

Similar situations

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This paper studies the notion of similarity with reference to situations of situation theory. While the commonsense notion of two situations resembling each other appears to be valuable in our daily life, we show that it is problematic for the same reasons researchers have been pointing out in psychological and philosophical literature. That human beings can use the notion naturally (without much effort) shows that their cognitive make-up is probably much more powerful than is commonly thought.

Introduction

There is nothing more basic to thought and language than our sense of similarity; our sorting of things into kinds. (W. V. Quine)

How do we ever understand anything? Almost always, I think, by using one or another kind of analogy – that is, by representing each new thing as though it resembles something we already know. (M. Minsky)

“I’ve been in a similar state before,” says a ruined entrepreneur to the manager of a bank and proceeds to explain his plan of survival. “Remember, we have faced a similar aggression last month.” Thus a lieutenant cautions his soldiers before he outlines his strategy of defense. “Maybe I must start to prepare for my next round of exams in order to avoid a similar reprimand,” confesses a lazy undergraduate on academic probation. Other examples easily come to mind. In all of these, the role played by the commonsense notion of ‘similar situation’ is clear but a formal account seems to be not easy and even murky.¹ An obvious question is this: When

1. There is an obvious problem lurking here. Maybe one is more interested in difference, not in similarity. In other words, let one’s attitude towards his current state be like “This is a very different state.” While there are contexts in which saying something like this would be natural, a simple trick would let us reduce such utterances to their equivalents formulated in terms of

is it appropriate to think that two situations (faced by an intelligent agent) are similar? If I am meeting with the Prime Minister tonight, maybe I am entitled to thinking that this will be comparable to my earlier meeting with the mayor of my town, but would it be all right to say that I would be in similar situations?² If yes, in what sense? If not, why not? Our goal in this paper is to study such questions of appropriateness³ using the basic ontology of situation theory (Barwise & Perry 1983; Devlin 1991).

A caveat is needed at this point. Similarity has always been a thorny topic (Gleitman et al. 1996). To use a stale turn of phrase, a lot of ink has been spilt to figure it out in its entirety. While we indisputably know more about it now compared to say, some decades ago, we still have a long way to go to achieve a fully worked out account. To put the matter less obliquely, this paper does not pretend to demystify similarity once and for all to brush it aside. It only adds to the number of growing literature in ascertaining that similarity is a complicated notion. It is quite remarkable that we human beings have the cognitive make-up to use it with ease and assurance, and more often than not, with profit (Rosch 1978). Thus, looking at Figures 1 and 2, a grown-up person would be able tell with confidence that these are both meeting situations and hence can be regarded as similar (e.g., both have participants, most probably a chair administrating the meeting, notepads, tables, etc.). It is a goal of this paper to propose a (mildly original) explication of this feat.

similarity, to wit: “Among all the states I have been to, there is not one similar to the current one.” On a related note, Minsky (1986: 238) writes that ordinary thought relies on recognition of differences. Consider two situations S (source) and G (goal). You are in S and you want to end up at G . Denote the difference between S and G by Δ and suppose there are a number of actions that can be applied at S . A straightforward approach to achieve G might be to apply actions that remove or reduce Δ . If a certain action causes Δ to become bigger, you might want to look for another action that counteracts the former.

2. According to Tversky and Gati (1978), in saying “ α is like β ,” we are inclined to think of α as the ‘subject’ and β as the ‘referent.’ People tend to select the more prominent stimulus (also known as the ‘prototype’) as the referent and the less prominent stimulus (also known as the ‘variant’) as the subject. Thus, during the early years of the Reagan era, one would be entitled to say, “Poland is like the Soviet Union” (but usually, not vice versa). In other words, people attend more to the subject than the referent.

3. Our use of appropriateness here is in line with Fetzer (2004: 85): “Appropriateness is a social- and communicative-action-based construct which is calculated with regard to the connectedness between the force of the communicative action, its propositional content, its linguistic representation and their embeddedness in the immediate linguistic, sociocultural and social contexts, and their embeddedness in the remote linguistic, sociocultural and social contexts. Appropriateness is a constitutive part of practical reasoning and manifests itself in felicitous communication in which the coparticipants’ information wants and face wants are satisfied.”



Figure 1. A meeting situation (from <http://www.phoenixexecutivegroup.com/aboutus.html>)



Figure 2. Another meeting situation (from <http://www.ofm.org/3/econ/ECOesc01.html>)

Psychological and cognitive science work

Important early work on similarity and analogy can be found in psychological and cognitive science literature. We will presently touch upon such work to offer a glimpse of their essence. There are also numerous proposals in artificial intelligence (AI) which study analogy from a computational perspective. We will omit such work in its entirety but refer the reader to Gentner and Markham (1995) and the slim but significant volume that includes it. Two concise appraisals of analogy, Gentner (1998) and Gentner (1999), are also valuable.

Gick and Holyoak (1983) report the results of an experimental study concerning what is known as 'analogical transfer.' Subjects are presented with an assign-

ment in which they must suggest a way to heal a deadly tumor without using a strong beam of radiation. (A strong beam would kill the surrounding tissue.) The superlative solution is to converge on the tumor with a number of weak beams of radiation. About 10% of the subjects propose this technique. If a prior story about some soldiers converging on a fortress is told, 30% of the subjects produce the previously mentioned solution. Finally, if the subjects are overtly told to bear in mind the soldiers' story while thinking about the tumor problem, the rate of success reaches almost 90%. Gick and Holyoak conclude that while one might have prior experience stored in his memory, it may still be challenging to retrieve this in order to employ it in a novel (but similar) situation.

One early, formal view of similarity uses a geometric approach (Shepard 1974). This boils down to mapping each object to a point in a space so that the metric distances between points correspond to the similarity of the respective objects. Challenging this approach, Tversky (1977) came up with the simple proposal that each object α is characterized by a set of features A . The observed similarity of two objects, α and β , is then expressed as a function of their common and distinctive features. Thus, the observed similarity is a function of three arguments (Tversky & Gati 1978):

- The features shared by α and β , i.e. $A \cap B$ (set intersection)
- The features of α that are not shared by β , i.e. A/B (set difference)
- The features of β that are not shared by α , i.e. B/A

In what is commonly called a 'contrast model,' the similarity of α to β is given as a linear combination of the measures of their joint and idiosyncratic features, viz.

$$c_1 f(A \cap B) - c_2 f(A/B) - c_3 f(B/A), \text{ where } c_1, c_2, c_3 \geq 0.$$

In this way, the contrast model expresses similarity between two objects as the weighted difference of the above (three) feature sets (c_1, c_2, c_3 being the weights). Here, f is a function reflecting the salience of the various features; it measures the contribution of any particular feature – be it common or distinguishing – to the similarity between objects.⁴

In Tversky (1977), an interesting experiment is reported. Subjects are asked which country, Sweden or Hungary, most resembles Austria. No relevant dimension of similarity is specified; this means that the answer will depend on the (background) set of countries under consideration. The answers are as follows. If the backdrop set includes Poland, then the subjects tend to say Sweden. If the set includes Norway, they are inclined to pick Hungary. The rationalization for this

4. See Kittay (1982) for a particularly clear account of Tversky's theory of similarity and its implications *re* simile and metaphor.

is evident: Poland and Hungary have – or had, at the time of the experiment – salient geopolitical features in common. Likewise, Sweden and Norway have such features. Tversky concludes that judgments of similarity appeal to features having a high classificatory significance. Furthermore, he notes that while the similarity features depend on the relevant contrast set, the set itself depends on the interests of the participants (thus he is making a pragmatic point bearing upon appropriateness).

