First Steps Towards an Ontology of Belief

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Abstract. This paper presents first steps towards a formalization of beliefs. It argues for the multiple nature of beliefs: the term "belief" can refer to a mental process of taking something to be the case, or to a disposition realized by such a mental process. The categorical basis of a disposition-belief has as part the concretization of an information content entity, which is in a relation of aboutness with the entities concerned by this belief.

Keywords. Belief, disposition, process, plan, intention, information content entity, aboutness, quality

1. Introduction

Belief is a central construct in several artificial intelligence models of agency – such as the Belief-Desire-Intention (BDI) model [1]; an ontological formalization of beliefs would therefore be highly valuable. For example, we might want to formalize patient's beliefs underlying their adherence or non-adherence to medication prescriptions [2] (e.g. beliefs about a medication's efficacy). Currently, the Mental Functioning Ontology (MF [3]), an OBO Foundry candidate [4], classifies belief as a *Mental disposition*, without further analysis (but see the recent [13]). This paper will present why it makes sense to classify belief as a disposition, and argues that there is also another kind of belief, namely occurrent belief. It should also be possible to extend this account to other ontological frameworks formalizing dispositions, such as UFO [5] – a foundational ontology tailored for general conceptual modeling languages.

The term "belief" is polysemous. Suppose that Mary believes that amoxicillin cures bronchitis. The term "Mary's belief" may refer to the content of Mary's belief, or it may also refer to an entity in Mary's mind. The philosophical literature standardly takes the former entity to be a proposition, and the latter entity to be a cognitive attitude towards this proposition. The ontological nature of propositions is a highly complex topic, and we will not delve into it in this paper, building instead in section 3 upon information content entities ("ICE"), as defined by the Information Artifact Ontology (IAO [6]). As a matter of fact, there are several ontologies based on the theory of ICEs,

such as the Prescription of Drugs Ontology (PDRO [2]), where an ontology of belief would be useful. We will first show in section 2 that beliefs in the second sense have both a dispositional and occurrent nature. We will suggest here first steps in developing a formalization in OWL (and point to some insufficiencies of this language to formalize beliefs). In the remainder of the paper, universals or classes will be italicized and capitalized, and names of particulars will be written in bold.

2. The Dual Nature of Beliefs

In the Basic Formal Ontology (BFO [7]), a realizable entity is as an entity that is manifested or exhibited during some process, but continues to exist even when it is not participating in a process (where a process is a temporally extended entity, whose existence depends on at least one material entity). Realizable entities are further specialized into dispositions and roles. Dispositions are realizable entities "that exists because of certain features of the physical makeup of the independent continuant that is its bearer" (such as being flammable), whereas roles exist because the bearer is in special physical, social, or institutional circumstances (such as being an employee). Given this, we classify beliefs in BFO as a subtype of dispositions. My belief that amoxicillin cures bronchitis exists even when sleeping – that is, even when I am not consciously thinking it – and exists in virtue of the physical makeup of my neuronal system.

Next let us consider how beliefs (as dispositions) are realized. A proposal [8] is that beliefs are dispositions to physically perform certain kinds of actions (that is, dispositions to behave in a certain way). My belief that amoxicillin cures bronchitis, then, is realized when I perform the action of taking amoxicillin when I have bronchitis.

This approach, however, does not seem to account for the nature of beliefs. I can have a belief that amoxicillin cures bronchitis even if I'm totally paralytic and not able to take amoxicillin. To answer this objection, one might argue that beliefs are dispositions to act if further conditionalized: my belief that amoxicillin cures bronchitis is a disposition to take amoxicillin if I have bronchitis *and* I am not paralyzed. However, this proposal only seems to capture the practical dimension of beliefs (how they relate to action), not how they relate to the purely theoretical attitude of taking some state of affairs to be the case. Consider the fictional counter-example of a supernatural spirit with no power of action at all, who would have many beliefs about the world (e.g. that the sea is mostly composed of water, etc.), but no disposition to act.

Thus, following a classical philosophical distinction [8,9], we hold that dispositional beliefs are not realized by physically performing actions, but by some occurrent mental process that we call "occurrent belief", namely the cognitive process of taking it to be the case that amoxicillin cures bronchitis. For example, Jones may believe that amoxicillin is helpful to cure his bronchitis, but this (dispositional) belief is not being continuously activated (or said differently, realized) in his mind. At t_1 (see figure 1 below), he deliberates whether he should take amoxicillin, and his dispositional belief is realized by a process of him taking amoxicillin to be helpful to cure his bronchitis. His dispositional belief is then realized a second time at t_2 by a similar process. Thus, a person may have a dispositional belief that amoxicillin cures bronchitis even when sleeping or unconscious. We can then suggest the following definitions:

- Dispositional belief: A disposition that can be realized in an occurrent belief.

