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Why Maps Are Not Propositional∗

A number of philosophers and logicians have argued for the conclusion that maps are logically tractable modes of representation by analyzing them in propositional terms. But in doing so, they have often left what they mean by 'propositional' undefined or unjustified. I argue that propositions are characterized by a structure that is digital, universal, asymmetrical, and recursive. There is little positive evidence that maps exhibit these features. Instead, we can better explain their functional structure by taking seriously the observation that maps arrange their constituent elements in a non-hierarchical, holistic structure. This is compatible with the more basic claim advanced by defenders of a propositional analysis: that (many) maps do have a formal semantics and logic.

§1. Introduction

Contemporary theorists of representation often assume a dichotomy between two basic modes of representation: 'imagistic', pictorial, or depictive representations, and 'discursive', logical, or propositional ones (Fodor 2007). Rational thought and inference are assumed to require implementation with representations that are internally structured and systematically interconnected; but only one sort of structure is assumed to suffice. In one version of the view, found in philosophers like Rey (1995), Bermudez (2003), and Devitt (2006), genuinely logical thought is assumed to require a specifically linguistic medium. A more ecumenical stance allows for the possibility of non-linguistic logical thought, but because any differences in representational structure are assumed to be ultimately notational (Sober 1976, Szabo 2012).

Given this background picture, establishing that apparently non-linguistic representational formats are logically respectable entails establishing that they are propositional. And establishing this in turn requires specifying what 'propositionality' (and 'pictorial') amounts to. But this can seem like a frustratingly fruitless and abstract terminological matter (Johnson 2015). Given that predication is both relatively well-understood and the canonical mechanism for constructing propositional representations, an alternative strategy is to establish that maps are specifically predicative. This strategy has been pursued by Pratt (1983), Casati and Varzi (1999), and Blumson (2012), among others. Against this, extending work by Sloman (1978), Camp (2007), and Rescorla (2009), I argue that cartographic structure is neither predicative nor propositional. Maps work in an importantly different way from sentences.

The existence of a multiplicity of representational formats has potentially significant implications for the philosophy of mind, which I will not explore here. One notable implication is that by attending to

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the distinct profiles of expressive and computational strength and weakness generated by different representational formats, we can begin to achieve a clearer understanding of key differences among human and non-human cognitive abilities. Instead of an apparent chasm between mere imagistic perception and full-fledged linguistic representation, we can identify families of distinct, sometimes overlapping representational systems that exploit various representational principles in different combinations (Camp 2009, 2015; Camp and Shupe forthcoming).

My discussion here aims only to establish the need for a formal, non-propositional semantics for an important but restricted class of maps. Actually providing such a semantics is a topic for another day. So is extending the conclusions here, which will focus on external, physical maps, to questions about cognitive architecture. Further, in order to focus on establishing the core claim that maps are not propositional, I will simply help myself here to the assumption that maps do have some sort of formal structure, and in particular that many familiar maps are compositional. This should not be highly controversial for very simple maps like seating charts (Camp 2007), or even for more sophisticated systems that employ a fixed base of markers and coordinates – which are the sorts of maps that have been at issue in the debates between advocates and skeptics of predicative and propositional analyses. These cartographic systems permit the construction of indefinitely many maps, such that the representational import of any one map is a rule-governed function of the values of its constituent markers and the locations at which those markers are placed. Thus, such systems are clearly systematic and productive – the classic motivations for compositionality.

Ultimately, I believe we can construct a formal, compositional semantics for a much larger class of maps, including those that lack a fixed base of markers, like familiar highway maps and atlases. Such map systems employ lines and areas of potentially continuous variability to denote the shapes of objects like roads, forests, and lakes. They often also employ multiple further dimensions of potentially continuous variation: for instance, a map might use variations in hue, saturation, and texture to represent variations in the total quantity, duration and intensity of rainfall (MacEachren 2004). However, they still permit a robust formal analysis, insofar as marks can be typed in wholly formal (ultimately physical) terms and assigned contents via a straightforward algorithm on those types, and the entire map's content is fully determined by the way those marks are combined. And like their simpler siblings, they can employ markers whose connection to their denotation is arbitrary rather than imagistic (Camp 2007, 2015).

I believe these maps are still fundamentally compositional, despite the absence of a finite lexicon. If we reflect on the reasons for caring about compositionality in a theory of meaning, we should accept a more abstract notion of 'part' on which the representational import of an entire representational unit is an exhaustive, bottom-up function of its parts and mode of composition, so long as these 'parts' are formally individuated.[1] I bracket this more controversial claim about compositionality here, however. Readers can either focus just on maps with a finite base and mode of combination, or else grant that a formal semantics is possible for a wider range of maps, whether or not it deserves to classified as compositional.

Our question, then, is whether maps are propositional representations. In §2, I argue that if the question is to be a substantive one, we should interpret propositionality in terms of functional structure; and that propositional structure is characterized by being digital, universal, asymmetrical, and recursive. In §3, I present the two most developed semantics for maps, by Pratt (1983) and Casati and Varzi (1999), both arguing that maps have a specifically predicative structure. In §4, I examine the elements and constructions that are posited by a specifically predicative analysis and by a propositional analysis more generally: names and predicates, and complex propositions and truth-conditions; in each case, I argue, the application to maps is awkward at best. Standard maps exhibit expressive limitations and advantages that are left unexplained on a propositional analysis. By contrast, a non-hierarchical, holistic structure better explains the distinctive contours of cartographic representation.

§2. Propositionality and Non-propositionality

If the question about whether maps are propositional representations is to be a fruitful one, the term 'propositional' needs to be interpreted in a way that integrates with other standard uses of the term, that is specific and robust enough to make substantive claims, and that marks a useful distinction among representational formats. In particular, it should not follow trivially, just from the operative notion of propositionality, either that all representations are propositional, or that only sentences are. But 'propositional' is used in many different, sometimes cross-cutting ways in philosophy and related fields. In this section, I survey the leading philosophical understandings of propositionality, and articulate a notion of propositionality that is grounded in, but more general than, the functional structure of language. My aim in this section is just to establish a useful, non-question-begging framework for conducting the debate about maps' propositionality – a framework I think is implicitly shared by current parties to the debate.

2.1 Propositions as Sets of Possible Worlds

Many philosophers hold that a representational state or entity has propositional content just in case it can be the object of belief, can be shared by multiple cognitive agents, and can be evaluated for truth and falsity. A particularly elegant way to capture these requirements treats propositions as partitions

[1] Even with this expansive notion of compositionality, the claim that natural languages are compositional is best seen as a regulative ideal (Szabo 2012); the operative notion of 'language' in most discussions of cognitive architecture is that of formal predicate calculus rather than e.g. English (Camp 2015).

in a space of possibilities (Lewis 1968, Stalnaker 1976). This sense of propositionality clearly does not trivialize the question whether a given intentional state or entity is propositional: for instance, merely considering mental states, it counts both objectual and expressive attitudes as non-propositional.[2] Moreover, it links propositional content closely to information, in a way that has clear theoretical utility, as evidenced by the ubiquity of possible-worlds accounts in, for instance, philosophical and linguistic accounts of conditionals, epistemic modals, and many other constructions (e.g. Stalnaker 2014). So it has a lot going for it.