Sloman (1999:567) cites a 1983 study by Tversky and Daniel Kahneman in which subjects are first told the following story:

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice and also participated in antinuclear demonstrations.

The subjects are then asked to pick the more likely statement: (i) Linda is a bank teller or (ii) She is a bank teller and is active in the feminist movement. The response turns out to be overwhelmingly (ii). This is an illustration of the so-called conjunction fallacy. Statement (ii) cannot possibly be more likely than statement (i), for it takes (i) for granted. Tversky and Kahneman attribute the subjects' disappointing performance to the 'representativeness' heuristic, i.e., the likelihood of an event increases to the degree that it is similar to the category under consideration.

Situations

We begin with a brief overview of situation theory (or rather, situations). The theory starts with the levelheaded assumption that what is called 'Reality' is one big (seemingly unbounded or at least inconceivably large) situation. Limited parts of Reality are called 'situations' and can be individuated by cognitive agents (say, human beings). Thus, we perceive situations, cause them to be brought about, and have all sorts of attitudes toward them. One fact remains: we are always in situations. An example might help at this point. I have recently been in a flight situation where the neighboring passenger suddenly choked on his food. By calling the attention of the flight attendant to this (and she immediately asking for help from other passengers), I had my share in saving him from a dreadful end. I felt that this was one hard-hitting situation; I really detested being in it.⁵

5. Notice that what I have just said could have been fiction. In other words, I could have shamelessly made this whole story up. However, and this is interesting, you would have no trouble in following it and believing it. Fictional situations are inspirational but in this paper I assume that we are always talking about real situations.

Situations usually have individuals standing in relation at various (spatiotemporal⁶) locations. The individuals have properties. Situation theory posits that real situations are metaphysically and epistemologically prior to individuals, relations, and locations.

Human beings and lower organisms display a fundamental ability to notice the similarities between situations. This is done by noting the regularities – individuals, properties, relations, or locations that endure from one situation to another. Thus, I believe that snow is slippery, that police are usually available for help, that mothers care about their children, that I will receive presents on my birthday.

Barwise and Perry (1983: 10) put the matter elegantly:

The situations we perceive and participate in are always limited, a small part of all that has gone on, is going on, and will go on.⁷ Situations overlap in time and space in complicated ways, but each situation is unique unto itself, no one quite the same as any other. And in this uniqueness resides a puzzle. For if living things are to survive, they must constantly adapt to the course of events in which they find themselves, to ever changing, fleeting, and unique situations.

As Barwise and Perry also note, this adaptation takes place as a consequence of attunement to similarities between situations. Let us agree to call such similarities ‘uniformities.’ A useful uniformity in my life has to do with the newspaper boy. Every morning (a different situation), he brings the paper at about 8 o’clock and leaves it in our doorsteps. By just being attuned to this uniformity, I contribute to my well-being. Unfortunately, there is no newspaper service on Sundays; I have to go out and buy the paper myself. Unless I am aware of this, chances are that I will be disappointed from time to time: I will open the door, will not find the paper, start wondering what happened, and then suddenly realize that this is a Sunday.

6. This clumsy adjective may be omitted in the sequel, with the understanding that a location is a space-time location.

7. Clearly not all situations are current. My dentist appointment last week was one mean situation, which, thankfully, is now over. The upcoming session scheduled to next week promises to be even more troublesome. Notice that in this example I am referring to past and future situations. Someone could have videotaped the whole visit to the dentist and that would be a good representation of the past situation. No one can really predict what the future visit will be like. (For instance, it may not materialize at all if I suddenly die this week.) It is clear that future situations are vastly different from fictional situations. I can provide you with a detailed and believable account of how my visit next week will be like. While this account will necessarily be defeasible (i.e., “rationally compelling but not deductively valid,” cf. *The Stanford Encyclopedia of Philosophy* <http://plato.stanford.edu/entries/reasoning-defeasible>), it may nonetheless be quite useful for assorted purposes.

Nastier examples also come to mind. Suppose one notices a small, hard bump in his arm one day. He gets curious and starts observing it on a regular basis, say every week. He notices that the bump is growing in size and it is starting to hurt too. Now he is really concerned and will in all probability pay his doctor a visit soon. Once again, being attuned to this uniformity does contribute to the welfare of this person. To quote Barwise and Perry (1983: 10):

[I]t is by categorizing situations in terms of some of the uniformities that are present, and by being attuned to appropriate relations that obtain between different types of situations, that the organism manages to cope with the new situations that continually arise.

Devlin (1991) has done much to clarify what exactly situations amount to and how we ‘individuate’ them. This last term means that we can single out and treat situations as identifiable entities that can later be talked about. Thus, Devlin (1991: 31):

But in what sense does an agent *individuate* a situation (when it does)? Not, in general, as an individual. Rather, the agent individuates a situation as a situation, that is to say, as a structured part of Reality that it (the agent) somehow manages to pick out. There are a number of ways an agent can ‘pick out’ (that is, individuate) a situation. Two obvious examples are direct perception⁸ of a situation, perhaps the immediate environment, or thinking about a particular situation, say last night’s dinner party.

8. Direct perception of a situation is not as unproblematic as it sounds, due to ever-present, high-level interpretation. The following excerpt from Foster (2000: 212–213) explains the problem:

Think of the situation of someone watching a live football match on television. In some ways, this situation is like that of [a] radar operator. Both subjects are looking at a screen. Both have visual experiences which are caused, in the normal neuro-physiological way, by light which comes from this screen. [...] But there is also a crucial difference. In the case of the radar operator, this information becomes available purely by inference, from his more basic information about what the screen itself displays. [...] The situation with the television viewer is quite different. It is true that the viewer may – almost certainly will – make certain inferences from the information which he visually acquires. But, even in its most basic form [...] this information is not about the two-dimensional pattern of colours on the screen, but about the three-dimensional colour-arrangement of the football scene itself. This is because the visual experience includes not just the visual registering of the screen-pattern [...] but also the interpretation of that pattern in three-dimensional terms, making it experientially seem to the viewer as if he is watching the match from a location in the football stadium – though, of course, he will know that this is not so.

