Levels of Analysis for Evaluating Complex Systems

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Historically, many disciplines have posed and answered questions about the systems they investigate within a single level of analysis. For example, economists have sometimes examined the behavior of individuals without considering the effects of their membership in various groups. With more understanding of the nature of complexity, self-organizing, adaptive systems, emphasis has shifted to evaluating system behavior using multiple levels of analysis. As noted previously, the behavior of complex systems typically must be analyzed at different levels to comprehensively explain the nature of the system. To use a familiar example, there are fruitful ways of describing an individual bird's motion, and different but also fruitful ways of describing the motion of the flock as a whole. This approach takes into account that:

- Systems can be observed at different scales, each of which constitutes a distinct level of analysis
- Complex systems typically evolve in a manner that cannot be described by a single rule, or by examination of a single level of analysis in isolation
- In a non-linear system, a small change at a lower level of analysis may result in a small change, large change, or even no change at a system-wide level of analysis

Complexity can arise at different levels, and a key challenge is understanding how behavior propagates across levels: that is, how phenomena and interactions at one level shape phenomena and interactions at other levels.

Using levels of analysis to explain the behavior of complex systems

We have observed that the behavior of complex systems is a product of interacting agents or components, but what scale provides the most insight? Just as we can decompose a system into its constituent components, we identify appropriate levels of analysis for specifying the scale(s) at which we investigate a phenomenon of interest. Depending on the question one is asking, a different level of analysis may be appropriate for the answer. For instance, the insurance adjuster seeking the cause of the house fire may not be interested in the underlying principles of combustion or the overall pattern of house fires in a given city, but rather focus on an individual's habit of leaving burning candles unwatched. Any event or system can be understood at multiple levels of analysis, and it is appropriate to focus on different levels for different purposes.

When using levels of analysis it is important to consider both:

- At which level(s) of analysis the phenomena or behavior of interest can be observed
- Which level(s) of analysis contain events or interactions that have a causal impact on the phenomena

For example, if we are interested in the behavior of social groups, we might consider both interactions at a *lower* individual level of analysis that lead to groups forming, but also the influence of factors from a *higher* or overarching cultural level of analysis that impact group behavior.

Examples of levels of analysis

While levels of analysis should always be tailored to the specific system and phenomenon in question, different disciplines may have *general* sets of levels that can be used as a starting point. You do not need to be constrained by these, and in many cases a novel perspective can bring significant insight into the behavior of a system. Always remember to focus your analysis on the most relevant levels, given your explanatory challenge.

Example levels of analysis in psychological science	
Biological	Neuroanatomy, genetics, biochemistry...
Individual / Cognitive	Individual differences such as personality, gender, language, memory...
Social	Interpersonal behavior, social cognition and social context
Cultural	Cultural norms, values, beliefs...

Adapted from Gazzaniga, 2012

Example levels of analysis in political science	
Individual	The individuals that make up a state
Domestic	The overall characteristics and behavior of a given state
Systemic	The status and position of states, and their relationships within the system. This can include larger groupings (e.g. based on wealth) or institutions (e.g. NATO)
Global	Overarching factors such as patterns of behavior, conflict, climate, etc

Adapted from Nau, 2012

Example levels of analysis in information processing systems	
Physical	Hardware, circuits, physical limitations (how is it computed?)
Algorithmic	Algorithms, languages, operating systems (what is computed?)
Computational	Output or system behavior, videogames, Twitter... (why is it computed?)

Adapted from Marr (1982) and Carandini (2012)

References

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