Even so, interpreting the question whether maps are propositional in such coarse-grained terms does run a significant risk of trivializing questions about representational format, by rendering all truth-assessable representations propositional. Like pictures, maps have informational contents: they represent situations, and make cuts in possibility space. As a result, they are plausibly assessed as true or false, although that assessment is typically relativized to certain purposes, and often also to just a subset of a given map's overall representational content.[3] Further, again like a picture, the informational content of any given map can plausibly be captured in an (extremely long) sentence, at least in the weak sense that the map or picture itself can be recovered from that sentence by pixelating the picture to an arbitrarily fine degree of resolution and specifying the values of colors (perhaps using demonstratives) for each pixel (Anderson 1978, 253; Crane 2009, 460).

It is natural to respond that such a weak sense of equivalence ignores crucial implicit assumptions about how users extract information about the world from those representations. This response is correct, but of limited use for a proponent of the coarse-grained analysis of propositions here. Within a possible-worlds framework, many of the cognitive, semantic, and pragmatic phenomena for which propositions are traditionally invoked must instead be explained by appeal to the different *ways* or forms in which a common informational state can be presented. And since maps, sentences, and pictures do take different forms, and produce distinct cognitive, semantic, and pragmatic profiles, the questions that theorists attempt to explore by asking whether maps are propositional end up being recapitulated in terms of those forms and functions.

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[2] Thanks to Alex Gzrankowski for pressing this point.

[3] Crane (2009) argues that pictures are non-propositional on the ground that truth is an absolute property and accuracy a matter of degree, and that pictures can only be accurate, not true. I do think the difference between truth as an on-off matter, and accuracy as a graded, respect-relative one points to a correlative difference between propositions as discrete, digital representations, and more holistic, analog modes of representation. However, I also think that we do often assess maps for truth as well as accuracy, and that such assessment is more natural for maps than for pictures. Further, intuitive assessments of truth are themselves often interest- and context-relative, and it is often at least as natural to assess complex collections of sentences, like books, for accuracy as for truth. I lack the space to fully discuss these differences here. Thanks to Peter Godfrey-Smith for discussion.

In order for the question of representational format to be a substantive one, we need to interpret it as concerning *how* maps and other representational systems work, where this involves more than identifying either what information they represent or the physical marks that constitute any one representational vehicle. Instead, we need to determine how such marks function within a larger system, including how users access and manipulate that representation, what other representations the system generates, and how altering any one aspect of any given representation affects its overall representational content. The identification and assessment of representational form is thus inevitably directed at a complex package of representations and interpretive processes (Anderson 1978, 263). At the same time, the question is also not directed at the representational system's ultimate underlying implementational mechanism, given that the same functional pattern of representations and operations can be instantiated in physically distinct ways (Marr 1982).

In his classic discussion of the mental imagery debate, John Anderson proposes a minimal addition to the purely informational model of propositions which shifts the analysis to the level of a representational system's functional profile. He takes propositions to possess three features. First, they have truth-values. Second, they are abstract, in the sense of not being essentially tied to a particular mode of expression; Anderson interprets this condition in terms of invariance across at least some range of paraphrases, or substitution of semantically equivalent marks. Third, they have explicit formation rules, which determine well-formedness and impose a "structural aspect" that underwrites psychological laws and/or logical rules of inference (1978, 250).

By understanding propositions as truth-evaluable, abstract, and structured, Anderson shifts the analysis from a purely semantic one, concerning only what is represented, to a partially syntactic one about form what principles govern the system's formation, compilation, and manipulation of representational states or entities? At the same time, by understanding this form abstractly, in terms of permutations over multiple classes of distinct expression-types, he frees propositions from any essential connection to particular vehicles.

I think this locates the question at the right level. Anderson's own aim in proposing this model is merely to distinguish propositional from imagistic representations. And for this purpose, the combination of abstractness and structure is arguably sufficient, since it is far from obvious that images do have formation rules that determine well-formedness or underwrite systematic manipulation. However, Anderson's criterion simply assumes that all structured representations have fundamentally the same structure – an assumption that, as we saw at the outset, is ubiquitous in discussions of representational type. In the current context, though, it answers the question whether maps are propositional by stipulation. Maps, graphs, diagrams, and sentences all meet all of Anderson's criteria. In particular, they are all abstract in his sense of not being essentially tied to any particular implementation: many different types of marks can represent trees on a map, or magnitudes in a graph. Further, any given cartographic or diagrammatic system might employ multiple markers for what is in fact the same entity (arguably unlike a picture): thus, a map of the night sky might have functionally distinct markers for the Morning and Evening Stars. At the same time, these representational systems also display differences among each other and from sentences, in their modes of operation, patterns of breakdown, and expressive power (Camp 2007). What we want to ask is whether these differences are mere *ad hoc* contingencies, or reflect a more fundamental difference. And to even ask this question, we need to distinguish, at least in principle, among at least some types of structured representations; in particular, we need to identify a type of combinatorial structure that is distinctive to propositions, without being stipulatively identified with sentences. Thus, I now turn from coarse-grained, possible-worlds accounts of propositions to ones that posit internal structure.

2.2 Structured Propositions

The two classic models of structured propositions, Fregean and Russellian, differ in their constituents and criteria of individuation. Both count as abstract by Anderson's criterion, in allowing multiple distinct representations – most obviously, translations in different languages – to express the same proposition. The choice between Russellian and Fregean propositions turns on theoretical matters outside our concern, which is just about propositional *structure*; and in this respect the two are quite similar.

On Frege's model, functional application is a general combinatorial mechanism. In the basic case, an object serves as input to a special kind of function, which Frege calls a 'concept', that delivers Truth or Falsity as its output; a Fregean proposition, or Thought, is then a sense or mode of presentation of Truth or Falsity which combines the modes of presentation of the represented object and concept. The different roles played by objects and concepts – the former serving as input to the latter – establishes a corresponding asymmetry between types of senses, and in turn of the signs that express them. As Frege (1892, 54) famously puts it, "For not all parts of a thought can be complete; at least one must be 'unsaturated', or predicative; otherwise they would not hold together." More complex propositions are formed by recursive application of the same functional machinery.

Where Fregean propositions are types of abstract thoughts, individuated by cognitive significance, Russellian propositions are ordered *n*-tuples of objects and properties. Thus, where Frege introduces the metaphor of "saturation" as a gesture at why the senses of concepts form whole thoughts when 'completed' by the senses of objects, Russell faces the question more directly of what unifies an ordered sequence into a truth-evaluable whole. The most common answer appeals to the metaphysical structure of instantiation: basic atomic propositions are complexes of objects instantiating properties;

more complex propositions are property-object complexes instantiating higher-order relational properties. An alternative answer, picking up on an equivalence between predication and saturation suggested by Frege above, appeals directly to predication (King 2007).