It is probably redundant to remind that when an agent individuates a situation, he cannot be held to that he gives a precise description of everything that that situation comprises. Take this case of two friends (Devlin 1991: 31–32):

[...] John and David are having a conversation about a particular football game, say one they have both seen. Then they are both referring to a very definite *situation* – namely that particular game. This is a situation that they both individuate (as a *situation*, not as an individual). A long, informative, and confusion-free discussion can take place. And yet neither John nor David would be able to list every single event that formed a part of that game, or every item of information that related to it in some essential way. Indeed, it is highly unlikely that what makes their conversation about the game of interest to both parties is the fact that each one acquires from the other *new* items of information about the game, information that the one picked up but the other did not. The fact that each person left the game with some information that the other did not does not mean that their subsequent conversation is about two different games. The situation is the same for both individuals, a highly structured part of the world, having a fixed duration in time. What differs is what each knows about that situation.

Let us call what John and David know about the game situation their ‘epistemological positions.’ It can (and does) happen that maybe they are talking about two different games, say g_1 and g_2 . Obviously, g_1 should be similar to g_2 in some respects. This can happen in countless ways, e.g., they were played in the same town, they were both important games, the scorers in both games had the same names, both games were interrupted by violent demonstrations, and so forth. In this case, after a while the parties (John and David) would notice – perhaps gradually – that something is amiss, that their epistemological positions no longer overlap in significant ways. A brief investigation by one or more of the parties (“What do you mean by the second penalty? There was only a single penalty.” or “The French referee? I thought he was Italian.”) would then resolve the problem and set things straight. In this case, the similarity of situations g_1 and g_2 is the source of confusion. Devlin (1991: 32) says:

[I]f you were to interrupt John and David in the middle of their conversation and ask them *what* they were talking about, they would reply “Last night’s football game.” Are we then to conclude that they were in fact talking about nothing; or that neither was really sure *what* it was they were discussing? Clearly not.

While we are in general unable to trim down situations to a complex of more familiar objects, we are nonetheless able to enumerate the ingredients that make up a situation. A situation is a rich (intensional) object consisting of individuals enjoying various properties and standing in a variety of relations. It is, in a sense, a small world.

One of the attractive features of situation theory is its insistence on an information-based account of communication (an account first championed by Fred Dretske). To this end, infons are posited as discrete items of information. An infon supplies a single piece of information. It is denoted as the $(n + 2)$ -tuple $\langle R, a_1, \dots, a_n, p \rangle$, where R is an n -place relation,⁹ a_1, \dots, a_n are objects appropriate for the respective argument places of R , and p is the polarity (0 or 1). If $p = 1$ (respectively, 0) then a_1, \dots, a_n stand (respectively, do not stand) in the relation R . Take the infon $\langle \text{father of, George Herbert Bush, George Walker Bush, 1} \rangle$. This is a fact (corresponds to the way things are in Reality). On the other hand, the infon $\langle \text{father of, George Herbert Bush, Prescott Bush, 1} \rangle$ is not a fact. (If we swap the argument values in this infon, it will start denoting a fact though.)

Abstract situations are proposed to be the counterparts of situations in order to make the latter more amenable to mathematical manipulation. An abstract situation is a set (Devlin 1991). Given a situation s , the set $\{t \mid s \models t\}$, where t is an infon, is the corresponding abstract situation. Notice that this set collects all facts (infons that are made true by the situation). Here, s is said to ‘support’ an infon t – denoted as $s \models t$ above – just in case the infon t is true of the situation s . The opening propositions of the *Tractatus* can then be handily (if not in a caricatured manner) summarized as $\text{Reality} = \{t \mid \text{Reality} \models t\}$, i.e. “Die Welt ist die Gesamtheit der Tatsachen.”

A ‘scheme of individuation’ – a way of carving the world into uniformities – is an essential aspect of situation theory. The notions individual, relation, and location depend upon this. In other words, the basic constituents of the theory are determined by the agent’s schema of individuation. Formal representation of these uniformities yields ‘types.’ Situation theory provides a collection of basic types for individuating or discriminating uniformities of the real world. These are some indispensable types: situation, individual, relation, temporal location, spatial location. (This is not an exhaustive list.)

Parameters are generalizations over classes of non-parametric objects (e.g., individuals, spatial locations). Parameters can be associated with objects which, if they were to replace the parameters, would yield one of the objects in the class that parametric object abstracts over. Hence, allowing parameters in infons re-

9. Unary (1-place) relations are commonly called properties. This is probably the right place to warn the reader about the difference between situation-theoretic and mathematical relations. The latter are set-theoretic constructs whereas the former are relations of the kind recognizable by human beings. Thus, in the former account, ‘being tall’ is a property and ‘being the father of’ is a relation. No doubt, we can (and do) use mathematical relations to model these. To this end, ‘father of’ is rendered by the mathematical notation xFy , denoting that ‘ x is the father of y .’ The relation F is a set of ordered pairs, including, among many others, the pair $\langle \text{GHB, GWB} \rangle$ (see presently).

sults in parametric infons. For example, $\langle \text{sees}, \hat{g}, \text{Alice}, 1 \rangle$ and $\langle \text{sees}, \hat{g}, \hat{h}, 1 \rangle$ are parametric infons where \hat{g} and \hat{h} stand for individuals. These infons are parametric on the first, and the first and second argument roles of the relation ‘see,’ respectively.¹⁰ Anchoring (binding) parameters of an infon to objects yields parameter-free infons. For example, given $\langle \text{sees}, \hat{g}, \text{Alice}, 1 \rangle$, if $F(\hat{g}) = \text{Bob}$ (F is an anchoring function) then we obtain the parameter-free infon $\langle \text{sees}, \text{Bob}, \text{Alice}, 1 \rangle$.

Suppose Alice was eating ice cream yesterday. She is eating ice cream now. Both of these situations share the same ‘constituent sequence’ (basically, an infon lacking a polarity) $\langle \text{eats}, \text{Alice}, \text{ice cream} \rangle$. These two events, occurring at different times, have the same ‘situation type.’ Situation types can be more general. For example, a situation type in which someone is eating something at home contains the situation in which Alice is eating ice cream at home.

