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Language, concepts, and the nature of inference

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Abstract

Traditionally, analytic philosophy has been affiliated with a formalist conception of inference which understands reasoning as a process that exploits syntactic properties of natural language according to a set of formal rules that are insensitive to conceptual content. This chapter discusses an alternative approach that takes semantic properties as the underlying forces driving rational inference. Building on Wilfird Sellars' notion of material inference and analytic tools from cognitive linguistics, I will show how parts of the inferential structure of natural language can be explained in terms of semantic relations between extra-logical concepts. In the end, I will outline a strategy for explicating some of these inference-types using Peter Gärdenfors' theory of conceptual spaces.

1. Introduction

The central motivation behind this chapter is to discuss the relationship between language and rational inference. Inference is a widely used yet underdefined notion whose meaning varies across research traditions and disciplines. Here, I will use it to refer to a kind of mental act that consists of transitioning from one mental state to another according to some systematic information-based criterion. The fact that inference is guided by a criterion (or "rule") distinguishes it from mere association of ideas (i.e., a kind of mental transition that can be idiosyncratic or arbitrary) and makes it a normative activity. The specific question I will try to address is: In which sense is this activity related to our linguistic competence?

Mainstream Analytic Philosophy often answers that question by focusing on the *logical* properties underlying natural language. Inference is then seen as a syntactic-based mechanism that operates according to some set of domain-general (formal) rules. This is the view I criticize in what follows. I will start by discussing the origins of this idea in logic and its influence in the philosophy of cognitive science. I will later propose an alternative approach inspired by Sellars' ideas about the inferential structure of natural language. The main thesis I defend is that rational inference is a mechanism that exploits semantic properties of language instead of syntactic properties. I will propose cognitive semantics as a useful theoretical framework for developing this idea, and I will sketch a possible formal explication of it using the theory of Conceptual Spaces.

2. The formalist view of inference

As it is well known, formal logic played a crucial part in the development of analytic philosophy. It shaped, to a significant extent, our understanding of how reasoning and justification should work. A direct consequence of this influence was a strong tendency to see inference as a formal mechanism. The *formalist view of inference* (FVI), as I will call it, assumes that reasoning happens in a language-like representational medium with a clear syntactic structure. Inferential transitions exploit syntactic properties of this language, disregarding the specific semantic content of premises and conclusion.

The sources of FVI can be found in what John MacFarlane calls the "hylomorphic tradition" in logic (Macfarlane 2000), that is, the Aristotelian idea that reasoning and argumentation exhibit both formal and material properties[1] (see also, Conway 1995) and that the notion of inferential validity can be specified as a function of logical form through abstract (*content-independent*) schemes.

These ideas were assimilated by modern logic through the identification of a set of morphemes that are invariant across subject matters in arguments: logical constants. The central feature of these terms is that they are *topic-neutral* (Ryle 1945, 116), i.e., their content emerges from the structural role they have in articulating and relating concepts and propositions, and not from any representational relation with objects or classes of objects in the world. Logical constants are *truth-functional*: they cannot have a truth-value by themselves, but they determine the truth value of the expressions in which they participate. Topic-neutrality and truth-functionality make it possible to define the normative notion of inferential validity in purely formal terms (as a function of logical form) and thus independent of content (see also, Read 1994).

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[1] "Material properties" are those properties of words and sentences related to their subject matter.

Now, which is the contribution of content to the process of inference according to this approach? Truth-transmission is a bottom-up process that starts with atomic propositions being assigned a truth-value. The only semantic property which matters here is that propositions are truth-bearers. All other semantic properties, like those associated to the topic of the predicates in these propositions, are completely irrelevant. Since the truth-functional structure of arguments can be mirrored by syntactic features of language, and since this structure has nothing to do with content or subject matter, the hylomorphic tradition explains deductive inference as the result of a sort of division of labor between the syntax and the semantics of language: we can make valid inferences about things without having to "look into" the content of extra-logical terms because all what matters to validity is truth-transmission, and this is precisely mirrored in the syntax of sentences.

2.1 FVI in the philosophy of psychology

FVI had a strong impact in the psychology of reasoning due to its compatibility with the computational view of cognition, largely dominant in Cognitive Science (see, Piccinini and Scarantino 2011, Dennett 1984). One of the most influential computationalist philosophers, Jerry Fodor, defended FVI in the philosophical arena with arguments that rely heavily on the logical distinction between form and content discussed above. In what follows, I will briefly explain the connection between logical formality and the idea that reasoning can be described in formal terms.