Given that both Frege and Russell were interested primarily in constructing the predicate calculus as an ideal formal language for scientific inquiry, and secondarily in analyzing natural language, it is no accident that both analyze propositional structure in a way that establishes a close connection to predication. However, for our purposes, without an independent grip on what predicative structure itself is, we risk distorting the question of whether maps or other formats are propositional by fixating on features of logical or linguistic structure that arise from contingent implementational factors. Rescorla helpfully characterizes predication as "a compositional mechanism whereby [denoting] terms fill the argument-places of a predicate that carries their denotations into a truth-value" (2009, 177). Like Rescorla, I will argue that maps do not exhibit predicative structure, albeit on somewhat different grounds. However, I am primarily concerned with this question as an instance of the more general issue of propositional structure, as a way of achieving a more systematic understanding of significant dimensions of variation among representational structures. So we still need a characterization of the genus of which predication is a canonical species.

Moreover, there are lively debates within linguistics about the combinatorial structure of language, and the role of predication in particular. On some views, predication is a special case of a fully universal principle of functional application; while many think that additional mechanisms, such as predicate modification, are required (Heim and Kratzer 1998). And many others posit a different, more general mechanism, such as Merge – an operation of set formation targeting two objects (Chomsky 1995, Collins 2011). Finally, we should not foreclose by stipulation the possibility that maps lack predicative structure at the atomic level, but that entire maps can still be analyzed using a propositional logic that combines non-predicative atomic units into larger wholes.

We thus have several reasons to inquire into propositional structure without essentially tying it to predication. Stepping back, we can identify four key features shared by all five of the candidates for propositional structure so far mentioned: conceptual saturation, property instantiation, predication, functional application, and Merge. First, the candidate combinatorial operations are highly *digital*: they take a small number (typically, a singleton or pair) of discrete elements as inputs. Second, they are *universal*, or at least highly general: they can combine a wide range of elements. Thus, instantiation is a highly general metaphysical relation binding many different kinds of properties and objects into situations or facts, while functional application is a highly general operational relation taking many kinds of objects and functions and delivering truth-values. Third, the candidate combinatorial operations are *asymmetrical*: either just one element must be of a type that enables it to serve as input for the other; or the operation itself creates an asymmetry among elements via the order of application.[4] Fourth, the operation is *recursive*, so that its outputs can serve as inputs to the same operation: thus, quantifiers are functions that take functions as inputs and deliver truth-value as outputs. The recursive application of an asymmetrical relation produces *hierarchical* structure, containing nested iterations of the same type of representation. Other representational formats, like genealogical trees, employ combinatorial operations that exhibit some of these features to at least some significant degree (Camp 2009, 2015); and some will deny that even language exhibits all of these features. But together, they offer a cluster of features that underwrite a substantive notion of 'propositional' that is both familiar and relatively well-specified.

I will argue that maps exhibit a very different sort of structure: that they are non-hierarchical, holistic modes of representation. In §3, I briefly present the leading formal analyses of maps, which treat them as having specifically predicative structure. In §4, I survey various features we would expect maps to display if they did employ predicative or more generally propositional structure.

§3: Predicative Map Semantics

In this section, I present two leading proposals for a cartographic semantics, both claiming that maps have propositional, specifically predicative structure. On the account offered by Roberto Casati and Achille Varzi (1999), a map is a collection of colored regions. Map-regions are defined by their mereotopological relations and assigned to regions in the world by a mereotopologically well-behaved interpretation function *f*, so map-regions are parts of, or contiguous with, one another if and only if the world regions to which they are assigned are related in the same way (Casati and Varzi 1999, 194). A color patch covering such a region is "an unsaturated predicate, which gets saturated when it is juxtaposed to a map region" (199, 192). An "atomic map-stage" is a mereological fusion of all regions of a single color, *F,* on an entire map, with a two-part truth condition. First, all of the world regions denoted by *F*-colored map-regions must have the *F*-associated property; and second, the complement of those regions must lack that property (1999, 194). Casati and Varzi hold that the semantics is "compositional" and "recursive" (1999, 193) insofar as entire maps are constructed by layering atomic map-stages; and the truth-condition for the entire map "results from the conjoined truth" of all of its map-stages (1999, 195). The upshot is that maps "are propositionally structured albeit in a peculiar way" (199, 191).

In the interest of tractability, Casati and Varzi restrict their semantics to a narrow class of formalized cases. They do not consider maps containing arbitrary labels; nor do they address richer geometrical relations, such as distance, direction, and orientation. By contrast, Pratt (1993)'s account

[4] E.g. the set formed by Merging the singleton set of Bob with the set of love and Mary is {Bob {love, Mary}}, which differs from the set formed by Merging the singleton set of Mary with the set of love and Bob:{ Mary {love, Bob }}.

hews more closely to a linguistic model by taking as its basic case the locating of word-like symbols. Following Schlichtmann (1985), Pratt treats an individual "map-symbol" as having two aspects: a "substantive component" X (e.g. '🖃') and a "locational component" (x, y), each with a distinct interpretation function. The symbolic function I assigns symbols to a domain of individuals in D (e.g. assigning the post office to '🖃'); while the spatial function μ assigns locational components to places in a space S. An individual map-symbol is true just in case $I(X)$ is located at $\mu(x, y)$ (Pratt 1993, 80). Symbols covering extended regions are treated as true (roughly) just in case the element assigned to that symbol-type is present at all locations within the relevant region (1993, 86).[5] Finally, an entire map is true if and only if, first, all of its individual map-symbols are true, and second, the overall extensions of the substantive components are *minimal*, so that there are no elements in D of the type assigned to X by I that are not located on the map (1993, 82).

The semantic analyses proposed by Casati and Varzi and Pratt are very different, in ways we will consider. But they both arguably get the truth-conditions largely right – at least, for the classes of maps they consider. They thereby demonstrate that many maps are indeed formally structured in such a way that it is possible to assign truth-conditions to entire maps by identifying stable, formally individuated parts, and assigning a stable semantic interpretation to those parts and to their mode of combination. By contrast, it is much less obvious that an analogous formal semantics is constructable for pictures. Further, if it worked, a propositional model would have important explanatory advantages. Although there will obviously be some implementational differences, a common propositional code would streamline informational integration across representations couched in apparently different formats (Pylyshyn 2003). We might also look to more sophisticated aspects of predicate logics for inspiration about how to extend the analysis to address more complex maps.

Despite these potential advantages, I will argue that neither a predicative nor a more generally propositional analysis captures the way maps work. There is little positive evidence that maps employ a structure that is digital, universal, asymmetrical, recursive, and hierarchical. On the one hand, the expressive power of distinctively propositional structure is representationally inert if it is indeed present; and on the other, the constraints associated with propositional structure impose restrictions on how maps are constructed and manipulated that don't appear to be independently warranted.

§4. Problems with Propositionality

§4.1: Names

[5] Pratt argues that issues involving figure-ground ambiguity undermine a straightforward interpretation along these lines problematic; but his various disambiguated analyses all share the common structure stated in the text.

Casati and Varzi explicitly state that "map regions are to be considered symbols in themselves, akin to individual constants such as linguistic proper names" (1999, 191). While Pratt does not say this, he too analyzes map-locations as object-level inputs to predicates; and like them, he treats map coordinates as mere 'tags', where the assignment to map-locations of world-location-values is determined directly by the interpretation function, without condition-determining mediation. So the first question we need to ask is whether map-locations do behave like names.