Figures 3 and 4 show two ‘feeding’ situations. Each of these are about actual situations, one depicting a woman feeding penguins, and the other depicting four persons feeding dolphins. It is true that the number of ‘feeders’ and ‘fed’ change. (Even the food will be different. Maybe it consists of small fish but the kinds may be different.) Still, both situations are of type ‘feeding situations.’ The constituent sequence $\langle \text{feeds}, \text{feeder agents}, \text{fed animals}, \text{food} \rangle$ characterizes this type conveniently.

In situation theory, a network of abstract links between situation types (which are uniformities) provides information flow. Thus, the statement “Smoke means fire” expresses the law-like relation that links situations where there is smoke to situations where there is a blaze. If a is the type of smoky situations and b is the type of fire situations, then having been attuned to the constraint $a \blacktriangleright b$, an agent can pick up the information that there is a fire in a particular situation by observing that there is smoke.¹¹ Anchoring plays a major role in the working of constraints. If the above constraint holds then it is a fact that if a is realized (i.e., there is a real situation a_0 of type a), then so is b (i.e., there is a real situation b_0 of type b). In order to invoke the constraint, we have to use an anchoring function which binds the location parameters to appropriate objects present in the ‘grounding situation,’ i.e., we have to first find a place and time at which there is smoke.

10. Their meaning can be rendered in English as “Someone sees Alice” and “Someone sees someone,” respectively. In order to keep things simple, we do not worry about tense in this paper but see Barwise and Perry (1983: 288ff.) and Devlin (1991: 228ff.).

11. $a \blacktriangleright b$ is shorthand for the factual, parameter free infon $\langle \text{involves}, a, b, 1 \rangle$, where ‘involves’ denotes the linkage between a and b . Devlin (1991: 91) notes that “many living creatures are aware of, or attuned to, this particular constraint, and make use of it in order to survive, though only humans have the linguistic ability to describe it with an expression such as SMOKE MEANS FIRE [...]”

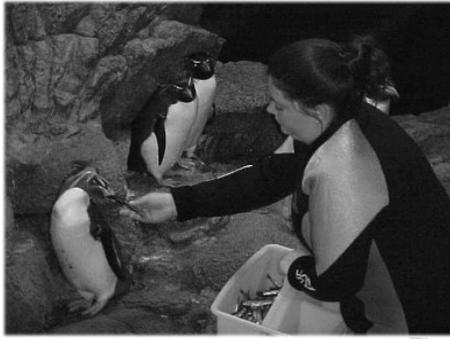


Figure 3. Feeding penguins (from <http://gonewengland.about.com/library/blneaq14.htm>)

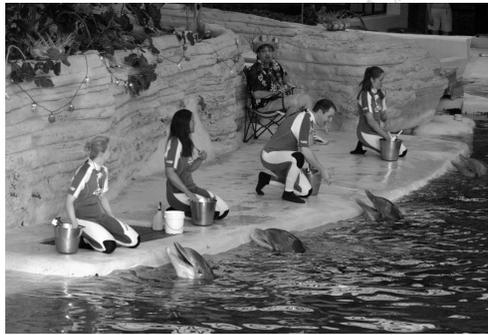


Figure 4. Feeding dolphins (from http://www.pirateplanet.com/Brookfield_Zoo.html)

Are situations vague objects? (Digression)

Any approach which claims to regard the situation-theoretic approach fruitful for the study of a given problem (in our case, similarity) runs a certain risk. This has to do with the ontological status of situations. While lay people do not seem to detect deep-seated problems with the situations – as a matter of fact, they view them as highly intuitive and commonsensical – philosophers, having a natural tendency to make finer distinctions, unearth points to debate. One such point concerns the spatio-temporal boundaries of situations.¹² Before the emergence of situation theory, ‘ontic vagueness’ (could the world itself be vague or is it only

12. Suppose it is ambiguous whether some individual in a given situation has a given property. (Alternatively, suppose it is indeterminate whether two or more individuals in a given situation have a given relation.) These possibilities could make situations problematic entities but will not be considered here further.

linguistic expressions that can be vague?) drew the attention of Evans (1978). He provided a terse slingshot argument to give a negative answer to the question “Can there be vague objects?”¹³ Still, a number of philosophers think that there are vague objects (Parsons & Woodruff 1996).

Take Ben Nevis, the highest mountain in the United Kingdom. Keefe (2000: 15) says the following about it:

[A]ny sharp spatio-temporal boundaries drawn around the mountain would be arbitrarily placed, and would not reflect a natural boundary. So it may seem that Ben Nevis has fuzzy boundaries, and so, given the common view that a vague object is an object with fuzzy, spatio-temporal boundaries, that it is a vague object.¹⁴

It is not difficult to multiply the examples. Thus, the singular term ‘Toronto’ seems to pick out a unique object (Toronto), despite the fact that that object has fuzzy spatiotemporal boundaries, cf. Keefe (2000: 159–160). Now consider the sentence “Toronto has an odd number of trees.” Keefe observes that the truth of this would depend on assorted ways of circumscribing the extent of Toronto. The sentence would sometimes be regarded as making a true claim – because the orders of Toronto have been drawn in a certain way – and sometimes a false claim – because the borders have been drawn in another way. Thus, the interpretation of ‘Toronto’ is indeterminate. Keefe also notes that the sentence “Toronto is in Canada” is true (simpliciter) because regardless of how one goes about delineating the boundaries of the city it would turn out to be true.

Keefe’s approach is easily applicable to situations. Consider, once again, the football game situation. “There are an odd number of spectators watching the game” would most probably be regarded as having an indeterminate truth-value

13. Evans characterizes a vague object as one about which it is a fact that the object has fuzzy boundaries.

14. Compare this with the following view of Wiggins (2001: 166):

It may be said that one candidate [for a vague object] is some mountain the ordinary individuation of which leaves over numerous questions of the form ‘Is this foothill a part of x ? Is that foothill a part of x ?’ But this is a strikingly poor illustration of what would be needed. For it can be *perfectly determinate* which mountain x is without x ’s extent being determinate. A mountain is not, after all, something essentially demarcated by its extent or boundary. It is not as if there were just as many mountains to be found with x ’s peak as there were rival determinations of x ’s boundary. An idea like that could not even occur to one with the good fortune to be innocent of classical extensional mereology.

because it is not clear how one should delineate the boundaries of the game.¹⁵ On the other hand, the truth “The game was played in Istanbul” is unquestionably independent of how these boundaries are drawn.

Our take on this matter is as follows. As long as the similarity of two situations does not concern problematic features (e.g., in the aforementioned example, oddness or evenness of number of spectators), we do not have to pay attention to vagueness. It remains to be seen, on the other hand, whether there is a proof (or disproof) of the proposition that situations are vague objects.

