***Instructor Notes***

*The* Thematic *notes for each chapter are detailed “deeper dives” that either explore a specific topic in more detail than is appropriate for the main text, or address a question that diverges from the main thread of the chapter. Some may find these valuable either for inclusion in lecture or as discussion topics small-group settings. The* Finer points *either relate to more specific points that may benefit from additional explication, or call attention to resources from the author’s Cognitive Neuroscience Compendium* (CNC; https://postlab.psych.wisc.edu/cog-neuro-compendium/; https://www.youtube.com/channel/UCF44YYwYYn1CUAcLuk-rhZA) *that* *may be useful either to supplement lecture material or for outside-of-class-time viewing by students. In particular, the narrated videos were solicited and curated by the author, and produced by international experts on each topic.*

CHAPTER 1

*Thematic*

**1.1 Localization vs. mass action as a framework for thinking about how to approach studying brain-behavior linkages**

The core question in cognitive neuroscience is *How does the functioning of the brain give rise to cognition and behavior?* Localization vs. mass action is a theme that the text will return to periodically to help students appreciate the interplay (and tension) between reverse engineering approaches that lend themselves to thinking in terms of modularity, and approaches that emphasize distributed processing, dynamical systems, and emergence. I have found the following analogies to be helpful in getting these ideas across to students:

One way to approach the question of how a system works is to divide its overall behavior into logically discrete functions, and to determine whether different physical parts of the system might differentially support the different functions. To determine how an automobile works, for example, one might start by logically “decomposing” its overall behavior into two plausibly separable functions, accelerating and sustaining movement vs. decelerating and stopping. This approach naturally leads to a way of thinking about the system as being made up of discrete parts, each of which carries out a different function. However, not all systems are made up of discrete parts, each with a separate function, in the way that an automobile is. One example of such a system is a school of fish. It has properties (overall shape, smoothness of outside surfaces, changes of speed and direction) that cannot be localized to component parts. These properties can be said to be emergent, in that they don’t exist in any of the constituent elements (i.e., in any one fish), but they “emerge” at the level of the school. (We shall see that many cognitive functions, including consciousness, are believed by many to be emergent.) When considering the school of fish, all parts perform the same function and are interchangeable (i.e., they display equipotentiality), and removing 20% of the fish from one region of the school vs. from a different region will have identical effects on the school (i.e., the principle of mass action applies). Localization of function is not possible with a school of fish. (Note, however, that localization of functions within an individual fish (e.g., moving the tail vs. extracting oxygen from water) *is* possible, and so specifying the grain of detail at which one is studying a system is also very important.)

Because automobiles are manmade, we don’t actually have to perform experiments to determine how they work. And it is precisely because we know how they are designed and built that we know that a localization-of-function perspective is the correct way to think about how the different functions of the car are accomplished. Because a school of fish is fully observable (i.e., we know effectively everything that there is to know about what it’s made of), we know that the properties of emergence, equipotentiality, and mass action apply to it. (These are often summarized under the rubric *distributed*.) The brain is different from these two examples, however, in that we don’t know all there is to know about how it is “made,” nor the principles underlying how it “works.” To study it, therefore, cognitive neuroscientists devise models, then test these models with experiments. Although it is not always explicitly acknowledged, these models and/or the techniques used to test them often make an assumption that the brain system under investigation works on fundamentally localizationist or distributed principles. For every contemporary problem in cognitive neuroscience, it is important keep in mind how the choice of model and/or method can bias the extent to which one is likely to draw localizationist or mass-action/emergence conclusions from one’s experimental data.

**1.2 The role of nonhuman animals in neuroscience research**

It is evident from this historical overview that modern cognitive neuroscience could not have been developed without research conducted on nonhuman animals. It is equally true that research performed on nonhuman animals continues to play a critical and necessary role in every branch of contemporary cognitive neuroscience. The reason for this, as you will see in each chapter, is that many questions about physiology and anatomy cannot be answered scientifically without carrying out experiments that are invasive. Reading this book will also make clear that, although we have learned an astounding amount of information about how the workings of the brain give rise to cognition, there remains an enormous amount that we still don’t know. Despite recent and ongoing advances in a variety of noninvasive methods that can be used to study the brain (such as neuroimaging and computer modeling), there will continue, for the foreseeable future, to be questions that can be answered through no means other than invasive experimentation.

Because of these facts, another sociological factor with which the cognitive neuroscientist must be conversant (in addition to those raised in the second paragraph of this chapter) is the ethics of animal research. This is true even for researchers such as the author of this textbook, whose research is conducted exclusively on human subjects. This is because many ideas that motivate our experiments come from research that was performed with animals, and our ability to interpret our data often depends on what has been learned from animal research. For an informal index of this, consider the syllabus for my research group’s lab meetings. During the academic semester that preceded the writing of this thought box, my group met on 14 occasions, and on each we discussed an article from a scientific journal that is relevant for our research. Of these 14 meetings, four (i.e., nearly 30%) were devoted to articles describing research performed with nonhuman animals.

This brings up a stylistic point: throughout the book, when I refer to “primates” without any other context, I’m referring to all species within this taxonomic order (which includes humans). Typically this will be in the context of a structure/function/behavior that is shared by primates, but does not generalize to other mammals.

The ethics of animal research are complex, and the topic can arouse strong emotions. Debates are often framed in hypothetical terms for which there are no objectively “right” or “wrong” answers. One question that has been contemplated, for example, is *If one encounters a burning building and there’s only time to save the human who is inside or the mouse that is inside (or the dog, or the monkey, …), which does one save?* You can see how two people could devote an afternoon to debating whether or not this analogy is even appropriately relevant to the question of animal research. Although a more detailed consideration of this topic is outside the purview of this book, the *Further Reading* from neuroscientist Dario Ringach (2011) nicely summarizes many of the arguments in favor of and in opposition to animal research, and provides references to writings that represent both the pro and the con sides of the debate.

*Finer points*

- You may find it useful to qualify/expand on the assertion that “… variations in gross shape from one brain to another have little, if anything, to do with the “kind of person” that one is.” Cognitive neuroscience is grounded in the governing assumption that all cognitive functions arise from the physical, chemical, and physiological properties of the brain and central nervous system. Thus, all differences between individuals must reduce to physical factors. In typically developed humans, however, these will be microscopic (e.g., connections between neurons (*Chapter 2* and *Chapter 11*); varying levels of concentration of chemical transmitters (*Chapter 2*)), and underlain by differences in genetics and/or life experience.

- Some scientists reserve the use of *neuropsychology* to refer to studies with humans who have sustained damage to the brain, and refer to analogous experiments with nonhuman animals simply as *lesion studies*.

- Gall’s formal study of localization of function was not only controversial in scientific circles, but also had political implications. As the historian of science Stanley Finger puts it, “Authorities of the Austrian Catholic church viewed this work as championing materialism, atheism, and fatalism bordering on heresy.” As a result, the Holy Roman Emperor (who ruled Vienna, where Gall had launched his career) sent to Gall a threatening letter that read, in part, “This doctrine concerning the head … will perhaps cause a few to lose their heads” (Finger, 2000, pp. 124–125). Within a few years, Gall (and his head) left Vienna permanently, eventually settling in Paris.

- One example of the two major categories of neuroscience influencing the work of one investigator can be seen with Eduard Hitzig. His electrical stimulation experiments with Frisch are recognized as foundational in launching systems neuroscience. A formative influence that may have inspired these experiments, however, was the time earlier in his life when Hitzig served as a battlefield physician in the Prussian army. In this capacity, he encountered many soldiers who evinced various sensory and/or behavioral deficits as a result of head injuries acquired in battle.