The most literal, straightforward understanding of the predicative model would seem to entail that coordinates are essential to a map's well-formedness. That is, if basic map markers (arbitrary symbols on Pratt's analysis; colored regions on Casati and Varzi's) are predicates, then in the absence of an assignment from map-locations to world-locations, a map should just be a collection of predicates denoting a collection of properties, rather than a well-formed, fully 'saturated', truth-condition-determining whole.

At least two factors make it make it less than straightforward to assess this prediction. First, where linguistic names are distinct identifiable marks, maps typically lack purely location-denoting markers; the closest analogue would seem to be grid quadrants (e.g. 'C4'), but these are often marked only by lines at the map's periphery. So it's not obvious, in purely syntactic terms, what a collection of mere unsaturated map predicates would look like, and how it would differ syntactically from a map that has been assigned world-locations. Second, the interaction between syntactic structure, semantic content and pragmatic supplementation is considerably less systematic in maps than in language – where it is already far from straightforward. In particular, just as utterances of isolated linguistic predicates can be elliptical for complete sentences and used to make complete assertions (e.g. 'Gone!') and other speech acts (e.g. 'Gone?'), the proponent of a predicative analysis can hold that unarticulated coordinates are indeed implicitly present in maps.

Even with these caveats lodged, though, it seems that having assigned world-locations is not essential to a map's being either syntactically well-formed or semantically interpreted. For instance, I might make a map of the estate I plan to construct if I win the lottery, deciding where the pond should go relative to the flower and vegetable gardens, the alder copse, the circular driveway and the grand house's corner tower. Not knowing the extent of my future riches, I might refrain from determining a scale for the whole estate; and certainly I have not determined where it will be built. Yet my map still fixes substantive satisfaction conditions: it rules in some ways the world could be and out others. When I do win, I could offer it as a command to my realtor/architect team: make the world be *this* way. Likewise, if I were CEO of a drugstore chain obsessed with maximizing efficiency and the uniformity of patron experience, I might construct a map indicating where each type of item (toothbrushes, cosmetics, soda) is to be placed in every store; and I might issue the map as an order to my workers to arrange their stores in that way. Once they have obeyed, I might issue copies for patrons to use in navigating any store.

The coherence of these cases undermines the *prima facie* prediction that maps with uninterpreted coordinates should be at least semantically, and possibly syntactically incomplete. Further, it suggests that map coordinates do not always function as names, because they are not necessarily rigid: my architectural blueprint could be, and my drugstore map is, satisfied by many different locations. Finally, these cases point to another way in which our actual use of maps fits poorly with assigning an essential, name-like role to map-locations. Often, our only practical interest in, and epistemic access to, the world-locations that are denoted by map-locations goes through the objects and properties located at them. (Indeed, this is reflected in Casati and Varzi's semantics, insofar as map regions are constituted *as* syntactic elements, with an object-level denoting function, *by* being colored.) More generally, many maps – not just informal ones drawn on napkins, but published tourist maps – rely on landmarks to implicitly fix the interpretation function from map-locations to worldly ones.

Finally, it is notable that the metaphysical distinction between objects and properties, which is closely mirrored by the distinction between 'saturated' subjects and 'unsaturated' predicates in language, is not nearly as important in maps. Insofar as the distinction between individuals and properties shows up, it seems to be an *ad hoc* constraint (a 'meaning postulate') on whether the marker can be multiply tokened on a single map. This might seem like an expressive limitation of maps: that it fails to mirror a deep metaphysical feature of the world (Fodor and Pylyshyn 1988). But it might instead be construed as an expressive advantage, given the tradition of skepticism about the notion of subsisting essences that the object/property distinction seems to entail (Camp 2007, 157). Some theorists maintain that individuals and species just are homeostatic clusters of properties (Boyd 1999); while others hold that no real reference to individuals is possible without quantificational structure (Quine 1958, 1995; Davidson 1999) – or at least, that there is a level of cognitive representation at which no genuine distinction between individuals and kinds can yet be drawn (Millikan 1998).

All of this suggests that rather than map-locations functioning as names, their closest propositional analogues might be quantifiers. A map-location on a map that employs an implicit, landmark-relative interpretation function would then have roughly the significance of 'the location of the denotation(s) of this marker'. My architectural blueprint would count as true just in case there existed some set of appropriately spatially-related world-locations to which the map-locations could be assigned, such that the object/properties denoted by the markers at those map-locations were indeed located at those world-locations. And my store locator maps would be true of a particular store if it arranged its stock in the specified pattern; while my master map would be true only if and only if all my stores were laid out that way. In §4.3, I canvass the possibility of more direct evidence for quantificational structure in maps.

First, though, in §4.2, I examine the predicative view's core assumption: that map markers predicate properties (or objects) of locations.

§4.2: Predicates

In this section, I argue that there are at least two deep disanalogies between predicates as they function in language and the way they should function in maps given a predicative analysis.

§4.2.1: Expressive Limitations on Predication

The first difference follows directly from the account developed in §2.2 of propositional structure. A distinctive feature of predication, as of propositional operators more generally, is that a very wide range of predicates can be predicated of a wide range of objects. In its strongest form, any expression of predicative type can be combined with any expression of subject type. Many theorists have wanted to impose categorical restrictions on such combination, on the ground that sentences like 'Julius Caesar was a prime number' are too absurd to express genuine thoughts. I reject such semantic restrictions (Camp 2004). But actual natural languages impose many syntactic restrictions within expression types, some but not all of which appear to have at least some semantic basis (Johnson 2004). Even if we include both semantic and syntactic restrictions on predication, however, it remains true that language enables us to say of a very wide range of things that they are a very wide range of ways. And a key reason for this generality is that predication itself contributes very little to the overall semantic import of the sentence, beyond simply *applying* the denoted property to the denoted object. The point holds with even greater force for other candidate propositional operations: saturation, functional application, and Merge (Camp 2015).

By contrast, the 'propositions' that result from placing map-markers at locations are much more expressively restricted: they always say '*X* is *here'*. This restriction does not arise from any inherent constraint on the meanings of the markers themselves, which can be just as arbitrary as in language (indeed, map-markers often are words). Rather, they arise because the *placement* of a marker at a map-location has a fixed significance: that the denoted object/property is located at the denoted world-location (where, as we saw in §4.1, those world-locations may be specified in relational rather than absolute terms). The fact that it is impossible to 'predicate' object/properties of anything *but* locations strongly suggests that the combinatorial operation itself is something other than predication.

To see the contrast more clearly, consider a branching tree structure, interpreted as instantiating either a genealogical or a propositional structure (Camp 2009). In both cases, the combinatorial principle is digital, recursive and asymmetrical, and thus hierarchical. But because in a genealogical tree, a common node means something very specific – common ancestry – such trees can only represent entities *as* being related by ancestry and descent. In principle, we could interpret genealogical trees as having propositional structure, and claim that their users are only ever interested in representing a single topic; but the imposition of this expressive limitation would be *ad hoc*. It makes more sense to treat the combinatorial principle itself as semantically loaded, in a way that constrains the sorts of inputs for which it can deliver true representations. Similarly for maps, we could posit an *ad hoc* constraint blocking maps from exploiting the full generality of propositional structure; or we could posit a distinct combinatorial principle – of using spatial structure to represent spatial structure – from which this expressive limitation follows directly.