Russell and Goodman on similarity

Bertrand Russell was especially interested in the ‘similarity of structure.’ He used the term ‘structure’ in several senses but in general meant something along these lines: a blueprint of relations holding among parts of a complex.¹⁶ Briefly, to reveal the structure of a complex is to spell out its parts and the ways in which these are interconnected. According to Russell, two classes are similar with respect to structure if and only if the following conditions are satisfied (McLendon 1955: 83):

- A relation *P* relates members of the first class to one another.
- A relation *Q* relates members of the second class to one another.
- Each member of the first class corresponds to one and only one member of the second class, and vice versa. This relation of correspondence requires a one-to-one relation *S* which holds between the members of the first class and the members of the second class and at the same time preserves *P* in the first class and *Q* in the second class. (*S* is the ‘correlator’ of the two classes.)
- Whenever *P* relates two items in the first class, the corresponding images of these in the second class are related by *Q*, and vice versa.

The proverbial (if not boring) structural similarity consideration that we are all familiar with regards an atom analogous to a miniature solar system. Both the

15. When I was a kid, I used to watch all the games of my hometown team from a two-storey apartment building next to the stadium. The owner of the building was a distant relative and she would let me sit in one of the upper balconies. The building was literally meters away from the low walls of the stadium. Was I a part of the game situation? I think so.

16. It is fitting to observe that one of the most influential research programs in computational analogy – the so-called structure-mapping engine – is based on similarity of structure, cf. Markman and Gentner (2000) for recent work and Falkenhainer et al. (1989) for the classical paper on the subject.

atom and solar system consist of one inner object, surrounded by a number of smaller objects. The orbiting objects are attracted to the middle object by a force both in the atomic and in the solar case. If one is able to see in his mind's eye the solar system, then this depiction may act as a model for the corresponding facets of the atom (Taber 2001).

A legendary critic of similarity, Goodman (1972) noted that objects could be similar in numerous ways.¹⁷ According to him, we must specify in what respect two objects are similar; otherwise, we would be making a vacuous statement. To talk about similarity, one needs a frame of reference – just like those used by physicists studying motion. If Carol says that John is similar to David, you would have no idea until she quips that they are both football fanatics or that they are pathetic liars or that they are both bald, etc. To quote Goodman (1972:445), “we must search for the appropriate replacement in each case; and ‘is similar to’ functions as little more than a blank to be filled.” By ‘appropriate,’ we think that Goodman presumably refers to the following trick.¹⁸ Two things are similar when certain predicates hold of them. Now, of two far and wide dissimilar actual animals (say a horse and a bee) can one say that they are similar (because after all they are both ‘real’)? Yes, but this is usually absurd; the predicate ‘real’ has little communicative significance in the context of a talk about real animals. The claim would be sensible though if it were made in the context of a chat about real and unreal (fantastic) creatures, say unicorns and elves.¹⁹ A comparable argument shows that when Carol uttered, “John is similar to David,” she made an ill-defined claim. Only when she specifies the particular ‘respects’ in which these two men are similar, does she start to make sense.

Overall, Goodman's critique can be seen as paving the way to a conception of similarity as a ternary predicate, i.e., it is only meaningful to state that *A* is similar to *B* with respect to *r*. That similarity seems to disappear when it is analyzed closely is best rendered in this memorable definition of Goodman (1972:439): “[T]o say that two things are similar in having a specified property in common is to say nothing more than they have the property in common.”

Medin et al. (1993:272) draw attention to a weak spot in Goodman's thesis:

17. Our review of Goodman is based on an account by Medin et al. (1993) and also Medin and Goldstone (1995). Unfortunately, we have not yet been able to locate the original paper (Goodman 1972).

18. Our explanation was inspired by a footnote in Recanati (2004:150) where he refers to a passage from Tverksy (1977).

19. To wit, “A bee is similar to a horse” (respectively, “An elf is similar to a unicorn”) because they are both real (respectively, imaginary) but “A unicorn is not similar to a horse” (because one is imaginary and the other is real).

[C]onsider what one might know about *quaggas* (some hypothetical or unfamiliar entity) from the statement “Quaggas are similar to zebras.” Although we have no data bearing on this question, our intuitions are that people might be at least modestly confident that quaggas are hooved animals and not especially certain about whether or not they are striped. *Hooved* is (by conjecture) part of an inter-related set of properties associated with zebras, whereas *striped* seems more to be an isolated property.²⁰ In any event, Goodman’s framework would find the comparison completely uninformative until the respects were specifically mentioned.

Nonetheless, Medin and Goldstone (1995: 106) concur with the general thesis and extend Goodman’s original proposal in the following way: “A is similar to B” is, according to them, shorthand for “A is similar to B in respects *r* according to comparison process *c*, relative to some standard *s* mapped onto judgments by some function *f* for some purpose *p*.”

Lewis on similarity

In his landmark work on counterfactuals, Lewis (1973) studied counterfactual conditionals of the following form:

If it were the case that *A* (antecedent), then it would be the case that *C* (consequent).

According to Lewis, this roughly means:

In certain possible worlds where *A* holds, *C* also holds.

Lewis asks which *A*-worlds – worlds in which *A* is true – should be considered as candidates; his answer is that not all *A*-worlds will do. For one thing, those that differ greatly from our actual world should be ignored. To put it more positively, we need to consider the *A*-worlds most similar – overall – to our world. That it is not meaningful to consider a world where *A* holds but everything else is just as it really is seems to require an argument. Lewis (1986a: 5) puts the matter stylishly:

Differences never come singly, but in infinite multitudes. Take, if you can, a world that differs from ours *only* in that Caesar did not cross the Rubicon. Are his predicaments and ambitions there just as they actually are? The regularities of his character? The psychological laws exemplified by his decision? The orders of the

20. Incidentally, our intuitions in this example *re* ‘striped’ differ from the authors’. This does not make their general point any less valid though.

day in his camp? The preparation of the boats? The sound of splashing oars? Hold *everything* else fixed after making one change, and you will not have a possible world at all.

This informal but convincing line of reasoning shows that we cannot have an *A*-world that is otherwise just like our world. Therefore, we must search for an *A*-world that does not differ greatly from ours. Ideally, such a world would be in disagreement with our world only as much as it is required to while making *A* true. Moreover, such a world will be closer to our world in similarity than other *A*-worlds. Based on this notion of ‘being closer,’ Lewis (1986a) offers a preliminary analysis of counterfactual conditionals as follows.²¹

Let $A \square \rightarrow C$ denote the counterfactual conditional with antecedent *A* and consequent *C*. Then $A \square \rightarrow C$ is true at a possible world *i* if and only if *C* holds at the closest (accessible²²) *A*-world to *i*, if there is one.