As the story goes, the main challenge for cognitive psychology is to provide a causal explanation of intentional phenomenon like thinking (see, Horst 1999). Psychology needs to explain how the intentional and semantic properties of thoughts are preserved through coherent inferential transitions. In other, it needs to offer a "mechanical" reconstruction of rationality and reasoning.

Jerry Fodor's answer to this issue consisted of a psychological interpretation of logical formality (Fodor 1975, Fodor 1980, Fodor and Pylyshyn 2015). Roughly, he urged psychology to understand the mind as a syntax-driven machine that performs formal operations over language-like entities —thoughts— with both syntactic and semantic properties. Causal transitions between thoughts are possible due to their syntactic (formal) properties.[2] Since these properties *mimic* the semantic properties of thoughts, rational thought is also possible. In Fodor's words:

> *Thinking can be rational because syntactically specified operations can be truth preserving insofar as they reconstruct relations of logical form; thinking can be mechanical because Turing machines are machines... [T]his really is a lovely idea and we should pause for a moment to admire it. Rationality is a normative property; that is, it's one that a mental process ought to have. This is the first time that there has ever been a remotely plausible mechanical theory of the causal powers of a normative property. The first time ever.* (Fodor 2001, 19)

Computationalists such as Fodor often see classical proof theory as a model of how logical formality can shed light on reasoning.[3] Proof-theoretical systems show us how the manipulation of a set of syntactic rules operating on the form of propositions can mirror truth-preserving transitions between premise(s) and conclusion. The division of labor between syntax and semantics is such that inferences can be proven valid without the need to refer to the content of the predicates or propositions involved. The influence of this idea on the psychology of reasoning can be directly seen in theories such as Mental Logic (see Braine 1990) or Rips' "Deduction-System Hypothesis" (Rips 1994), where all inferential moves depend on the application of domain-general rules of inference.

FVI lost many supporters in the psychology of reasoning after empirical studies started to show that we often struggle following logical rules (e.g., Wason 1968), and that our performance while reasoning is seriously affected by the content and the prior knowledge we have about the subject matter of the tasks (see Pollard and Evans 1987,

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[2] Fodor understands syntactic structure as "abstract features" of the shape of symbols (Fodor 1987). These shapes are the ones having a causal role in the mechanics of thinking.

[3] For instance, Fodor and Pylyshyn claimed that classical cognitive science is "an extended attempt to apply the methods of proof theory to the modeling of thought (and similarly, of whatever other mental processes are plausibly viewed as involving inferences; preeminently learning and perception.)" (Fodor and Pylyshyn 1988, 30).

Manktelow and Evans 1979, Evans and Feeney 2004). This led researchers to claim that agents do not typically use domain-general rules of inference, but that they look for information and counterexamples in domain-specific memories in problem-solving contexts.

These kinds of findings clearly suggest that there must be a strong interaction between inferential mechanisms and the content of the extra-logical terms in the premises-conclusion, and that, unlike what FVI claims, reasoning cannot be purely formal. In what follows, I will present a view of inference that challenges the formalist approach, and sees reasoning as intimately related to conceptual content.

3. Beyond logical forms

Our everyday inferential practice does not exhibit a clear formal structure. While reasoning and arguing, people rarely make explicit all the formally relevant premises for their conclusions, and they very often engage in fallacious reasoning that deviates from logical principles. In general, everyday reasoning seems to be more sensitive to the conceptual content of sentences and predicates than to formal principles. For instance, formally invalid inferences like (i) "Fido is a dog, then Fido is a mammal" or (ii) "Munich is south of Berlin, then Berlin is north of Munich" are generally considered as completely reasonable for competent language users.

