

## Modularity, abstractness and the interactive brain

James M. Clark

Department of Psychology, University of Winnipeg, Winnipeg, Manitoba, Canada R3B 2E9

Electronic mail: [clark@uwpg02.uwinnipeg.ca](mailto:clark@uwpg02.uwinnipeg.ca)

Farah has contested the assumption that brain functioning is localized or modular and has argued for a highly interactive brain. I cite another example against modularity, describe an added benefit of the competing associative view, and challenge further the received view of brain functioning.

**Number processing.** The locality assumption rejected by Farah for semantic taxonomies, visual attention, and face recognition is also central to other areas. In number processing, McCloskey and his colleagues (e.g., McCloskey et al. 1986; 1992; Sokol et al. 1989) have proposed a modular view based on distinct comprehension, calculation, and production modules that communicate solely by mediating abstract number codes.

Campbell and Clark (1988; 1992; Clark & Campbell 1991) have presented an alternative, encoding-complex view of number processing in which numbers are represented as concrete codes in diverse formats (e.g., digits, number words, analogue codes). In place of function-specific modules, interactive excitatory and inhibitory associations among specific codes perform number identification, calculation, and production.

The arguments advanced against modular views of number processing have reflected criteria similar to those cited by Farah. In particular, nonlocalized associative theories can accommodate findings thought to support modularity and can explain phenomena that are awkward for modular views. The

abstract number codes that segregate modules are also questionable (see below). Although these claims have been challenged (see papers cited earlier), the example nonetheless demonstrates the generality of the issues and arguments advanced by Farah.

**Associative models.** Modular views are weakened by demonstrations that nonlocalized associative theories can explain behavior in terms of excitatory and inhibitory connections among mental representations. Associative theories include connectionist models, such as those described by Farah, as well as related approaches that do not assume distributed representations (e.g., Campbell & Oliphant 1992). Farah points out the empirical adequacy and other benefits of such models.

One particular strength of associative models not emphasized by Farah is that they are undeniably mechanistic; that is, they identify physical events (e.g., representations, activation) intervening between inputs to and responses of the cognitive system. This mechanistic quality elevates associative models above psychological theories that interpret behavior by abstract symbolic processes (e.g., "if-then" procedures, retrieval) that all too often say little about concrete, underlying mechanisms. The associative approach compels researchers to deal with the underlying mechanisms, or at least to admit their present ignorance about those mechanisms. In turn, the translation of psychological metaphors into physical mechanisms will perforce reveal the associative quality of the underlying causal links and neuronal systems.

Associationism has a controversial history. Associative models have been criticized for being vague and weakly specified, and for lacking formal constraints. Farah correctly noted that connectionist models are not intrinsically more *post hoc* than high-level, symbolic models, and also that empirical constraints should be more important than formal constraints. Undue emphasis on formal properties has contributed to the unwarranted faith in modularity and obstructed the development of mechanistic, associative models. Bever et al. (1968), for example, argued on formal grounds that associative models in principle could not explain many facets of human behavior. Such arguments count for little in the face of successful connectionist and other associative models.

**The received view.** Farah challenged the tacit and widely held assumption that brain and cognitive processes are localized and modular, but the received view is based on other fundamental premises that are similarly doubtful. In particular, a critical evaluation is needed of the assumption that abstract semantic codes and processes underlie human behavior. The abstract code and locality assumptions tend to cooccur (e.g., abstract codes define the boundaries between McCloskey et al.'s modules).

Despite rejecting modularity, Farah retained abstract semantic codes and, implicitly, the assumption of a distinct semantic module. This is clearest in her models for taxonomic categories and face perception (Figs. 1 and 11). Figure 11, for example, identified special semantic units to identify such features as "actor." This abstract code assumption is unnecessary, inasmuch as the word "actor" and other similarly specific codes can subserve functions attributed to semantic codes and can avoid the artificial distinction between semantic and nonsemantic processing modules (i.e., hidden "locality").

Thus Farah unadvisedly left intact a second central fallacy of much cognitive and brain theorizing, namely, that a semantic system exists distinct from patterns of activation in specific verbal or nonverbal codes. According to strong associative views (e.g., Campbell & Clark 1988; Clark & Campbell 1991; Paivio 1986), meanings and concepts emerge from interactive brain processes involving associations among words, objects, motor images, and other concrete representations. The added assumption of abstract, semantic codes is superfluous.

**Conclusions.** Farah's challenge to locality is a positive step toward ridding the behavioral and brain sciences of unwar-

*Commentary/Farah: Neuropsychological inference*

ranted, restrictive assumptions about the human brain and related psychological processes. The modularity assumption and correlated claims about abstract codes lack a sound empirical foundation. They only became dominant because of fallible rational arguments and because their proposed view of cognition and the brain was amenable to scientists' thought processes and available computational tools. More generally, Farah has demonstrated how vital it is that every scientific assumption, no matter how rational it seems, be questioned, be put to rigorous empirical test, and be challenged by contrasting theories, such as associative models based on interactive excitatory and inhibitory mechanisms.

**ACKNOWLEDGMENT**

Preparation of this paper was supported by grant OGP0042736 from the Natural Sciences and Engineering Research Council of Canada.