§4.2.2: Predicates and Absence

The second point also concerns a respect in which the predicative view is committed to treating predication as having an unexplained representational import in maps as compared to language: the 'Absence Intuition'. In §4.1, I considered collections of map-markers that lack assigned world-locations, and concluded that they still comprise a well-formed map, which can sometimes also be assessed for truth, depending on the 'force' with which it is pragmatically presented. What about the converse case, of map-locations without markers? If map-markers are predicates, then *prima facie* one would expect unmarked map-locations too to lack truth-conditions: they should be 'bare' location-denoters. Likewise, one would expect deleting a single marker to produce a syntactically incomplete expression – or at least, to delete just one proposition. However, both Pratt and Casati and Varzi construct their semantics quite differently, in order to respect the intuition that the *absence* of a marker-type at a map-location represents the absence of the denoted object/property from the denoted location.

As noted in §3, Casati and Varzi implement this with a 'complementation' clause on the truth-conditions of atomic maps: a map stage for color *F* is true just in case all *F*-colored regions possess the associated property, *and* the complement of those regions does not possess that property (1999, 194). The second clause entails both that maps never contain bare, 'unsaturated' locations, and also that deleting a marker introduces the absence of the denoted property rather than simply erasing the associated proposition. We might already worry that the first clause renders atomic propositions in maps too 'big': insofar as we can intuitively assess individual sub-regions within an atomic map-stage for truth, an atomic map stage does not constitute the most basic unit of information and assessment for maps. The second clause amplifies this worry at a more fundamental level, because it makes the basic unit of assessment in maps depend not just on just how things are at the world-regions where the denoted object/property is represented as being located, but also on how they are at world-regions where the denoted object/property is *not* represented as being located. But, as Michael Rescorla (2009) argues, predication just *is* a function from the denotation of the predicate's input to a truth-value. Moreover, as I argued in §2.2, propositional structure more generally employs a recursive, asymmetrical operation which delivers a unique output given the values of its inputs, where the number of inputs is very small, typically a singleton or pair. Casati and Varzi's semantics either makes the value of the whole proposition depend on something other than the values of its parts, or else individuates atomic propositions in a way that doesn't fit with the way they define the individual parts.

Pratt's treatment of Absence avoids both of these problems. His basic unit of assessment is a marker at a single point. A region is assessed as true iff only all points within that region instantiate the object/property denoted by the symbol. More importantly, he treats Absence as arising from a general, entirely format-neutral feature of default reasoning: an inference from the failure to explicitly say that something is abnormal to the conclusion that it must be normal. This general inference can be captured within a predicate logic by stipulating that an entire set of formulae counts as true in a model just in case the individual formulae are true and the predicate *abnormal(x)* has no unmentioned members. Analogously, Pratt holds that an entire map is true iff each of its individual symbol-pairs is true, and the overall extensions of the symbols' substantive components are all minimal (or '*circumspect*'), so that there are no unmentioned elements of those extensions within the entire represented domain (1993, 82). Thus, unlike Casati and Varzi's analysis, this model does assign truth-conditions that depend only on the values of a given symbol-location pair; Absence is enforced as a condition on the truth of an entire map.

Although Pratt's analysis avoids the letter of Rescorla's criticism, it still introduces a fundamentally holistic element to the determination of truth-conditions, for which the propositional analysis has no motivated explanation. Rescorla concludes that Absence "reflects [a] fundamental representational disparit[y] between attaching a marker to a coordinate and attaching a predicate to a singular term (2009, 197). I am not convinced that the difference is quite so robust. Although the Absence Intuition is very strong for published maps designed for general navigation, many other maps are more informal, more restricted in their representational purposes, and/or weaker in their epistemic authority; and for them the intuition is much weaker (Camp 2007, Blumson 2012). For instance, if I draw a map showing you the route from the hotel to the party, then my placing a gas-station-denoting marker next to a McDonald's-denoting-marker just before a crucial left turn would not normally be taken to represent the absence of any other gas stations along the route. The assumption in such cases is only that the map will contain markers for all *known, relevant* objects and properties, where what counts as relevant may be temporally and functionally quite restricted.[6] Further, parallel forms of default reasoning involving circumspection pervasively generate scalar implicatures in linguistic communication. Linguists

[6] Similarly, Kulvicki (2015, 152) cites official navigational maps, which mark only those structures visible from the sea that are relevant for navigation (US Department of Commerce and US Department of Defense (2013: 6, 26).

generally take such inferences to be merely pragmatic, although some such inferences arguably produce genuinely semantic effects (Chierchia 2004). Perhaps a parallel analysis is appropriate for at least many maps.

John Kulvicki (2015) takes the Absence Intuition to be pervasive and robust enough to warrant semantic treatment. Like Casati and Varzi and Pratt, he claims that maps predicate properties of locations, but argues that they "organize" those predicates in a fundamentally different way than sentences. This is partly because they exploit spatial structure (as we'll discuss in §4.3); but also because they introduce families of incompatible predicates "en banc" (2015, 158). So, if blue denotes water and green denotes land, the incompatibility between being simultaneously blue and green mirrors a corresponding incompatibility between being simultaneously sea and land. (Incompatibilities among markers may also be defined purely conventionally.) In the simplest case, the incompatibility is just between the presence or absence of a single isolated marker; but many "incompatibility classes" contain indefinitely many marker-types, of arbitrarily fine-grained difference. The number of contrasting marker-types in the class defines a "degree of freedom" for how things could be at that location: for instance, an incompatibility class containing blue, green and beige, representing land, water, and beach, has three degrees of freedom. Markers from distinct incompatibility classes are mutually compatible: for instance, if distinct textures represent variation in elevation – smooth, rugged, mountainous – then a single location could be both green and notched.

In effect, Kulvicki saves the claim that maps predicate features of specific locations from the threat of holism posed by the Absence Intuition by proposing a systematic meta-semantic constraint on relations among predicates. The presence of a marker at a location simply predicates the denoted property of that location. But the absence of any marker from within a given incompatibility class counts as a predicate in its own right, which denotes the "zero value" for that class: the property of having *none* of the features in the class.

The proposal that maps employ families of markers linked by relations of incompatibility is attractive. It explains Absence by citing a deep and ubiquitous feature of maps. It also naturally generalizes from absolute incompatibilities – e.g. that green-land entails *not* blue-water – to maps' frequent use of marker-type-families to express positive relational information: for instance, the use of greater color saturation to represent higher density of rainfall.[7] Nevertheless, because Kulvicki's analysis retains the claim to a fundamentally predicative structure, it does nothing to explain why maps should exhibit this systematic interpretive constraint, and in particular why it should contrast with language. In

[7] Further, it plausibly helps to address the worries that Pratt (1993, 84 ff.) raises about figure-ground ambiguities in connection with Absence, which Pratt takes to ultimately undermine the possibility of a fully formal semantics that could explain map use.

this respect, Pratt's analysis of Absence in terms of format-neutral principles of default reasoning offers a deeper explanation.