Wilfrid Sellars (Sellars 1953) was one of the few philosophers who tackled this issue by advancing a view of inference and meaning that diverges from the formalist perspective. Roughly, Sellars understood inferences as intra-linguistic moves regulated by rules at the level of the meta-language.[4] While he thought that formal rules —logical

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[4] Sellars identifies various kinds of rules governing language: language-entry rules, which specify how to verbally react to an environmental —non-linguistic— stimulus; language-exit rules, which regard the coherence between y actions and what I express about my intentions; and language-language rules, that concern our verbal behavior before linguistic inputs and play a crucial role in reasoning and understanding, according to Sellars (1953 and 1974).

rules— did play an important role, he claimed that most of our inferential moves were regulated by a different kind of rule that builds on the content of the extra-logical terms of the language: *material rules.* Unlike formal rules, material rules of inference operate at the subsentential level by exploiting semantic relations between predicates. For instance, (i) and (ii) are materially valid in virtue of the lexical relation between *dog* and *mammal* and between *south* and *north* respectively. In Sellars' words:

> …a logical rule of inference is one which authorizes a logically valid argument, that is to say, an argument in which the set of descriptive terms involved occurs vacuously (to use Quine's happy phrase), in other words, can be replaced by any other set of descriptive terms of appropriate type, to obtain another valid argument. On the other hand, descriptive terms occur essentially in valid arguments authorized by extra-logical rules. Let me now put my thesis by saying that the conceptual meaning of a descriptive term is constituted by what can be inferred from it in accordance with the logical and extra-logical rules of inference of the language (conceptual frame) to which it belongs. (Sellars 1953, 136) [5]

While FVI sees inference as unrelated to concepts, Sellars understands conceptual competence and inferential competence as two converging phenomena. Possessing concept *A* depends on having the ability to make inferences from *A* to related concepts *B*, *C*, *D*…, etc. in our conceptual repertoire. As Robert Brandom claims: "concepts come in packages" (Brandom 2000, 15), and possessing a package of concepts implies to know how to draw inferences among them. In other words, concepts and inference are two sides of the same coin since learning concepts is learn how to reason with them.

There is no need to enter the philosophical details of Sellars' position to realize that it is substantially different from FVI. While in the latter all inferences are seen as cognitive mechanisms relying on syntactic properties of some language of thought, in the former, inferences exploit semantic properties of natural language. In particular, they

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[5] Carnap anticipated the idea of meaning-constitutive inferences when claiming that the meaning of extra-logical terms is fixed by the set of deduciblility rations between expressions containing these terms and other expressions. For instance, the meaning of arthropod is determined by inferences from "Athropod(x)" to "SegmentedBody(x),"

exploit the kind of properties that make natural language *empirically meaningful* (see Sellars 1947), i.e., which make it a system that encodes information about empirical regularities.

Sellars' claim that an analysis of meaning cannot be given independently of an analysis of inference was disruptive in his philosophical context, dominated by the idea that the notion of meaning could be exhausted in those of reference and truth-functionality. However, it laid the foundations for a new trend in semantic theory, named "Functional Role Semantics", whose central claim is that meaning must be analyzed according to its role in the cognitive ecology of agents, and not exclusively in terms of the relation between natural language and the world (Block 1986, Harman 1982, Brandom 1998).

A problem with functional approaches to meaning is that they rarely offer a fine-grained explanation of how conceptual content is structured; as Block has admitted, they give us a general framework for rethinking what concepts are, but not a systematic theory about them (Block, 1998). This seems to be also the case for Sellars' inferentialism, where any kind of conceptual relation is explained using the same notion of material rule. Nevertheless, relationships between concepts are varied, and this is reflected in their inferential use. For instance, the concepts *fruit* and *apple* are in a subordinate-superordinate relation, therefore the inference "$Apple(x) \rightarrow Fruit(x)$" is intuitively valid for competent language users; however, *apple* and *red* are also related since apples are typically red, but the inference "$Apple(x) \rightarrow Red(x)$" is uncertain and therefore nonmonotonic (cf. Osta-Vélez & Gärdenfors, 2021). Furthermore, it is not clear where the rules of material inference come from, nor how they are represented psychologically. In what follows I will show how it is possible to refine the notion material inference by using tools from cognitive semantics.

4. Cognitive Semantics

Although Sellars' ideas serve as guidelines for rethinking the relationship between inference and meaning, more precise tools are needed for analyzing it in detail. I believe that these tools can be found in Cognitive Linguistics, an interdisciplinary research program that followed the Chomskyan revolution in linguistics in the second half of the 20th century. Roughly, Cognitive Linguistics claims that natural language must be understood as a constituent part of the human cognitive system which is in constant interaction with other cognitive faculties such as memory, categorization and reasoning (see Geeraerts and Cuyckens 2007).

