Title

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Author
Thagard, Paul

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RULES FOR CONCEPTUAL COMBINATION

Paul Thagard
Philosophy, University of Michigan, Dearborn
Psychology, University of Michigan, Ann Arbor
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Fodor (1981) and Osherson and Smith (1981) have claimed that interpretations of concepts as prototypes encounter problems in dealing with combined concepts such as "striped apple" and "brown cow". This paper offers a theory of how concepts, construed as prototypes, can be combined. The theory takes the form of three kinds of rules for selecting what elements of the component concepts will be carried over into the new one. _Pure_ rules take into account only the prior elements of the components. _Data-driven_ rules are contextual in that they employ features of prospective instances of new concepts. Finally, _goal-directed_ rules are contextual in a larger sense, in that they take into account the problems and goals of the inductive system.

A theory of conceptual combination requires that concepts have components which can be used to form new concepts. This assumption is rejected by some who want to treat concepts as unitary nodes, atomic in the original sense of indivisible (e.g. Fodor 1981). Such writers are reduced to silence about how new concepts might arise. The justification for considering concepts as componential is empirical: the assumption enables us to account for a variety of empirical phenomena.

But what are those components? I shall adopt the terminology of Minsky (1975) and treat concepts as _frames_ which are data structures consisting of _slots_. Such structures can be easily implemented in computer programs (Winston and Horn 1981).[1] A frame contains information about the typical characteristics of a kind of thing; for example, the frame for dog will contain a slot with the information that dogs typically have four legs. It is crucial that the slots need not contain _definitional_ information. Having four legs is neither a necessary nor sufficient condition for dogness, but is nevertheless typical and should generate an expectation. We therefore say that the _default_ value for the number of legs of a dog is four. The slots in the frame for dog do not constitute a _definition_ of dog, but contain lots of information about what is typical of dogs or what it is useful to expect about dogs. Slots in the concept of dog will generally contain _default_ values, not _actual_ values which must hold of all dogs universally. But some actual values may be included, for example that dogs are warm-blooded. There is thus no problem in seeing a concept as containing some slots which involve features which are in fact definitional, but it would be a major mistake to suppose that such slots, if available, would exhaust the meaning of the concept. Looser connections of the sort established by additional default values also matter.

2 Pure, Concept-driven Rules

Definition is the epitome of pure conceptual combination, independent of context. Suppose you have necessary and sufficient conditions for existing concepts C_1 and C_2. Then it is simple to define the new concept C_3 whose set of necessary and sufficient conditions is just the union of the set of necessary and sufficient conditions for the donor concepts. For example, if we have definitions of "square" and "table", the concept of "square table" is formed merely by amalgamating the existing definitions. However, such definitions can be hard to come by, and all we often have to work with in amalgamating concepts are default expectations rather than defining conditions. Because the expectations generated by combined concepts may conflict, conceptual combination requires complex processes of reconciliation. To repeat an example from Osherson and Smith (1981), our concept of a striped apple is no simple sum of "striped" and "apple", since we expect apples to be green or red. As a result, any instance of a striped apple is more typical of the concept "striped apple" than it is of either "striped" or "apple". How, then, do we combine "striped" and "apple" into "striped apple"?

The following very simple rule suffices:

R1. Actual values drive out defaults.

The concept of an apple contains a slot which sets up the expectation that an apple will be red or green or some combination of those colors, but this expectation is not definitional: a golden delicious is still an apple. The adjective "striped" however incorporates an expectation about coloring which is more than a default, since, to put it tritely. something has to be striped to be striped. Hence this definitional expectation overrides the merely default expectation found in the apple concept. In most adjective-noun combinations of this sort, the actual value found in the adjectival concept will drive out the merely default value in the noun. Green cows are green.

Most conceptual combination will not be so simple. Consider an example of Tversky and Kahneman (1983). They show that subjects will often violate the conjunction law of probability, which says that the probability of the conjunction of two propositions is always less than the probability of either conjunct. They gave subjects a description of a woman Linda who had been a philosophy major, was outspoken, bright, and concerned with issues of discrimination and social justice. Then they asked how probable subjects would estimate her to be 1) a feminist 2) a bank teller and 3) a feminist and a bank teller. Unsurprisingly subjects thought it more probable that she was a feminist than a bank teller, but the startling result, violating the conjunction law for probabilities, is that subjects think it more probable that she is a feminist bank teller than that she is a bank teller simpliciter.

According to Tversky and Kahneman, subjects think that Linda is more probably a feminist bank teller than a bank teller because the former category is more <u>representative</u> of Linda. I shall describe a rule for conceptual combination based on representativeness below: such a rule will be data-driven since the description of Linda appears to play a role in how people construct the new concept of feminist bank teller. In this example, however, conceptual combination should not be data-driven, since subjects are not told that Linda is a feminist bank teller, only asked whether she might be. A normatively correct rule of conceptual combination should ignore Linda.

An appropriately pure rule can be formed on the basis of considerations of variability similar to those which play a role in assessing the degree of confirmation of a generalization (Thagard and Nisbett 1982; Nisbett, Krantz, Jepson, and Kunda 1983). Suppose the slot in the new concept of feminist bank teller under dispute concerns political activity. Here we have a case of real conflict, since our default expectations are that feminists will be politically active but that bank tellers will not be. R2 resolves the conflict by saying:

R2 On a given dimension, carry over the value from the donor concept which is less <u>variable</u> on that dimension.