Kulvicki's discussion of how map systems "organize" their constituent expressions into families points to a further dimension, beyond spatial organization, on which maps are holistic, in contrast to the highly digital structure of propositional representations. As I argued in §2.2, predication and other candidate propositional combinatorial principles generate individual propositions by recursive application of an operation that takes a small (typically single or pairwise) input and delivers a small (typically single) output. Any non-pragmatic treatment of Absence thus fits uncomfortably with the standard propositional model, simply in virtue of introducing a significant degree of holism into the analysis.[8] I will argue in §4.4 that even putting Absence aside, maps' holistic organization is not well modeled by a propositional analysis. Thus, although I believe we should adopt something like Kulvicki's proposal about families of marker-types, we should do so without grafting it onto a predicative or propositional foundation.

§4.3: Complex Propositions

So far, I've been assessing the propositional model at the basic level: of predicates taking object-level inputs to form atomic propositions. When we turn to the ways in which maps compile information about particular locations into larger wholes, the disparities with propositionally structured formats become more stark. On the one hand, propositions are constructed by a digital, asymmetrical, recursive mechanism which creates hierarchical structure of indefinitely nested depth; but this structure is not obviously manifested in maps. On the other hand, maps encode information in a holistic, relational way that is not directly captured with a propositional mechanism.

I mentioned above that the predicative analyst could accommodate cases of 'unanchored' maps like blueprints by appealing to quantification. However, such cases aside, there is notably little role for quantification in maps. In particular, because maps work by placing markers for object/properties at locations, maps (at least, 'anchored' maps) cannot represent purely quantificational information. For instance, on a map, one can only represent that someone with a red shirt is carrying a gun by representing an individual or type as being at some more or less specific location (whether relational or absolute) (Camp 2007, 165). Likewise, one cannot explicitly represent that everyone wearing a red shirt is carrying

[8] The contrast with natural language here should not be overstated. In particular, it is a deep, productive insight in linguistics and the philosophy of language that actual sentences in natural languages occur within extended discourses, with systematic semantic effects (e.g. Roberts 1996/2012, Kehler 2002, Asher and Lascarides 2003). This constitutes another respect in which natural languages depart from the traditional model of predication and propositionality. In this sense, Pratt's analysis of Absence in terms of general principles of default reasoning comports nicely with pragmatic analyses of discourse structure, even though he assigns Absence a global semantic effect.

a gun. At best, one can co-locate all the markers for red-shirt-wearers and gun-carriers, and rely on Absence to communicate that no one else is; but this still requires locating red-shirt-wearers and gun-carriers *somewhere*, and thus includes location-specific, not purely quantificational information.

This limitation suggests that maps are primarily first-order modes of representation: they just place objects and properties at locations. One might be tempted to hold that this is all maps can do. In support of this, one might point to the implausibility of modifying a predicative map-marker denoting red-shirt-wearing by an adjectival map-marker denoting gun-carrying, or of applying a predicative marker denoting red-shirt-wearing to a marker denoting Steve. Again, it seems that all one can do is to co-locate markers for Steve, red-shirt-wearing, and gun-carrying. This suggests that map markers all have the same basic syntactic status, and that the semantic import of co-locating markers is always just the conjunction of their denoted objects and properties.

I don't think maps' restriction to a flat, first-order mode of representation can be quite so absolute. For one thing, there are arguably some cases of nested maps – say, a computer map of a city, where icons for individual buildings expand to maps of the buildings' interiors. More importantly, maps often deploy marks with second- or higher-order significance (MacEachren 2004). For instance, a cartographer might deploy hue to denote the most common disease in the denoted region; saturation to represent the frequency of that disease there; and textural density to represent the reliability or evidentiary status of the representation of disease as having that frequency in that area. The information thereby conveyed is hierarchically structured: not just that disease *x* plus frequency *y* plus reliability *z* are present at this location, but that there is reliability *z* of disease *x* occurring with frequency *y* here.

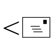
At the same time, I don't think the presence of such layered information warrants an ascription of hierarchical structure to maps. When maps do support a layered semantics, I claim, it is because the markers have been assigned values that mandate this interpretation, not because their syntax is hierarchical. Thus, the assignment of evidentiary status to a certain texture entails, merely in virtue of what evidentiary status *is*, that the presence of that texture can only coherently be interpreted as modifying the significance of another marker rather than the other way around. By contrast, in propositional systems, the asymmetrical nature of the combinatorial operation entails that same set of expressions can often produce semantically distinct results: there is a crucial truth-conditional difference between the sentences "Bob loves Mary" and "Mary loves Bob," which results from the different orders in which the expressions are combined. I have been unable to conjure up analogous syntactically-generated truth-conditional differences in maps. Nor do maps appear to permit the construction of indefinitely complex hierarchical structures by repeated iteration of the same operation, as in "Everyone who is carrying a gun is standing next to someone who is wearing a red shirt, and owes money to someone who was wearing a blue shirt yesterday." Indefinitely deep hierarchical recursion is highly characteristic – some would say definitive (Chomsky, Fitch, Hauser 2005) – of propositional structure. By contrast, cartographic structure appears to be largely, if not absolutely, flat.

§4.4: Conjunction and Holism

The semantics proposed by both Pratt and Casati and Varzi comport with this basically flat structure, insofar as they analyze entire maps as mere conjunctions of atomic representations, and conjunction itself imposes no hierarchical relationship between conjuncts. An exclusive focus on conjunction as the mechanism for compiling entire maps from atomic parts also makes sense, given that maps don't usually obviously represent other sorts of connections between and modifications of basic states of affairs, such as disjunction, conditionalization, temporalization, and modalization.

Pratt's and Casati and Varzi's circumspection about such connectives might be seen as a tacit endorsement of the common assumption that maps lack the capacity to express information relating multiple states of affairs in these ways – although it might also just derive from their focus on simple cases in an initial proof of principle for a formal cartographic semantics. Extending the discussion of layering from §4.3, it is important to note that much as we imagined texture indicating a level of credence about the reliability of the density and quantity of rainfall, so to in principle can maps employ markers that achieve the effect of disjoining, conditionalizing, or modalizing one or more states of affairs. So, for instance, disjunction might be represented by coloring disjuncts in stripes or with flashing lights; or one might use a solid color to indicate the antecedent of a conditional and stripes or flashes to represent the consequent (Camp 2007, 164). Again, however, this effect appears to be achieved semantically rather than syntactically – in virtue of constraints on coherence originating from the values assigned to the marks, rather than in virtue of the way the marks themselves are combined.

Putting aside the question of whether and how maps can represent more complex relations between basic, independently variable bits of information, I will focus on the question of whether conjunction offers a plausible model for capturing the relational structure among located map markers, as Pratt and Casati and Varzi claim. I will argue that it does not: the conjunctive model fails to explain the direct, explicit way in which maps represent multiple spatial relations simultaneously as an integrated whole.