A sub-field of Cognitive Linguistics called Cognitive Semantics (CS) (see Fillmore 2008, Jackendoff 2002, Lancgacker 1987, Gärdenfors 2014) proposes to study *meaning* following the aforementioned principle. In contrast to the externalist tradition in semantics, CS understands both lexical and sentential meaning as *conceptualization*, i.e., as anchored in rich representational structures in the mind/brain of the speaker/listener. In this sense, the basic units of linguistic meaning are not propositions, but mental entities like concepts, prototypes, frames, or image schemes, depending on the specific approach.

Like Sellars' inferentialism, CS endorses a holistic view of meaning. Lexical terms cannot be grasped in isolation but depend on being associated to clusters of concepts, also called *frames* (Fillmore, 2008) or *domains* (Langacker, 2002). The meaning of linguistic units involves a specific configuration of these bodies of concepts that is analyzable, according to Langacker (2000), in terms of *profile-based alignments* in which a designatum *stands out* against a broad conceptual context or "base". For instance, the expression "the goalkeeper of Manchester United" profiles an individual with a specific property against a base containing concepts like *game*, *football*, *ball, hand*, etc. At the sentential level, each profile-based alignment (with its associated grammatical construction) introduces a specific *construal* or *perspective* from which a situation or entity is described. Changes of the grammatical construction might lead to a new construal that "re-profiles" the situation within the same conceptual base. For instance, the sentences "John is painting the door green" and "The door is being painted green by John" are cases of re-profiling the same situation in different ways.

Construals are generally seen as attention-based mechanisms (see, Verhagen 2007, Talmy 2008). Using Langacker's terminology (Langacker, 2001), sentence-meaning involves attentional frames that set the focus of the speaker/listener on some specific object(s) while attributing less attentional weight to the rest of the elements in the situation. I believe that these ideas can be applied for explaining material inferences. My claim is that these inferences operate under a common principle: Material inferring is an attention-based mechanism that involves re-profiling a designatum within an agent's conceptual base of background knowledge. The uniqueness of this mechanism, compared to simpler forms of re-profiling (such as the one in the previous example), lies in the fact that the conceptual base encompasses all the conceptual knowledge that the agent possesses about the extra-logical terms in the premise.

CS offers interesting and psychologically informed ways of relating inference to meaning. For instance, Jackendoff's decompositional theory of meaning (Jackendoff, 1992) proposes that the structure of sentential meaning supports different inferential patterns. According to him, meanings are ultimately anchored in a set of elementary units called "conceptual primitives" that are combined during language processing based on innate rules that constitute a sort of conceptual grammar. Examples of these conceptual primitives are "thing", "place", "path", "property", "event", and "action". But, how is this related to inference? according to Jackendoff, decompositional analysis uncover patterns of entailment relations between sentences in natural language. These patters can be generalized by identifying shared structures between lexical types. Let's see an example of this from Jackendoff himself (1992, 39). Consider the following causal inferences:

X *killed* Y → Y *died*.

X *lifted* Y → Y *rose*.

X *gave* Z *to* Y → Y *received* Z.

The semantic structure of these sentences is:

X *kill* Y: X_{cause}[Y *die*];

X *lift* Y: X_{cause}[Y *rose*];

X *gave* Z to Y: X_{cause}[Y *toreceive*Z]

And the generalized inference pattern for causal sentences is the following: X_{cause}[E*tooccur*] → E*occurs*.

This kind of analysis that uncovers inferential patterns associated with meaning structures can be carried out systematically with other lexical types in this framework. The strategy that I will sketch in the remainder of this chapter is in the spirit of Jackendoff's idea. The difference being that I propose Conceptual Spaces as the modeling framework instead of Jackendoff's Conceptual Grammar. The underlying idea is the same: instead of focusing on the syntactic structure of language for analyzing inference, we should investigate the structure of concepts and their relations. In what follows I will briefly introduce the theory of Conceptual Spaces for later showing through some examples how this strategy unfolds.

4.1 Conceptual Spaces

Conceptual Spaces (Gärdenfors 2004, 2014) is a theoretical and formal framework that has been proved useful for modeling several cognitive phenomena associated to concepts. It shares one fundamental assumption with CS: that there is an intermediate level of representation encoding semantic information mediating between natural language and the more fundamental psychological structures that make knowledge possible. A central claim of this theory is that conceptual knowledge depends upon a psychological space in which similarity relations between objects, properties, or concepts can be represented as an inverse function of distances within the space.