While this analysis is elegant and useful, it has a serious imperfection for people like us who want to know more about what ‘close’ means. Lewis (1986a: 6) agrees:

It may be objected that [the above analysis] is founded on comparative similarity – “closeness” – of worlds, and that comparative similarity is hopelessly imprecise unless some definite respect of comparison has been specified. [...] Imprecise though comparative similarity may be, we *do* judge the comparative similarity of complicated things like cities or people or philosophies²³ – and we do it often without benefit of any definite respect of comparison stated in advance. We balance off various similarities and dissimilarities according to the importance we attach to various respects of comparison and according to the degrees of similarity in the various respects.

21. By preliminary, we imply that Lewis offers further (more fine-grained and accurate) analyses in the remainder of that paper (and several other publications). However, these are not crucial for our present purposes.

22. The idea of one possible world’s being accessible to another is not a straightforward one. The reader is referred to Hughes and Cresswell (1989: 77ff.) from which the following excerpt is taken: “[A] world, w_2 , is accessible to a world, w_1 , if w_2 is conceivable by someone living in w_1 [...]” In the same reference, the authors exemplify this by stating that a world without telephones would be accessible to us – because we can easily conceive of it – but our world would not be accessible to it.

23. The following excerpt is again from Lewis (1986b: 42): “To what extent are the philosophical writings of Wittgenstein similar, overall, to those of Heidegger? I don’t know. But here is one respect of comparison that does not enter into it at all, not even with negligible weight: the ratio of vowels to consonants.”

Lewis's general awareness of the fact that similarity judgments are affected by the respects that enter into them is apparent in the following vivid passage (1986c: 54):

[C]onsider three locomotives: 2818, 4018, and 6018. 2818 and 4018 are alike in this way: they have duplicate boilers, smokeboxes, and fireboxes (to the extent that two of a kind from an early 20th century production line ever are duplicates), and various lesser fittings also are duplicated. But 2818 is a slow, small-wheeled, two-cylindereed 2-8-0 coal hauler – plenty of pull, little speed – whereas 4018 is the opposite, a fast, large-wheeled, four-cylindereed 4-6-0 express passenger locomotive. So is 6018; but 6018, unlike 2818, has few if any parts that duplicate the corresponding parts of 4018. (6018 is a scaled-up and modernized version of 4018.) Anyone can see the way in which 6018 is more similar to 4018 than 2818 is. But I would insist that there is another way of comparing similarity, equally deserving of that name, on which the duplicate standard parts make 2818 the stronger candidate.²⁴

Let *L2818*, *L4018*, and *L6018* denote the locomotives Lewis is talking about. The picture emerging from his description is as follows:

- $L2818 \equiv L4018$, meaning they have many duplicate parts in common, larger or smaller (the former is out-of-date and the latter is up to date).
- $L6018 \approx L4018$, meaning the former is a scaled-up version of the latter (they are both up to date cars).

Lewis states that $L6018 \approx L4018$ (the approximation sign standing for similarity), for the simple reason that they look quite the same (structural similarity). However, he thinks that $L2818 \approx L4018$ is also a sensible claim, for they have after all many parts in common. It is not easy to settle on which similarity judgment is the 'right' one, for it all depends on the context.

In Lewis' related work, 'counterparts' of persons – inhabitants of other worlds who bear a resemblance to him closely (or more closely, compared to other inhabitants of the same world – play a key role too. Not surprisingly, it is not possible

24. Similar examples are given in the analogical reasoning literature. Thus, the following excerpt from (Weitzenfeld 1984: 138) is relevant:

Consider, for example, two cars known to come from the same assembly line at approximately the same time. They are known to be identical in structure and composition and it is known that one of them is black. Does this justify the inference that the similar car is also black? Suppose there is a third car, sharing the common properties of the other two, but known to be yellow. Does it justify the inference that the unknown car is yellow? Clearly there must be some further link between the premises of an argument by analogy and its conclusion.

for a similarity theorist to find solace in this line of work either, for it is also based on an unanalyzed conception of similarity. Thus, Lewis (1983a: 28) states that the counterpart relation is a relation of resemblance and that

[...] it is problematic in the way all relations of similarity are: it is the resultant of similarities and dissimilarities in a multitude of respects, weighted by the importances of the various respects and by the degrees of the similarities.

Continuing on the same theme, he emphasizes the key role of ‘respects,’ a notion that carries for him essentially the same meaning that it enjoys in the cognitive science literature (Medin et al. 1993). Lewis’s following example is particularly instructive (1983b: 51–52):

[C]ounterpart relations are a matter of over-all resemblance in a variety of respects. If we vary the relative importances of different respects of similarity and dissimilarity, we will get different counterpart relations. Two respects of similarity and dissimilarity among enduring things are, first, personhood and personal traits, and second, bodyhood and bodily traits. If we assign great weight to the former, we get the *personal counterpart* relation. Only a person, or something very like a person, can resemble a person in respect of personhood and personal traits enough to be his personal counterpart. But if we assign great weight to the latter, we get a *bodily counterpart* relation. Only a body, or something very like a body, can resemble a body in respect to bodyhood and bodily traits enough to be its bodily counterpart.

One is undoubtedly entitled to asking whether Lewis ever comes close to proposing a scheme to deal with similarity (to bite the bullet, so to speak). The answer is in the affirmative. His so-called ‘spheres’ are aimed at exactly this issue. Let a ‘sphere’ (around a possible world i) be a set of worlds W such that for every w in W , w is accessible from i and is closer to i than any world w' not in W . A sphere is called A -permitting if it contains some A -world (remember that this is a world where A holds). With spheres at one’s disposal, the following rendering of counterfactual conditionals becomes possible (Lewis 1986a: 12):

$A \square \rightarrow C$ is true at possible world i if and only if $A \rightarrow C$ (where the second arrow denotes the material implication of classical logic) holds throughout some A -permitting sphere around i , if there is such a sphere.

Lewis’s spheres are no doubt well-designed as a mathematical apparatus but they offer next to nothing for a tangible analysis of similarity.²⁵ To be fair, it must be

25. The following three comments, all found in (Lewis 1986d: 163), make Lewis’s overall goals vis-à-vis similarity rather clear: (i) “To begin, I take as primitive a relation of *comparative over-*

noted that the spheres around a world are nested and thus they can be said to preserve or model comparative closeness in some sense. But this is taking us to the technicalities of Lewis's theory and with all due respect for the latter's brilliance this is not the place to do so.