Pratt treats each located marker as a symbol-pair (e.g. <, (x, y)>), with a spatial interpretation function μ assigning the second element to a world-location. But his semantics is largely silent about μ, and in particular about how map coordinates themselves are represented and interpreted. As far as the syntax, semantics, and meta-semantics go, a map simply consists of a list of ordered symbol-pairs. As a result, any constraints on relations among map-locations, and on their implications for relations among the corresponding world-relations – for instance, that (x+1, y+1) is a proximate diagonal neighbor of (x,

y), and that therefore $\mu(x+1, y+1)$ must also be a proximate diagonal neighbor of $\mu(x, y)$ – must be encoded meta-semantically as conditions on μ, much like constraints on symbolic interpretation such as the fact that markers denoting individuals can only be uniquely tokened on a given map.

I am happy to concede that given suitable constraints on μ, Pratt's semantics can derive the appropriate truth-conditions for any given map within its representable class. And if so, then a suitably constrained version of μ plus the substantive interpretation function and the atomic symbol-pairs will support the extraction of any given piece of information about spatial relations from a map. The question we need to ask is how the propositional model, and conjunction in particular encodes and recovers that relational spatial information. On Pratt's account, spatial relations among particular denoted objects/properties – for instance, that the post office is inside the strip mall, that it is closer to the park than to the grocery store, or that it is on the way to the grocery store from the park – will be generated by inference from the individual atomic symbol-pairs plus a set of general propositions – themselves either explicitly encoded in or else derived from the constraints on μ – about relations among the locations denoted by the locational component of the symbol-pair. So information about spatial relations among object/properties is inferentially derived, in part from meta-semantic constraints. This is exactly what we would predict from a propositional analysis, on which predicates ascribe properties to individual locations.

Unlike Pratt, Casati and Varzi explicitly invoke maps' topological structure – the fact that map-locations themselves stand in relations of containment and contiguity – and constrain their interpretation function to preserve that structure. (While they only appeal to topological structure, their interpretation function can easily be supplemented to incorporate more robust geometrical features like direction and distance.) Moreover, because they treat all applications of a given color to map-regions (plus the non-coloring of complementary regions) as a single predicate, there is an important sense in which for them, unlike Pratt, spatial relations among distinct instances and absences of any given object/property are represented directly and explicitly, rather than being inferred. However, insofar as Casati and Varzi analyze entire maps as conjunctions of monochromatic atomic map-stages, they are committed to treating spatial relations among *distinct* object/properties as inferentially derived, much like Pratt.

That is, much as predication just *is* an operation that delivers a truth-value based on the value of its input, so too conjunction just is an operation that takes multiple propositions[9] and delivers truth if and only if all of those conjuncts are true. This means, first, that the conjuncts are treated as distinct representational units, and second, that the truth-value of the whole depends only on truth-values of the parts: conjunction itself sets no further constraints on how those conjuncts are related or represented.

[9] Or other type-similar expressions; we are focused just on propositional conjunction.

Given this, as far as Casati and Varzi's analysis of conjunction goes, a series of atomic map-stages placed side-by-side on separate sheets of paper is equivalent to a series of map-stages that prints them directly on top of one another. But intuitively, only the latter genuinely compiles the common body of information into a unified whole; and only such compilation makes the spatial relations among distinct object/property types directly available.

The difference between direct and derived information about spatial relations is vividly illustrated by the comparative utility of a map versus a list of sentences for solving word problems about how to reconcile multiple geometric constraints, for instance in placing guests at a dinner party or paintings in an exhibit (Camp 2007, 161). As it's sometimes put, what would be an active inference from premises to conclusion in a predicate calculus comes along as a "free ride" in maps and diagrammatic systems (Shimojima 1996; Larkin and Simon 1987; Shin 1994, 2003).

A natural worry is that although such appeals to ease of use, or even to inference versus direct access might be highly intuitive, they are also suspiciously psychological, even phenomenological. Interpreting representations obviously requires significant processing; but much of it is not introspectable, and what is effortful for one user may be automatic for another. In order to make more principled sense of the distinction between direct representation and inferred information, it helps to shift focus from the generation of static truth-conditions to the dynamics of updating.

Maps are integrated representational wholes, in which a single token (which may itself be complex) represents how things are at a given location, and represented spatial relations among denoted object/properties are encoded by the spatial relations among those various tokens. As a result, moving or otherwise altering any given marker on a single map automatically updates the represented relations among that denoted object/property and/or location and all the other represented object/properties and locations. It is physically impossible to alter the map in a way that fails to update those relations. A map that failed to fully update the represented spatial relations among its denoted object/properties would be ill-formed in a very strong sense: it could not be drawn. By contrast, altering the object/property ascribed a location (and/or the location ascribed to an object/property) within one sentence still leaves further operations to be performed to propagate that new information to other propositions in the set. It is entirely possible, indeed all too common, to fail to fully update the represented spatial relations; and the resulting failure is simply one of semantic inconsistency, not of syntactic incoherence.[10]

Casati and Varzi's analysis captures this phenomenon of automatic updating for represented spatial relations among instances of a single denoted object/property (and its absence), because they analyze all instances of a given color (and its absence) as a single predicate, and the regions to which that

[10] The syntactic holism of cartographic spatial structure thus contrasts with the pragmatic or at most semantic holism manifested by the Absence Intuition.

predicate applies are defined by actually standing in the relevant topological (geometric, etc.) relations to one another. By contrast, Pratt's analysis appears to wrongly predict the possibility of partial updates, because he treats each symbol-pair as a separate proposition. What about spatial relations among distinct atomic map-stages? If a series of side-by-side atomic map-stages linked by conjunction is possible, then we should predict the possibility of failure of full update: after all, the printer might simply fail to run off a complete new set, merely replacing the first, *F*-colored sheet in the series, and leaving the rest of the map-stages, with their holes formed by the absence of *F*, unchanged.

Casati and Varzi can rightly object that their analysis classifies such a set of partially updated map-stages as syntactically ill-formed, since map-regions are defined by their topological relations and the series of partially-updated map-stages fails to define a well-formed set of regions. Indeed, they should object that even a fully consistent set of side-by-side maps is ill-formed, because topological relations among the represented world-regions are not preserved by the separate map-stages: for instance, a land-region that borders a given water-region is not represented by a green map-region that is actually contiguous with a blue map-region, since the green map-region and the blue map-region are on different sheets of paper.