The building blocks of conceptual representation are *quality dimensions* and *domains*. Quality dimensions represent different qualities of objects that are used for judging similarities and differences among different stimuli (Gärdenfors 2004, Sec. 1.3). For instance, *sweetness*, *brightness*, and *pitch* are quality dimension used to classify gustatory, visual, and auditory stimuli respectively. Dimensions can be innate, culturally acquired, phenomenal, or abstract depending on the concept or property they are part of. Some dimensions are *integral*, i.e., they cannot be attributed to an object independently of some other dimensions (see Garner 1975). For example, the pitch of a sound necessarily comes with a volume, making volume and pitch integral dimension of auditory stimuli. A set of integral dimensions that are separable from all other dimensions is called a *domain*. A classic example of a domain is the "Color spindle", composed by the three integral dimensions: *hue*, *intensity* (or saturation), and *brightness*.

A key point of Conceptual Spaces is that dimensions can be represented by geometrical structures and domains as the composition of these structures. Integral dimensions are often modeled with a Euclidian metric, while separable dimensions with a City Block Metric. For instance, hue has a circular structure, intensity is represented as an interval of the real line, and brightness, which varies from white to black, is represented as a linear dimension with endpoints. The topology of the color domain the composed structure of these three structures, like illustrated in Figure 1:

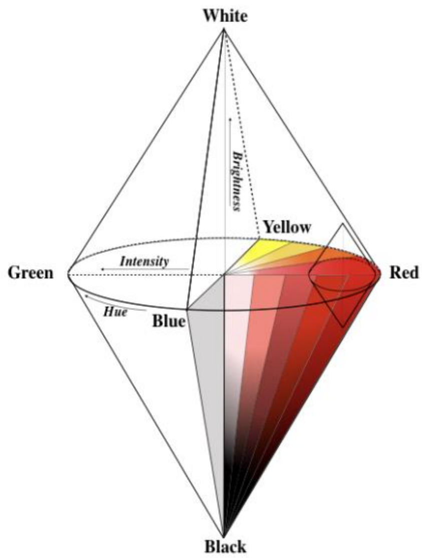

Figure 1- Color spindle. *Red* is represented as a convex subregion of the domain. From Osta-Vélez & Gardenfors (2020, 2).

The topological structure of domains serves to represent classes of properties of objects. In the color domain, for instance, different colors are represented as subregions of the domain. Through the definition of a distance function associated with this structure, we can compute the pairwise similarity between properties in the space according to how close they are to each other. For instance, the distances in the color domain allow us to see why orange and red are more similar than red and black.

A *conceptual space* is as a collection of one or more domains with a distance function —a metric— which represents properties, concepts, and their similarity relationships. Individual concepts are thus represented as convex subregions of some conceptual space.[6] For instance, the concept *lemon* will be represented as a convex subregion of a "fruit space" composed by domains like *color*, *shape*, *ripeness*, *taste*, and *texture*. In particular, the "lemon region" of the space will cover certain regions of the domains —those representing the common properties of lemons— while leaving other

[6] A region is convex when for every pair of points *x* and *y* in it, all points between them are also in the region.

regions "untouched" —for instance, the "lemon region" won't cover the blue or green region of the color space.

A crucial point for my analysis concerns how objects are represented in this framework. The idea is straightforward: concepts are subregions (sets of points) of conceptual spaces and objects are points within these subregions. For example, an object falling under the concept "lemon" will be represented as an arbitrary point in the subregion of the fruit-space that correspond to the representation of lemons.

In formal terms, the conceptual space of concept *M* —written *C*(*M*)— can be seen as a subset of the Cartesian product of *n* domains:

$$C(M) \subseteq D_1 \times D_2 \times \cdots \times D_n$$

An object *x* falling under *M* is represented as a *n*-dimensional point $x = < x_1, x_2, ..., x_n > \in C(M)$. Each x_i in *x* represents the coordinates of the point in the domain D_i, which will typically fall under some subregion $R_i \subseteq D_i$ that represent a subordinate category of D_i.

Like in the case of concepts, the similarity among two objects in the space can be estimated by using the built-in distance function. Similarity among objects is generally easier to compute than similarity among concepts, since the former requires to measure the distance among two points in the space and the latter the distance between sets of points in the space.

4.2 Material inferences in Conceptual Spaces

As explained before, according to FVI an inferential move consists of the identification of the underlying logical form of some proposition(s) and the further application of some domain-general rules that generate a conclusion. The approach I am proposing here is significantly different, I claim that material inferences are attention-based mechanisms that exploit structural properties of concepts. Therefore, explicating inference in this sense requires a theory of *conceptual form*, instead of a theory of logical form. In what follows, I will illustrate with examples how Conceptual Spaces can do this job.