Situations as 'icebergs'

In this final section, I will furnish an unfinished, highly tentative sketch for understanding similarity judgments (and their appropriateness). This sketch owes considerably to an approach first detailed in (Recanati 2004).²⁶

Let us go back to the very beginning and ask the following question again: What is it for someone to judge that two situations are similar? In other words, what is it for someone to claim that two situations are similar (while honoring appropriateness conditions)?²⁷

The main insight that is offered by situation theory is this. When we describe an empirical situation (say, Devlin's football game situation), we make certain features explicit, but indefinitely many other features remain implicit. These implicit features in fact constitute a sort of hidden, amorphous background. The parallel here – and this is also inspired by Recanati (2004) – is to an iceberg²⁸ (Figure 5).

Only in toy worlds (e.g., chess) we can hope to describe situations completely without omitting anything. In other circumstances, we cannot hope to describe them in their full complexity (detail). Accordingly, we will normally omit, in de-

all similarity among possible worlds." (ii) "I have not said just how to balance the respects of comparison against each other, so I have not said just what our relation of comparative similarity is to be. Not for nothing did I call it primitive." (iii) "But the vagueness of over-all similarity will not be entirely resolved. Nor should it be."

26. Recanati himself gives some credit to Friedrich Waismann, Hilary Putnam, and John Searle. In the present account, I will be content just citing from Recanati (2004), for his way of putting things is very instructive.

27. Recanati studies another pragmatic question, viz. what it is for someone to learn a predicate *P*. The idea is to observe the application of *P* in a particular situation *s*; this would let one associate *P* and *s*. When encountered with a new situation *s'*, we can apply *P* in *s'*, provided *s'* is sufficiently similar to *s*. There is a danger in doing so though. The new situation can resemble the old one in a way that is not relevant for the application of *P*. There is only one way to avoid this danger and correct it: to enlist the help of the language community. They would usually say something along the lines "No, you cannot apply *P* in this situation (*s'*)."

28. For, according to the *Wikipedia* (<http://en.wikipedia.org/wiki/Iceberg>), "[...] around 90% of the volume of an iceberg is under water, and that portion's shape can be difficult to surmise from looking at what is visible above the surface."

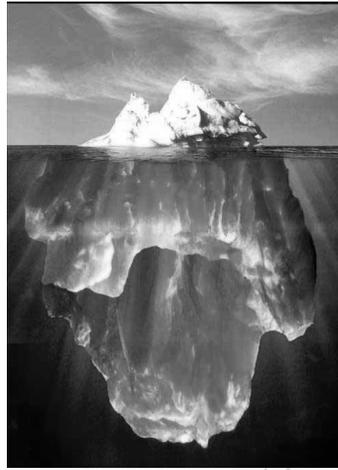


Figure 5. An iceberg (from <http://www.earthfuture.com/stormyweather/gallery>)

cribing a situation, those features which will not make a difference (in our view). Hence, infinitely many features of a given situation are kept implicit. Consider a situation s . Take two infons ι_1 and ι_2 supported by s , viz. $s \models \iota_1$ and $s \models \iota_2$. Assume that the infon ι_1 has to do with a particular feature that we are interested in (to be brought to the tip of the iceberg) and that the infon ι_2 has to do with another feature that we would like to suppress (to be pushed to the invisible part of the iceberg). We can then talk about ι_1 and forget about ι_2 .

The aforementioned exercise can be repeated with different features in an assortment of ways. Abusing the iceberg metaphor, we can think of the iceberg as if it is made of some elastic, malleable material (say, play dough). Depending on what collection of features we want to bring to fore (respectively, push to background), we promote them to the tip of the iceberg (respectively, demote them to the invisible part). Equivalently, those features that are at the tip of the iceberg gain prominence and those that are in the invisible part lose prominence (for the purposes of a particular similarity comparison).²⁹

29. Similarity judgments concerning two situations have all the signs of having an ‘open texture’ (a phrase coined by Waismann) like quality. Open texture means, in our context, that two situations judged similar may turn out to be dissimilar upon further scrutiny, and vice versa (two disparate situations can suddenly become similar in some respect). To formulate a similarity comparison using a novel situation, the novel situation should resemble the ‘source situations’ – situations which are similar. Yet, since we cannot hope to examine in advance all the possible dimensions of similarity between the source situations and possible target situations, we will invariably have open texture emerging.

Example. I intend to make a similarity comparison with the following ingredients: my dad and President Roosevelt. (The former will be the subject and the latter the referent.) Let the context of the conversation in which I find myself embedded as a coparticipant be ‘health’ (say, severe illnesses). If I utter “My dad is like President Roosevelt,” my goal may be to draw attention to the fact that dad is also incapacitated with polio. If this happened to dad when he was 39, the similarity is more powerful. If dad further was a onetime president of Turkey, then it is even more commanding. If, on top of all these, dad fought to recover the use of his legs, predominantly through swimming, then the similarity becomes astounding. With each such additional matching feature, I might be said to be making a more appropriate similarity judgment.³⁰ (Caveat: This last remark assumes that the coparticipants are in some way knowledgeable about the aspects of dad’s life that I have just mentioned. It is also assumed that the aforementioned facts about FDR are part of this ‘common ground’ – the knowledge, beliefs, and suppositions of the participants. If these assumptions do not hold, then it is my obligation to bring up the necessary elements in accord with the Goodmanesque recipe.)

Now, assume another context, that of ‘education’ (say, universities attended). When I make the same utterance as above, I may want to draw attention to the fact that dad also went to Harvard and Columbia Law School. A more impressive similarity case would arise if dad, like Roosevelt, passed the bar exam and fulfilled the requirements for a degree but did not care to actually graduate.

We conclude this paper by drawing attention to the inferential characteristics of similarity. From the viewpoint of situation theory, similarity may be due to

1. The individuals salient in the source situation,
2. The relations salient in the source situation, and
3. The locations salient in the source situation.

Let us exemplify, by way of corresponding examples, what these are all about.

Example 1. Suppose you have observed a certain individual on television in several occasions talking from a lectern in front of cameras, media representatives, etc.

30. Take a difficult question such as what makes a metaphor work (a.k.a. aptness of a metaphor). What I have in mind when I say ‘appropriate similarity judgment’ is along the same lines, i.e., what gives strength to a similarity judgment. In the context of my example, if many predicates are true of dad and FDR, I think that the strength of my judgment would increase proportionally. (We can measure the strength, at least in the context of this particular scenario, by the amount of nods of approval by the participants.) Note, however, that there is a singularity in this process. When dad and FDR are indistinguishable in terms of the predicates that hold of them, they have become identical. Therefore, the most perfect similarity judgment is not a similarity judgment anymore; it is an identity judgment!

You come to recognize these source situations as say, the White House spokesperson's press conferences. Now, when you catch a glimpse of the same person on some television channel the next time, you conclude that you are about to witness a press conference.

