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## More Is Sometimes More

### *Redundant mechanisms in the mind and brain*

Most problems in our everyday lives can be solved in multiple ways. If we want to write, we can use a pencil or a pen or a computer. If we want to warm up we can put on more clothes, make a fire, or eat a bowl of hot soup. Redundant mechanisms are also widespread in biological systems. Biological solutions for thermal regulation include fur, fat, size (larger animals lose heat more slowly), evaporation (a panting dog, a sweating athlete), various metabolic processes, and even anti-freeze molecules.

Although such redundancy can be costly (it takes more energy to make both fur and fat), it also confers important advantages. Different mechanisms are likely to have different characteristics. Together they can lead to improved flexibility and reliability. If one mechanism isn't working properly, others are there to take its place, providing a straightforward means for compensation.

So it is somewhat surprising that the notion of redundant mechanisms is often ignored in the study of behavior. We rarely hear people ask whether more than one mechanism can play the same functional role in carrying out a given behavior, or what factors within or across individuals may result in changes in the relative dependence on different systems serving the same function.

Instead, there is often a focus on revealing "the" mechanism for a given function, or on discovering how such a mechanism develops, how it evolved, or where it is located in the brain. For example, in my own area of research, controversies are centered on asking whether language (or some aspect of language, such as syntax) is computed or represented or learned in this *or* that way. That is, the debate is usually framed in terms of mutually exclusive competing hypotheses.

It's not that the assumption of a single mechanism for a given function is unreasonable. As noted above, redundant mechanisms can be costly, so one might expect them to be

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unlikely. William of Ockham's original Razor – *Pluralitas non est ponenda sine necessitate*, or "Plurality should not be posited without necessity" – suggests a preference for assuming the parsimony of a single mechanism rather than multiple ones. Even if one accepts the possibility of more than one mechanism, it may be easier to study them one at a time. And it may be that redundant mechanisms yield identical or similar behaviors, making it very difficult to distinguish them.

However, given the advantages of redundant mechanisms, and their prevalence in biological systems, it would be surprising *not* to find them in the mind and brain. Such redundancy seems particularly likely given both the computational flexibility of the brain and the importance of this organ. So the Anti-Razors such as Leibniz, Kant and Menger – "Entities must not be reduced to the point of inadequacy" and "It is vain to do with fewer what requires more" – should be taken seriously. In fact, the discovery of redundant neurocognitive mechanisms may help to resolve controversies that have been framed in mutually exclusive terms. That is, in some cases more than one side may be right, with different explanatory mechanisms playing mutually supportive rather than mutually exclusive roles.

Using various methods that can reveal underlying computational and biological mechanisms, studies have begun to demonstrate the presence of redundant mechanisms in the mind and brain. Here we will take a brief look at some recent work which suggests redundancy in language and memory functions.

A major issue in the study of language is how complex forms such as *walked* or *the cat* are learned, represented, and computed. Many explanatory accounts have been proposed. The basic theoretical debate contrasts two apparently mutually exclusive perspectives. On one side are those who argue that complex forms are put together from their memorized parts (*walk*, *-ed*, *the*, *cat*) by a rule-governed grammatical system. On the other side are those who argue that complex forms are

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in principle no different from simple forms like *walk* and *cat*, and that all linguistic forms are learned and processed by the same neurocognitive mechanisms. Both sides cite evidence supporting their perspective.

Recent psycholinguistic, developmental, neurological and neuroimaging evidence suggests that this controversy may be overly simplistic. The data actually seem to support specific claims on both sides. On the one hand, it does appear to be the case that there are (at least) two distinct systems, one of which seems to be particularly good at memorizing pieces of information, the other of which is good at rule-governed composition. However, it turns out that complex forms can either be composed by this latter system (e.g., *walk* + *-ed*) or simply stored as chunks in the former (e.g., *walked*). Thus when we hear or say “walked”, we could be doing it either way – even though on the surface the forms don’t seem to be any different.

Together, these two systems appear to work better and more robustly than either system could on its own. In some cases one system seems to have the upper hand, whereas

in other cases the other does. For example, forms that we encounter more frequently are – not surprisingly – more likely to be memorized than those that we encounter less frequently, which tend to be composed by the grammatical system. So we are more likely to retrieve *walked* from memory, while we tend to put together *balked* from its parts.

Individuals who have better memories are more likely to use stored complex forms than those with worse memories. For example, women, who have an advantage at remembering verbal material, are more likely than men to retrieve complex forms, and correspondingly less likely to compose forms in the grammatical system. In fact estrogen, which improves verbal memory, may lead to a greater dependence on memorized complex forms, even within subjects.

Additionally, weaknesses in the grammatical system can lead to compensatory storage in memory. For example, an increased dependence on memorized complex forms seems to be found both in adults learning a foreign language, and in children with disorders that affect grammar, such as Specific Language Impairment and autism.

The evidence from language is consistent with evidence from studies of memory. The two language capacities discussed here – memory for words and grammatical composition – appear to depend respectively on two distinct memory systems, declarative and procedural memory. Studies of these memory systems have also revealed redundant functionality outside the domain of language. For example, neurological and neuroimaging studies have shown that probabilistic rule-learning as well as category learning can take place in *both* memory systems.

Thus the evidence suggests that a given function can indeed be served by distinct neurocognitive mechanisms, which can work together to confer both flexibility and reliability. Such redundancy can reveal the false dichotomy of some debates previously framed as either-or propositions. Additionally, observed between- and within-subject variation in the relative dependence on redundant mechanisms shows that individual variation may be expressed in how we do it, even if on the surface the behavior looks identical.

The evidence also shows that redundant mechanisms can play a critical role in compensation. Moreover, neurocognitive similarities between healthy individuals and those with certain developmental disorders such as autism suggest that such compensation can be viewed simply as one endpoint on a spectrum of differential reliance on distinct mechanisms. Or to look at it differently, we may all be compensating to some extent.

Thus the consideration of redundant mechanisms in the study of brain and mind can lead to new ways of thinking about old problems, and to promising directions for research. Perhaps it’s time to give redundancy its due. Sometimes more really is more. ♦



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Questions, contact Dr. Sheri Levy, at (631) 632-4355 or [sheri.levy@sunysb.edu](mailto:sheri.levy@sunysb.edu).

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