Let us start with an analysis of material inferences with nouns. The classic examples here are inferences that move from one category to some of its superordinate's, like $Dog(x) \rightarrow Mammal(x)$. Their explanation is straightforward: consider the inference $N(x) \rightarrow M(x)$ such that *N* and *M* are nouns and *N* is a subordinate concept of *M*. In the conceptual spaces-framework, this last claim implies that $C(N) \subset C(M)$; then given that

"*N(x)*" means that $x \in C(N)$, it follows that $x \in C(M)$, which means "*M(x)*". In other words, to know that concepts *N* and *M* are in a subordinate-superodinate relation requires us to have semantic intuitions about a set-theoretical relation; then, the material inference *N(x) → M(x)* can be explained as an attention-shift from the conceptual representation of "*N(x)"* to the related representation of "*M(x)*" that build on these intuitions.

The situation is less simple when we take the opposite direction and try to explain inferences from a noun *N* to some of its properties. In general, this kind of inference depends on the internal structure of the conceptual representation of *N*, i.e., the dimensions and domains that constitute the concept. Two subtypes of inferences can be identified in this sense. First, we have inferences that account for a dimension or a domain that is constitutive of the noun in question, like *Bird(x) → HasWeight(x)* or *Car(x) → Colored(x)*. These inferences rest on semantic intuitions about the internal structure of the noun. Second, we have inferences that go from the noun to some specific property (subregion) of one of its domains, like *Apple(x) → Red(x)* or *Apple(x) → Roundish(x)*. In general, the degree of "confidence" we can have in inferences such as these depends on the number of subregions that the concept reaches for a given domain. For instance, *Horse(x) → Herbivore(x)* is a strong inference since in the "diet-domain" the concept *horse* only reaches the "*herbivore"* subregion. However, *Horse(x) → Brown(x)* is a rather weak inference since in the color domain, *horse* extends across various subregions besides the one corresponding to the property *brown.* In general, since concepts may extend across various properties of a domain, these inferences imply uncertainty and are often nonmonotonic (see Osta-Vélez and Gärdenfors, 2021).

Notice that material inferences with negation can be also explained as a function of conceptual structure. Many nouns and adjectives at the same categorization level (cohyponyms) are "semantically incompatible" (see Cruse 2004, 162), that is, they cannot be predicated simultaneously about the same object (e.g., *dog* and *cat*). In the conceptual spaces approach, two cohyponyms *N* and *M* are incompatible if the occupy disjoint regions of their common conceptual space. Then, given two incompatible nouns *N* and *M*, the inference *N(x) → ¬M(x)* is materially correct because "*N(x)"* means that $x \in C(N)$ and if $C(N) \cap C(M) = \emptyset$ then $x \notin C(M)$, which means "*¬M(x)".* In other words, the way in which conceptual spaces are partitioned and the way in which objects are represented in them explain semantic incompatibility among some cohyponyms and the fact that we can draw material inferences with negations from them.[7]

To see one further example with relational concepts, I will briefly discuss material inferences with kinship terms. Once again, a tool from CS will help us in this analysis. Clauses with predicates that relate two entities, like "Montevideo is in Uruguay", can be described as *trajector/landmark alignments* (Langacker 2008, 70–73) in which a prominent object, the "trajector", is "*located, evaluated, or described*" (Ibid. 70) in function of another less prominent object, the "landmark". For instance, in "*X* is the daughter of *Y*", *X* is the trajector that is described in a specific kinship relationship through the landmark *Y*. Relational concepts are inferentially rich; for instance, from "*X* is the daughter of *Y*" we can infer "*X* is a woman", "*X* is younger than *Y*", and "*Y* is the father or mother of *X*". Again, the inferential properties of these concepts can be explained with Conceptual Spaces.

The conceptual representation of Kinship terms can be described as the product space of three discrete dimensions (see Figure 2): a gender dimension with two disjoint subregions (*male* and *female*), a dimension representing "vertical" degrees of offspring —like son/daughter or father/mother— which will be isomorphic to the integers, and a dimension with the same mathematical structure that represents "horizontal" degrees of kinship —like brother/sister, cousin, second-cousin, etc.—Representing kin relationship in that space involve to take the landmark of the expression as the center of the space and to identify the trajector with a three-dimensional vector whose location will be a function of the landmark. For instance, the sentence "*x* is the son of *y*" will be represented by the vector < male, -1, 0 > while "*x* is the aunt of *y*" with the vector < female, 1, 1 >.