However, the relevant question is not just whether their overall semantics delivers the right verdicts about well-formedness – although that is important. Our primary question is whether Casati and Varzi's analysis of that semantics in terms of the construction of a propositional structure via conjunction is warranted. The contrast between automatic and partial updating provides a way both to diagnose the presence of multiple distinct representations and to see how the difference between direct and inferred information might matter. Inference is a way of extracting new information by connecting distinct representations; but the automatic updating of spatial relations that is exhibited by moving a marker on a map is only possible because all the markers occur within a single map, so that a single marker token simultaneously contributes to representing many distinct spatial relations. Conjunction is a particular way of connecting distinct representations, merely in virtue of their truth-values. By itself, it is compatible with mere side-by-side map-stages. Insofar as entire maps do exhibit automatic full updating of represented spatial relations, this suggests that they are unified wholes, where that unification must be achieved by a more robust, specific operation than conjunction – a form of compilation that actually places the atomic map-stages in the appropriate spatial relations to each other. It is a virtue of Casati and Varzi's account that they rely on actual spatial relations among map-regions in their semantics. But to the extent that they use these relations to argue either that no actual compilation is necessary (because the map-regions themselves already stand in the appropriate relations and they are merely being colored in stages), or that a specific form of compilation is required (of successively printing a single sheet of paper), they thereby undermine their claim that maps are constructed by the conjunction of a set of atomic predicative propositions.

Knowing that a represented domain *has* spatial (topological, geometrical, etc.) structure already itself licenses a rich set of assumptions about relations among elements in that structure – most notably, about containment, contiguity, direction, and distance; and these in turn license a rich set of inferences about the effects of altering structural relations among those elements. These assumptions and inferences can be encoded and implemented in any format; and they can be used to generate appropriate illustrations of the resulting state of affairs. But maps do more than just illustrate the resulting states of affairs: they represent those structural relations among elements by instantiating them. As Rescorla (2009, 197-8) puts it, "A map's geometric structure is not just another element to be listed alongside its markers and coordinates…Rather, the markers and coordinates *stand in* geometric relations, and those relations bear representational import." A direct consequence is that permutations of those relations within the vehicle automatically instantiate the relevant permutation to how the world is represented is being.

If maps don't have predicative or propositional structure, how should a formal cartographic semantics go? We can now say that rather than employing a digital, universal, and asymmetrical combinatorial operation, we need an operation that is holistic and symmetrical, and that permits automatic updating by isomorphic permutation. The discussion of conjunction – and of names, and predicates – also lends more specific sense to the claim that maps are holistic modes of representation. Because a propositional analysis first assigns denoted objects and properties to denoted locations, and then conjoins those located object/properties, thereby assigns a derivative status to spatial relations among denoted object/properties. A better model would begin with the fact that maps' markers themselves stand in spatial relations. Casati and Varzi almost achieve this, by taking seriously the fact that the regions to which those markers are applied are spatially related. But this compromises their claim to a propositional analysis. More importantly, their predicative analysis commits them to treating map-regions as analytically prior: as individuated and interpreted independently of the markers that are applied to them. A more promising approach would analyze a map as a spatial distribution of markers (rather than of regions to which marks are applied). An entire map would then be true just in case there exists a region in the world at which the objects and properties denoted by the markers are distributed in a way that preserves the relevant spatial (topological, geometrical, etc.) relations of that distribution.[11] Implementing this suggestion is obviously a task for another day.

[11] Familiar maps on paper employ spatial structure to represent spatial structure by replicating relevant aspects of that structure. Other maps – say, in a computer, or in a brain – implement geometrical, topological, and other, broadly 'spatial' structures in other ways. They are still maps if they have the function of representing a domain that has such a structure, and their constituent elements actually stand

5. Conclusion

The semantics offered by Pratt and by Casati and Varzi are formal, in the sense that they offer conditions for constructing and determining the truth-conditions of entire maps, stated in terms of relevant, formally-individuated features.[12] As Blumson (2012) emphasizes, a formal semantics of this sort suffices to address the traditional requirements invoked by defenders of the Language of Thought Hypothesis for a 'rational' cognitive architecture: systematicity and productivity. By contrast, it is not at all obvious that a similarly formal semantics can be offered for pictures, let alone perception. In particular, the representational significance of images often appears to be highly local and context-dependent: changes to the marks which make little semantic difference at one location produce significant semantic difference, or destroy the representation altogether, at another.

However, the possibility of such a formal cartographic semantics does not suffice to demonstrate that maps have propositional structure or the same sort of structure as language, as Blumson (2012, 414) also claims. Rescorla (2009) argues that the Absence Intuition demonstrates that the semantics proposed by Casati and Varzi is not predicative. Although I am less sanguine about Absence, I have argued that there are other reasons to reject a predicative analysis, as well as a propositional interpretation more generally.

The contrast between maps and propositional representations shows up especially clearly when we consider the dynamics of map construction, modification, and compilation. This suggests the need for not just formal cartographic syntax and semantics, but a logic of map dynamics. As Pratt (1993) and MacEachren (2004) emphasize, the interaction between map semantics and pragmatics is highly complex. But as linguists and philosophers of language have increasingly recognized, the same also holds for language, with many linguistic features having the conventional function of tracking, expressing, and modifying both truth-conditional and non-truth-conditional aspects of both the objective and conversational context. One especially fertile area for future research concerns the different ways in which conventional semantic meaning and pragmatic use interact in language and in maps.

In arguing that maps do not have propositional structure, I have relied both upon a restricted class of maps that are clearly formalizable, and upon an idealized analysis of language as a predicate calculus. Natural languages depart in deep and pervasive ways from the clean, universal systematicity of traditional

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in relations such that appropriate operations on those relations automatically produce structurally isomorphic representational effects.

[12] Pratt (1993) argues that figure-ground ambiguity rules out the possibility of a fully formal semantics. I don't have the space to address his concerns here, but I believe they can be resolved by distinguishing more clearly between cartographic semantics and pragmatics than he thinks possible, and by taking more seriously the sense in which an overall cartographic system includes principles for both constructing and manipulating maps.

formal logics. But this has not prevented semanticists from developing detailed, predictive formal analyses of apparently recalcitrant natural-language phenomena using tools and methods that are at least inspired by, and arguably extensions of, a predicate calculus. I have argued that the basis for a cartographic logic should be quite different; but I would urge a similar spirit of constructive optimism in this pursuit as for language.

The restricted class of formal maps and the idealized case of predicate logic also make the contrast between maps and language especially stark. When we turn to real maps and languages, we find much more intriguing complexity. Most obviously, many ordinary maps employ both words and also shapes that purport to replicate the shapes of roads and lakes – sometimes, as with Google Maps, in the form of a literal verbal overlay on aerial photographic images. In the other direction, Phillipe Schlenker (e.g. 2013) has argued that sign languages systematically employ, modify, and relate iconic or pictorial elements within linguistic structure. At the same time, we also encounter other representational formats – diagrams, graphs, musical scores – that are more or less map-like or language-like in different ways.

The point of contrasting maps and languages is not to erect sharp taxonomic boundaries or identify deep natural kinds (Johnson 2015). Rather, my aim is first, to argue that not all representations with a formally characterizable functional structure are therefore simply notational variants on language. Different representational systems employ different degrees and dimensions of resemblance and arbitrariness in the interpretive principle(s) that assign values to representational constituents, and also different degrees and dimensions of abstraction and holism in the syntactic principle(s) that combine constituents into larger wholes (Camp 2015). Contrasting maps and languages is one way to identify more clearly and specifically which dimensions of difference make a difference, and how. This will help us, among other things, to better understand how particular representational systems function out in the world, to build systems that more efficiently meet our representational needs, and to make better inferences from behavioral evidence about what cognitive architecture a given agent may be employing.

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