Example 2. You see someone standing before a lectern with the caption 'White House' on it. Although you have never seen this person before, you infer that he is the White House spokesperson. Here the salient relationship is that of 'being next to a lectern.' (We ignore the complications posed by the somewhat bizarre scenario that this person is the President and that you do not recognize this fact.)

Example 3. Whenever they show a particular landmark site (say the Trafalgar Square) on television on Fridays, you notice that people are holding demonstrations there, sometimes necessitating police involvement. Therefore, when you see today (a Friday) that there is a Breaking News broadcast where the anchor says, "We now go to our correspondent John Doe who is at the Trafalgar Square," you anticipate seeing some demonstration and perhaps, scuffles with the police.

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The opening quotes appear in Quine³¹ (1969: 116) and Minsky (1986: 57), respectively.

References

- Barwise, J. and Perry, J. 1983. *Situations and Attitudes*. A Bradford Book. Cambridge, MA: MIT Press.
- Devlin, K. 1991. *Logic and Information*. New York: Cambridge University Press.
- Evans, G. 1978. "Can there be vague objects?" *Analysis* 38: 208.
- Falkenhainer, B., Forbus, K.D. and Gentner, D. 1989. "The structure-mapping engine: Algorithm and examples." *Artificial Intelligence* 41: 1–63.
- Fetzer, A. 2004. *Recontextualizing Context: Grammaticality Meets Appropriateness* [Pragmatics & Beyond New Series 121]. Amsterdam/Philadelphia: John Benjamins.
- Foster, J. 2000. *The Nature of Perception*. New York: Oxford University Press.

31. It is probably apt to note that Quine's paper discusses concept development and is concerned with children developing 'similarity spaces' in diverse domains.

- Gentner, D. 1998. "Analogy." In *A Companion to Cognitive Science*, W. Bechtel and G. Graham (eds.), 107–113. Oxford, UK: Blackwell.
- Gentner, D. 1999. "Analogy." In *The MIT Encyclopedia of the Cognitive Sciences*, R.A. Wilson and F.C. Keil (eds.), 17–20. Cambridge, MA: MIT Press.
- Gentner, D. and Markham, A.B. 1995. "Similarity is like analogy: Structural alignment in comparison." In *Similarity in Language, Thought and Perception* [Semiotic and Cognitive Studies 1], C. Cacciari (ed.), 111–147. Turnhout, Belgium: Brepols.
- Gick, M.L. and Holyoak, K.C. 1983. "Schema induction and analogical transfer." *Cognitive Psychology* 15 (1): 1–38.
- Gleitman, L.R., Gleitman, H., Miller, C. and Ostrin, R. 1996. "Similar, and similar concepts." *Cognition* 58 (3): 321–376.
- Goodman, N. 1972. "Seven strictures on similarity." In his *Problems and Projects*, 437–447. Indianapolis, IN: Bobbs-Merrill.
- Hughes, G.E. and Cresswell, M.J. 1989. *An Introduction to Modal Logic*. London: Routledge.
- Keefe, R. 2000. *Theories of Vagueness* [Cambridge Studies in Philosophy]. Cambridge, UK: Cambridge University Press.
- Kittay, E.F. 1982. "The creation of similarity: A discussion of metaphor in light of Tversky's theory of similarity." In *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, Volume 1, 394–405. Chicago: The University of Chicago Press.
- Lewis, D. 1973. *Counterfactuals*. Cambridge, MA: Harvard University Press.
- Lewis, D. 1983a. "Counterpart theory and quantified modal logic." In his *Philosophical Papers, Volume I*, 26–46. New York: Oxford University Press.
- Lewis, D. 1983b. "Counterparts of persons and their bodies." In his *Philosophical Papers, Volume I*, 47–54. New York: Oxford University Press.
- Lewis, D. 1986a. "Counterfactuals and comparative possibility." In his *Philosophical Papers, Volume II*, 3–31. New York: Oxford University Press.
- Lewis, D. 1986b. "Counterfactual dependence and time's arrow." In his *Philosophical Papers, Volume II*, 32–52. New York: Oxford University Press.
- Lewis, D. 1986c. "Postscripts to 'Counterfactual dependence and time's arrow.'" In his *Philosophical Papers, Volume II*, 52–66. New York: Oxford University Press.
- Lewis, D. 1986d. "Causation." In his *Philosophical Papers, Volume II*, 159–172. New York: Oxford University Press.
- Markman, A. B. and Gentner, D. 2000. "Structure-mapping in the comparison process." *American Journal of Psychology* 113 (4): 501–538.
- McLendon, H.J. 1955. "Uses of similarity of structure in contemporary philosophy." *Mind* 64 (253): 79–95.
- Medin, D.L. and Goldstone, R.L. 1995. "The predicates of similarity." In Cacciari (1995), 83–110.
- Medin, D.L., Goldstone, R.L. and Gentner, D. 1993. "Respects for similarity." *Psychological Review* 100 (2): 254–278.
- Minsky, M. 1986. *The Society of Mind*. New York: Simon & Schuster.
- Parsons, T. and Woodruff, P. 1996. "Worldly indeterminacy of identity." In *Vagueness: A Reader*, A Bradford Book, R. Keefe and P. Smith (eds.), 321–337. Cambridge, MA: MIT Press.
- Quine, W.V. 1969. "Natural kinds." In his *Ontological Relativity and Other Essays*, 114–138. New York: Columbia University Press.
- Recanati, F. 2004. *Literal Meaning*. Cambridge, UK: Cambridge University Press.

- Rosch, E. 1978. "Principles of categorization." In *Cognition and Categorization*, E. Rosch and B.B. Lloyd (eds.), 27–48. Hillsdale, NJ: Lawrence Erlbaum.
- Shepard, R.N. 1974. "Representation and structure in similarity data: Problems and prospects." *Psychometrika* 39: 373–421.
- Slovan, S.A. 1999. "Rational versus arational models of thought." In *The Nature of Cognition*, A Bradford Book, R.J. Sternberg (ed.), 557–585. Cambridge, MA: MIT Press.
- Taber, K.S. 2001. "When the analogy breaks down: Modelling the atom on the solar system." *Physics Education* 36 (3): 222–226.
- Tversky, A. 1977. "Features of similarity." *Psychological Review* 84: 327–352.
- Tversky, A. and Gati, I. 1978. "Studies of similarity." In *Cognition and Categorization*, E. Rosch and B.B. Lloyd (eds.), 79–98. Hillsdale, NJ: Lawrence Erlbaum.
- Weitzenfeld, J.S. 1984. "Valid reasoning by analogy." *Philosophy of Science* 51 (1): 137–149.
- Wiggins, D. 2001. *Sameness and Substance Renewed*. Cambridge, UK: Cambridge University Press.

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