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[7] Concepts might have vague regions in which these properties are not satisfied (see, Douven et al. 2013), however, for the sake of simplicity I will not discuss this problem here.

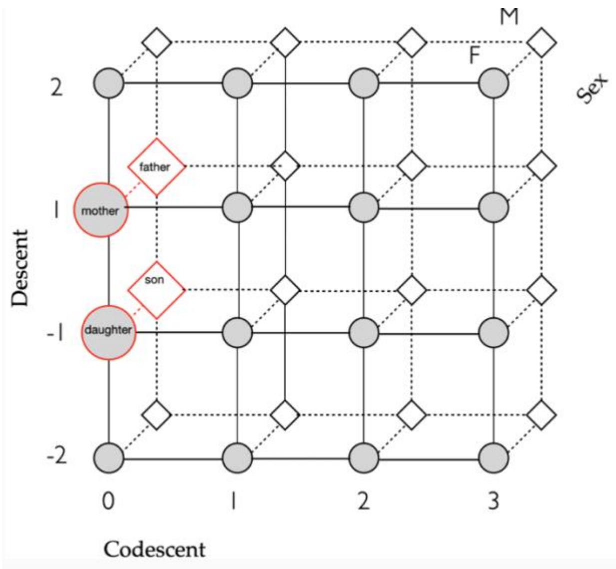

Figure 2- Conceptual space of common kinship relations.

In general, kinship terms appear in expressions with proper names that (in most of the cases) indicate the genders of landmark and trajectory. When this kind of information is available, it increases the inferential power of the expression in question. Consider the sentence “Peter is the grandson of Maria”, represented by the vector < male, -2, 0 >; if by an attention shift, we swap the roles and take Maria as trajector and Peter as landmark, we will obtain the symmetrical vector with respect to the "horizontal" dimension: <female, 2, 0 >, which “means” “Maria is Peter’s grandmother”. Again, the material inference “Peter is the grandson of Maria, thus Maria is Peter’s grandmother” would be explicated as an attention shift that reconfigure the conceptual space by reprofiling the original trajector/landmark alignment and returning a new vector representing the meaning of the conclusion. Notice that if we do not have proper names, the material inferences that can be drawn are less precise. For instance, from “*x* is the grandson of *y*” we can only materially infer “Male(x)” and “grandfather(y, x) or grandmother(y, x)”.

Like many concepts in natural language, Kinship terms are culturally grounded and have some degree of cross-linguistic variability (see, Read, Fischer, & Lehman 2014). For instance, in Spanish there is no lexical concept for gender-neutral brother/sister relations, like “sibling” in English. There is evidence showing that speakers of languages with significant differences in their representation of kinship structure think about these relations in different ways (cf., Read 2013). Within the semantic-based view of inference defended here, this kind of phenomena is completely expected, since reasoning depends directly on the structure of conceptual representation.

The purpose of this section has only been presenting, through some basic examples, a strategy to explicate material inferences in terms of Conceptual Spaces. Nevertheless, a robust model of this type of inference would require generalizing this kind of analysis to account for the inferential patterns associated with the most common lexical types in natural language, something that remains to be done.

5. Conclusions

The aim of this chapter was to argue in favor of a semantic-based view of inference that challenges the traditional formalist approach that put logical form as the driving force of reasoning. My analysis is motivated by Sellars' notion of material inference, with the difference that I understand material rules as based on semantic intuitions about the structure of concepts. My proposal builds on two assumptions: (1) material inferences are transitions between mental states that exploit properties of the semantic structures of the lexical concepts in the premise-conclusion; and (2), they can be understood as cases of reprofiling a designatum within a conceptual base driven by an attention-based mechanism.

Through different examples, I have provided guidelines on how to use Conceptual Spaces as an explanatory framework for this kind of inferring. However, a systematic theory of material inferences should explain the inferential affordances of each word class, according to its typical underlying representational structures. If such a theory is feasible, it would naturally fit into a recently developed framework that explains nonmonotonic inferences and category-based induction as cognitive mechanisms that exploit properties of Conceptual Spaces (Osta-Vélez and Gärdenfors 2020, 2021).

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