- Occurrent belief: A MF:*Mental process* of taking something to be the case.

The difficulty here would be to analyze what it means to take something to be the case, which might involve a cognitive attitude towards a proposition – two complex notions. This will remain out of scope of this paper, which will instead analyze how beliefs can be articulated with IAO's theory of ICEs.

3. Information Content Entities and Beliefs

In the following, we will use single quotes such as in 'amoxicillin' to refer to an ICE instance. ICEs are *about* something (see [6] and the two senses of aboutness they introduce, at the level of reference and the level of compound expression). For example, the ICE 'aspirin' on a drug product monograph is an ICE that is about the class of aspirin drug products. Following Smith and Ceusters [6], an ICE is concretized by one or several instances of a specific subclass of BFO:*Quality* named *Information Quality Entity* (*IQE*). For example, if Dr. Jones writes the word "amoxicillin" on a white paper, the ICE 'amoxicilin' that refers to the active ingredient amoxicilin is concretized by some qualities inhering in the mereological sum of ink molecules on this paper. Not all qualities of the ink are relevant from an informational point of view: for example, writing the dot on the "i" slightly more to the left or to the right is not relevant in this sense. According to IAO's theory, ICEs might also be concretized by a neuronal configuration. There is an important distinction between ICEs and IQEs. IQEs *specifically* depend on their bearer; that is, an instance of an IQE exists only as long as the unique entity it depends on exists. On the other hand, ICEs *generically* depend on their bearer: they can be copied or migrate on another bearer.

We hypothesize that a belief involves the concretization of an ICE in one's brain: if I believe that amoxicillin cures bronchitis, my brain must carry some associated information. For example, let's define 'Amoxicillin cures bronchitis' as ICE_1, and 'L'amoxicilline soigne les bronchites.' (the French translation) as ICE_2. Thus, if I believe that amoxicillin cures bronchitis, my brain may bear ICE_1 or ICE_2[2].

However, having ICE_1 (or ICE_2) concretized in one's brain does not imply that the person believes that amoxicillin cures bronchitis. Suppose that John holds at t_0 the **belief_0** that amoxicillin does not cure bronchitis, but after attending to a conference on the topic, holds at t_1 the **belief_1** that amoxicillin does cure bronchitis (note that holding **belief_1** is stronger than simply not holding **belief_0** anymore). At t_0, some ICE such as ICE_0 'Amoxicillin does not cure bronchitis' is concretized in John's brain by IQE_0, and he holds a belief attitude towards it. At t_1, ICE_0 might still be concretized in his brain occasionally (as it was presumably concretized in your brain when you read the sentence), but he does not hold a belief attitude towards it. Said differently, a mental representation of some information does not imply a belief in the veracity of the represented information. I can have a mental representation of the statement 'the Earth is flat' (and thus, I can have the ICE 'the Earth is flat' concretized in my brain), even if I do not believe it.

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[2] This shows how a theory of proposition would help to complement this account, as those two ICEs arguably express the same proposition.

Continuant

Occurrent

Independent continuant

Generically dependent continuant

Specifically dependent continuant

Process

Human | Drug product | Information Content Entity | Quality | Quality sum | Disposition

Amoxicilin

Information Quality Entity | Categorical basis | Dispositional belief | Occurrent belief

John —is about— ICE_1 = 'Amoxicilin cures bronchitis' | IQE_1 = concretization of ICE_1 in John's brain | categorical basis$_1$ of belief$_1$ | dispositional belief$_1$ of John that Amoxicillin cures bronchitis | occurrent belief of John at t1 that Amoxicillin cures bronchitis | occurrent belief of John at t2 that Amoxicillin cures bronchitis

