazier-Logue [15] in artificial intelligence; and also Bennett and Cialone [16] in formal ontology. Note that (canonical) image schemas are normally written in upper case letters in the relevant literature, and we adhere to this convention in this paper.

[6] Particulars and relations will be hereafter written in bold, and classes in italic.

by **key$_1$**. Those two dispositions have something in common: they can be triggered by instances of the same class of process, namely *key$_1$_pivoting_in_ lock*, and they can be realized by instances of the same class of process, namely *lock$_2$_opening*. We say that **d$_1$** and **d$_2$** are reciprocal dispositions; and affordances and effectivities are reciprocal dispositions in this sense of the term. For instance, the affordance **a$_0$** of **gap$_0$** to be contained in **gap$_0$** and the effectivity **e$_0$** of **John** enabling him to be contained in **gap$_0$** are reciprocal dispositions: they both can be triggered by the process of **John** entering into **gap$_0$** and be realized by the process (or state – we will not analyze this distinction here) of **John** being contained in **gap$_0$**.

2.3.2. Individual-directed and Family-directed Affordances and Effectivities

We can introduce dispositions that are closely related to but differ from **d$_1$** and **d$_2$**. Let *Q$_1$* be the universal of properties that characterize a key that can open a lock similar to **lock$_2$**, and *Q$_2$* be the universal of properties that characterize a lock that can be opened by a key similar to **key$_1$**, such that **q$_1$ instance_of** *Q$_1$* and **q$_2$ instance_of** *Q$_2$*, where **q$_1$** and **q$_2$** are categorical bases of **d$_1$** and **d$_2$**, respectively. Let *Key$_1$* be the class of keys which have a property instance of *Q$_1$* (hence **key$_1$ instance_of** *Key$_1$*); and let *Lock$_2$* be the class of locks that have a property instance of *Q$_2$* (hence **lock$_2$ instance_of** *Lock$_2$*). Then, we can define the following dispositions:

- the disposition **d$_1$'** of **key$_1$** to open locks instances of *Lock$_2$*.
- the disposition **d$_2$'** of **lock$_2$** to be opened by keys instances of *Key$_1$*.

Although they are similar to some extent, **d$_1$** and **d$_1$'** are not identical: contrarily to **d$_1$**, **d$_1$'** does not depend existentially on **lock$_2$** – that is, **d$_1$'** could continue to exist even if **lock$_2$** ceased to. Similarly, **d$_2$** and **d$_2$'** are not identical: contrarily to **d$_2$**, **d$_2$'** does not depend existentially on **key$_1$**. Dispositions like **d$_1$'** and **d$_2$'** reflect more general properties of **key$_1$** and **lock$_2$**, and therefore might be more relevant entities than **d$_1$** and **d$_2$**.

This strategy can be adapted to affordances and effectivities, since we have defined them as reciprocal dispositions. We have called the affordance **a$_0$** of **gap$_0$** to contain **John**, and the effectivity **e$_0$** of **John** to be contained in **gap$_0$** "individual-directed" affordances and effectivities, respectively [5]. Such dispositions are in line with Turvey's [7] analysis of affordances and effectivities, as they depend existentially on each other. However, more relevant dispositions might be the affordance **a$_1$** provided by **gap$_0$** to contain any member of a general class *Material object$_1$* (the class of material objects with the appropriate dimensions to be contained in **gap$_0$**) and the effectivity **e$_1$** of **John** to be contained in any member of a general class *Gap$_1$* (the class of gaps with the appropriate dimensions to contain **John**). We call such dispositions "family-directed" (abbreviated as "F-D") affordances and effectivities.

Because of their general character, F-D affordances and effectivities seem to be especially relevant for all fields using the notions of affordances and effectivities. Moreover, as explained in [5], individual-directed affordances and effectivities are vulnerable to "Cambridge change": **a$_0$** depends existentially on **John**, although **John** is external to **a$_0$**'s bearer **gap$_0$**. Similarly, **e$_0$** depends existentially on **gap$_0$**, although **gap$_0$** is external to **e$_0$**'s bearer **John**. On the other hand, **a$_1$** and **e$_1$** would not be affected by changes external to their bearers. And as we will see, F-D affordances and effectivities are also more relevant to image schemas.