In the case of feminist bank teller, we expect that feminists are more consistently politically active than bank tellers are politically inactive. Hence the slot in the concept "feminist bank teller" for political activity should contain the expectation that feminist bank tellers will be politically active. The description of Linda fits this expectation better than it does the expectations established by the bank teller concept alone.

A third rule of pure conceptual combination is necessarily more vague. We can expect that in some concepts slots are rules are linked to each other, developing connected expectations. For example, a concept concerning a kind of physical object which has a value for size is also likely to have a value for weight. Conceptual combination will want to preserve such linkages:

R3 If the new concept C_3 will contain the slot $C_{1,j}$ and $C_{1,k}$ is <u>linked</u> to that slot, then include $C_{1,k}$ in C_3.

The operation of this rule assumes that the representation of concepts will include some expression of linkages between slots.

<u>3 Data-driven Rules</u>

Conceptual combination requires the reconciliation of conflicting expectations, but there is no reason that the reconciliation should have to be a function of the donor concepts alone. Conceptual combination is selective: for most concepts, occasions of combination will simply never arise. You probably will never have occasion to think of Mongolian watermelon eaters. When occasions of combination do arise, they will do so in a particular context, and the context can help to govern default reconciliation.

The simplest sort of contextual factor consists of instances of the prospective concept. Suppose C_1 and C_2 are being combined to form C_3, and some slot is incompatible between the two donor concepts. For example, upon meeting a Canadian violinist, you are pressed to combine your two concepts of <u>Canadian</u> and <u>violinist</u>, which is difficult because you might expect Canadians to be rugged and outdoorsy while violinists are expected to be more delicate. Failing the kind of variability calculation suggested by R2, a natural solution is to reconcile the defaults in the direction of the one example of a Canadian violinist you have met, adding whichever value on the rugged/delicate dimension the person possesses. This process is different from bottom-up concept formation in its general form, since you are not generalizing all of your friends characteristics to be those of the typical Canadian violinist. The datum enters into the new combined concept only to the extent it enables you to reconcile conflicting defaults. The relevant rule is:

R4 If C_3 is being formed from C_1 and C_2 which conflict on some dimension, and you have examples of C_3 which have a value on that dimension, then choose for C_3 the value of the examples.

A looser variant of R4 is based on the notion of representativeness (Tversky and Kahneman 1974). Whereas R4 deals with the case where contextual examples have the properties which are needed to choose between the conflicting values in the donor concepts, R5 is designed to deal with cases where the combined concept is only similar to the examples. For example, in the feminist bank teller case, if Linda were taken to be an example of a feminist bank teller, then the default values of feminist would tend to win out over those of bank teller, since feminist is more representative of Linda than bank teller. The appropriate rule is:

R5 Choose for C_3 values taken from that concept, C_1 or C_2, which is more representative of the given instances of C_3.

4 Goal-directed Rules

A concept need not be completed all at once: default reconciliation may be an extended process. In some cases, none of R1-5 will be appropriate for reconciling conflicts between the expectations generated by donor concepts. The appropriate response then might be to wait and see which of the default values of the donor concepts will prove to be most suitable. Suitability here can mean just representation of the yet to be discovered properties of instances of the new concepts, but it can also mean usefulness in solving problems with which the new concept was intended to help. For example, the concept of a virus was formed from a kind of combination of concepts of macromolecule and living cell, and it was some time before biologists were able to reconcile conflicting properties of those entities. Induction and concept formation must be understood within the context of a scientist's general problem solving behavior.

This suggests the following rule:

R6 Reconcile slots in favor of ones which contribute to desired problem solutions.

The rules which result from R6 are likely to be tentative and subject to further testing, but can still play an important role in problem solving and explanation. Suppose, for example, that the situation which triggered the conceptual combination of feminist and bank teller concerned the need to explain some feature of Linda's political behavior, where it was given that she is a feminist bank teller. Then adding the slot that feminist bank tellers are politically active provides an explanation of why Linda is politically active, since she is a feminist bank teller. Of course we already had the slot that feminists are politically active, but this alone may not be a good explanation of Linda's political activity since our knowledge that she is also a bank teller suggests the existence of a potentially relevant alternative reference class. Adding the slot about the expected political behavior to the combined concept of feminist bank teller resolves the problem. Similarly, suppose that in forming the combined concept of a Canadian violinist you notice that your friend the Canadian violinist prefers hamburgers to classical French cuisine. In order to explain this preference, you may add the default expectation about Canadians to your frame for Canadian violinist, overruling the expectation derived from the frame for violinists.[2]

We have seen how Minsky's frame notion can provide the basis for plausible mechanisms of conceptual combination. Prototype theories are not contradicted by phenomena of conceptual combination, and in fact increase our understanding of them.

NOTES

[1]Psychologists usually prefer the term "schema". For a discussion of the epistemology of such structures, see Thagard (forthcoming-FKI).

[2]Goal-directed conceptual combination is particularly important for scientific discovery (Thagard forthcoming-CCSD). New scientific concepts referring to non-observed entities such as light waves can be formed by combination of existing concepts.

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