—concretized in— —part of— has categorical basis —realized in—

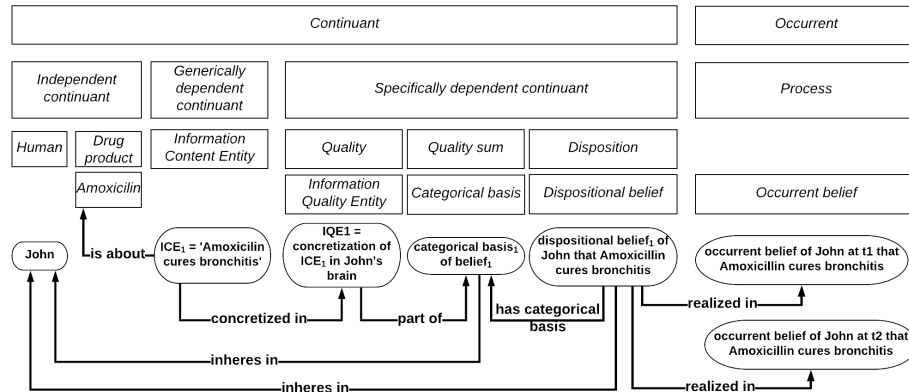—inheres in— —realized in—

—inheres in—

Figure 1: Relevant classes and instances (*Bronchitis* is omitted)

To connect a belief with its informational content, we will compare the qualities underlying the former with the qualities underlying the latter. Barton et al. [11] define the "categorical basis" of a disposition as the quality (or sum of qualities) in virtue of which this disposition obtains (and which therefore inheres in a part of the disposition's bearer named by BFO the "material basis" of this disposition [7]). For example, the categorical basis of a glass' fragility is constituted by some features of its molecular structure. Thus, the categorical basis of a belief is a sum of qualities of a brain – namely, those qualities in virtue of which this belief exists. The connection between **belief$_0$** and its informational content **ICE_0** can be formalized by stating that the quality **IQE_0** concretizing **ICE_0** in John's brain is a part at t_0 of the categorical basis of his **belief$_0$**.

Figure 1 illustrates how our formalization can be used to relate a belief to the object(s) of this belief. **ICE_1**, for example, is about the class *Amoxicillin* and the class *Bronchitis* (at the level of reference, cf. [6]). Therefore, **belief$_1$** can be connected to the classes *Amoxicillin* and *Bronchitis* by stating that **belief$_1$** has as categorical basis a sum of qualities that have as part **IQE_1**, and **IQE_1** is the concretization of **ICE_1** that is about the class *Amoxicillin* and about the class of *Bronchitis*[3].

4. Conclusion

In this paper, we have put forth the beginnings of a theory for representing two important ways that we understand beliefs: dispositional beliefs and occurrent beliefs. A dispositional belief exists even when we are not actively thinking it, and when we are actively thinking about a belief, we engage in an occurrent belief process during which we take something to be the case. Dispositional and occurrent beliefs are related using BFO's **realized in** relation: an instance of a dispositional belief is realized in an instance of an occurrent belief.

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[3] Note that **ICE_1** is also about the state of affairs of amoxicillin having a disposition to cure bronchitis (in the sense of aboutness at the level of compound expression [6]). This is however presently not easily formalizable in OWL. Also, relating a particular such as **ICE_1** with classes such as *Amoxicillin* and *Bronchitis* is not easily formalizable in OWL, although one could use the inverse relation of **is_about** to solve this difficulty [12].

Our analysis left open whether a dispositional belief could be causally active even if it is not realized. For example, I may believe that (*ceteris paribus*) massive objects accelerate towards the Earth. This belief certainly has a causal influence on some of my actions, even when I do not consciously deliberate about it. As a consequence, if one endorses a purely dispositional theory of causation, a dispositional belief is realized in an occurrent belief whenever it is causally active, even when the person having this belief does not consciously deliberate about it.

To relate our dispositional beliefs to the entities that are targets of our beliefs, we incorporate IAO's theory of ICEs, which enables us to e.g. relate **belief$_0$** and **belief$_1$** with the classes *Amoxicillin* and *Bronchitis*. A theory of proposition would be helpful to proceed further and be able to relate beliefs not only with the entities they concern, but also with their substantial content, such as the propositions "Amoxicillin does not cure bronchitis" (related to **belief$_0$**) and "Amoxicillin cures bronchitis" (related to **belief$_1$**) – the former being especially complex to analyze in a realist ontology, as it does not describe a state of affairs that obtains.

Finally, the present account has defined beliefs independently of practical rationality, that is, independently of any intention to act on it. However, beliefs do frequently play a role in motivating action. Future work should also examine how dispositional beliefs can lead to an intention to act, by being realized by an occurrent belief that is part of a plan making process, that leads to an OBI:*Plan* (as formalized by the Ontology for Biomedical Investigations [10]).

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