2.3.3. What Image Schemas are about

We will propose that (at least) most image schemas are closely related to special kinds of affordances and effectivities. First, we must make clear that image schemas are not identical to affordances and effectivities. As a matter of fact, according to classical views like Turvey's [7], affordances and effectivities are – at least partly – "out of the mind" of the agent. For example, $\mathbf{a_1}$ inheres in $\mathbf{gap_0}$, and has as categorical basis physical qualities of $\mathbf{gap_0}$ (or maybe qualities of the material in which $\mathbf{gap_0}$ is carved). Similarly, $\mathbf{e_1}$ inheres in **John**, and has as categorical basis physical qualities of **John** such as his height. Independently of the existence of agents, any site has a disposition (an affordance) to contain objects of appropriate dimensions, and any material object has a disposition (an effectivity) to be contained in sites of appropriate dimensions.

On the other hand, image schemas are arguably "in the mind" of the agent: they are mental patterns, and thus should be seen as inhering in the cognitive system of an agent, or maybe being a part of it (we will not take any further position here on the nature of mental patterns, though). Therefore, image schemas cannot be identified with affordances or effectivities.

Despite this, image schemas are strongly related with affordances and effectivities. More specifically, image schemas are related to family-directed affordances and effectivities rather than to individual-directed ones, because they are general mental patterns that are extracted from individual sensorimotor experience.[7] Granted that a gap is a kind of container, for instance, John's image schema CONTAINMENT should be construed in connection with FD-affordance $\mathbf{a_1}$ or FD-effectivity $\mathbf{e_1}$ (rather than in connection with individual-directed affordance $\mathbf{a_0}$ or effectivity $\mathbf{e_0}$). Actually, CONTAINMENT should be understood in connection with *classes* of such family-directed affordances and effectivities, such as the class A_1 (of which $\mathbf{a_1}$ is an instance) of gaps' affordances to contain material objects that can fit in them, and the class of material objects' effectivities E_1 (of which $\mathbf{e_1}$ is an instance) to be contained in gaps in which they can fit.

However, the existence of affordances and effectivities does not require an organism to have a corresponding image schema: $\mathbf{gap_0}$ has an affordance $\mathbf{a_1}$ and John has an effectivity $\mathbf{e_1}$ whether he (or any other agent) has a corresponding image schema or not.

As we said, image schemas are mental patterns. As such, there is arguably an intentional dimension of image schemas: they are about something. A natural proposal is that many image schemas are about classes of affordances and effectivities. For example, John's CONTAINS image schema would be about[8] the class of F-D affordances of sites (such as gaps) to contain objects, whereas his IS CONTAINED image schema would be about the class of F-D effectivities of material objects to be contained in sites.

It is not clear, however, that all image schemas are about classes of affordances or effectivities. Consider for example the image schema THING [13], that is involved in recognizing so-called "ordinary material objects" such as stones, people, and tables. This image schema might be about e.g. *Material object* or *Independent continuant*, rather than being about classes of F-D affordances or effectivities. Some bundle views of objects

[7] Kuhn [2] states: "Image schemas *generalize over concepts* (e.g., the CONTAINMENT schema abstracts container behavior from concepts like cups, boxes, or rooms)".

[8] See [23,24] for the usage of the **is_about** relation in formal ontology. See also [25,26] for careful consideration of the nature of aboutness.

might interpret material objects as bundle of dispositions[9] ; in such a framework, even image schemas such as THING might be about a class of effectivities. We do not take position here on the validity of such frameworks, and leave as an open question whether all image schemas are about classes of affordances and effectivities, or only most of them.[10]

3. Discussion

3.1. Applying Image Schema beyond the Realm of Material Objects

An agent's image schemas enable him to organize his perceptions, but they can then be used to fulfill a variety of purposes. That is, even if an image schema is about a class of affordances or effectivities (which are dispositions inhering in material objects), this image schema might then be used to conceptualize other, non-material entities. For example, Lakoff and Núñez [29] attempt to explain mathematics based on image schemas (e.g., the natural numbers by the image schema PATH). Such considerations might enlighten some discussions about constructivist interpretations of mathematics [30].

3.2. Representing Formally the Aboutness of Image Schemas

As we argued, many (if not all) image schemas are about classes of dispositions, namely F-D affordances or effectivities. Note that Web Ontology Language (OWL) [31] does not enable to represent relations of aboutness between a particular (such as John's CONTAINS image schema) and a class of dispositions (such as the class of F-D affordances of sites to contain material objects). A variety of technical workarounds might enable to represent such relation, such as punning [32] or referent tracking formalism [33].

