Corresponding Levels of Structural Complexity in Cognitive Processes and Neural Nets

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Three levels of structural complexity can be defined so that they correspond across psychological processes and neural net models, and each level has a unique empirical indicator. The lowest level comprises processes that are not dependent on internal representation. It is indicated by elemental association, which entails a direct link between input and output, without the need for intervening representation. It can be modelled by two-layered nets. The second level comprises computed, nonstructural representation and is indicated by conditional discrimination. It also includes image schemas and prototypes. It permits configural associations to be learned but not transferred to isomorphic tasks. It can be modelled efficiently by three-layered nets. At the highest level are symbolic relational processes, which depend on an internal representation of structure, and are indicated by transfer to isomorphs with prediction of unknown items. Processes at this level are symbolic, compositional, systematic, and modifiable on line. They include higher cognitive processes such as analogy. Three-layered nets can implement functions implicated by relations but are not an efficient way of processing relational representations. They can be processed by symbolic connectionist models based on tensor products of vectors or on synchronous oscillation. It is implied that the debate about the cognitive adequacy of neural net models is misconceived because feedforward nets are adequate to represent the first two levels, but not the third. The theory also provides a way of interpreting findings from nonhuman animals and infants.

The three levels of structural complexity can be compared with one paradigm so, for example, discrimination can be performed at any of the three levels. Simple discrimination can be performed by elemental association; e.g. triangle → left; square → right. It can be modelled by two-layered feedforward nets that have no internal representation, but there is limited transfer. When the locations are systematically changed (e.g. left becomes up; and right becomes down) no generalization is possible since all links must be relearned. Conditional discrimination (e.g. black/triangle → left; black/square → right; white/triangle → right; white/square → left) requires configural discrimination because of associative interference. It can be modelled by three-layered feedforward networks that have an internal, but non-structured representation. In this case, some degree of generalization is possible, since only the two unique links between internal representation and reward location need to be updated. Therefore, once two cases are relearned, generalization to the other two cases is possible. However this level does not permit transfer to isomorphic tasks. Relations and corresponding tensor networks permit greater generalization. Provided the new task has the same structure, the first stimulus-response pair is used to align task elements to the internal structural representation from which the remaining three pairs are predictable. In general, this is not possible with configural associations and three-layered nets, because the stimulus to internal representation links also change.