3.3. The Static and Dynamic Nature of Image Schemas

One of Tseng's [34] features of image schemas is that they are static and dynamic, although they may sound contradictory: "Image schemas can be experienced as states of being or as a process. For example, the PATH schema can be experienced in a dynamic way --- the process of moving from one place to another. Or it can be realized "as a static thing", the road, track or passage that has been traversed" [34, p. 143].[11] Our view of image schemas as being (in at least many cases) about dispositions solves this paradox. As a matter of fact, dispositions are static and dynamic in the sense that: "dispositions

[9] See [27] for the bundle theory of objects; and see [28] for dispositionalism, viz. the view that all properties are dispositional.

[10] Another difficult example would be the image schema CYCLE, which seems to be about processes rather than about dispositions – such as heartbeat, breathing, seasons, etc. However, one might interpret it as being about the dispositions that are realized by such heartbeat, breathing, seasons, etc. (the disposition of the heart to beat regularly, the disposition of a human to breath regularly, the disposition of the seasons to come back regularly, etc.) It is more difficult, however, to interpret such dispositions as affordances or effectivities.

[11] In a similar vein, Kuhn [2] says: "they [image schemas] are *internally structured* (e.g., the CONTAINMENT schema involves behavior associated with an inside, an outside, a contained entity, and possibly a boundary)".

connect the *static* structure of the world, i.e. the natural kinds of continuants, with the *dynamical* structure, i.e. the types of possible and actual causal processes" [8, p. 3, our italicization added].[12] In the aforementioned example, PATH can be about the class of disposition inhering in material pathways (which are static entities) that can be realized by an object moving along such pathways (which are dynamic entities).

3.4. Combining Image Schemas

Characteristically, image schemas can be combined in many different ways [2,12,13]. To take Kuhn's [2] example, CONVEYANCE (a vehicle for transporting something) is plausibly taken to be a combination of PATH and SUPPORT (or PATH and CONTAINMENT). By our lights, a combination of two image schemas $\mathbf{is}_1$ (which is about a class of disposition D_1) and $\mathbf{is}_2$ (which is about a class of disposition D_2) might be modeled as being about a collective complex composed by D_1 and D_2. A collective disposition is defined by the upper ontology Basic Formal Ontology (BFO) [35] as: "A disposition inhering in an object aggregate *OA* in virtue of the individual dispositions of the constituents of *OA* and that does not itself inhere in any part of *OA* or in any larger aggregate in which *OA* is a part" [36, p. 410].[13] For instance, a crowd has the collective disposition to do the wave in virtue of each individual crowd member's disposition to stand at the appropriate time [36, p. 409]. Understood by analogy with the wave of a group of people, for example, CONVEYANCE could be formalized as being about a class of dispositions composed by the class of dispositions that PATH and SUPPORT are about (or PATH and CONTAINMENT). Mereological relations between dispositions could help to analyze more finely such dependences [21].

4. Conclusion

To recapitulate briefly, we took a first step towards an extension of our ontological analysis of affordances and effectivities to image schemas: several important image schemas (not only CONTAINMENT, but also PATH, SUPPORT, CONVEYANCE, etc.) are about classes of family-directed effectivities and affordances. It might be possible to think that image schemas are the result of "dispositional evolution" of an individual's effectivities. At first, an infant might conceptualize only individual-directed affordances and effectivities: e.g., one effectivity of John to be inside *this* house and another effectivity of his to be inside *that* baby park; and the affordances offered by this house and that baby park to contain him. Through repeated interactions with individual-directed affordances, the infant later learns to conceptualize classes of family-directed affordances and effectivities, such as the classes of affordances of sites to contain objects of appropriate sizes. Such conceptualization leads to his image schema CONTAINMENT. We also discussed briefly some consequences of our dispositional account of image schemas.

Future work includes:

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[12] More specifically, in [8] and [9], those static and dynamic features of dispositions are accounted for respectively by the categorical bases of dispositions, and their triggers and realizations.

[13] An object aggregate is a BFO category: "A material entity that has as parts (exactly) two or more objects that are separate from each other in the sense that they share no parts in common. Examples include a heap of stones, a population of bacteria, a flock of geese" [35, p. 181].

i. the application of our dispositional interpretation of image schemas to e.g., analysis of metaphors [37] (e.g., the metaphor "marriage is a prison" stems from the CONTAINMENT-based conceptualization of marriage); and
ii. comparison and/or integration between our dispositional formalization of image schemas and e.g., the logic [38] for image schemas and directed movement.

A long-term project would be to provide a full formalization of affordances and image schemas that would contribute to the building of a core ontology [39] for cognitive and behavioral modeling: an ontology that covers the most basic categories and relations among them regarding agency, cognition, perception, and actions. As was implied in [4], it will also have crucial implications for the ontology of the environment [40-42].

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