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A Tribute to Michael I. Posner

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In May 2003, 10 speakers and a large audience gathered at the University of Oregon in Eugene to pay tribute to the enormously influential contributions Michael Posner has made to the disciplines of psychology and cognitive neuroscience. They gathered, moreover, to express appreciation for his profound influence, both personal and professional, on their careers at times when they were students—undergraduate or graduate—postdoctoral fellows, or collaborative scientists. Attendees converged from throughout the United States and around the world.

Posner is not a person who wishes to bask in tributes. Although he might (and did) tolerate tributes during two spring days of celebration, his longstanding goals have always been about science and not about him as a person. He would wish a conference not to focus on the past but rather to push the advance of cognitive science to new depths and into new directions. With this in mind, he himself requested a hand in setting the theme of the conference, a theme reflected in these resulting proceedings and titled Developing Individuality of the Human Brain: A Tribute to Mike Posner.

The theme of these chapters grew from a line of investigation, a rather straight line in retrospect, that stretches from the mid-1960s up to the present. In chapter 12 that Posner himself has prepared for this volume, he elegantly describes this trajectory from his perspective. He began by using simple reaction-time indicators to differentiate among elementary components of reading and of attention. These simple measurement techniques not only allowed isolation of the different components but also allowed investigation of the properties of each. Later Posner proposed that elementary components might constitute an appropriate grain of analysis for mapping mental function into brain structure. He initiated a systematic examination of this idea, first toward elucidating the fundamental cognitive deficit suffered by people with injuries to various brain

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regions. Subsequently he showed the community of researchers in the nascent field of cognitive neuroscience how neuroimaging techniques, starting with positron emission tomography (PET) scan but progressing to other techniques such as functional magnetic resonance imaging (fMRI), could be used to even more precisely map elementary function to specific brain area. Next he merged his interests in mind and brain with developmental psychology to understand the temporal development of component processes of attention. This line of investigation also yielded mapping of cognition to the brain by a correlation of developing mental components with developing brain substructures. The developmental thrust provided a basis for understanding how differences among humans—both normal variation and variation because of disorders—could be understood. The logical next step in this progression, linking specific components to specific genes and to specific environmental input, has already begun, and again we see Posner and some of his close colleagues (e.g., Rothbart & Rueda, chap. 9; Neville, chap. 11, both this volume) as pioneers in this emerging field.

Early Academic Career

In his junior high school years, Posner moved with his family to Seattle, where he subsequently attended the University of Washington, attaining in 1957 a bachelor of science degree—not in psychology but in physics. As a freshly minted physicist, he took a position at Boeing Aircraft as associate research engineer, while simultaneously pursuing a master's degree. Mixed in with studies and work, Posner and Sharon Blanck were married in 1958. Both received their degrees in 1959, this time Posner's was in psychology. The exposure to the Pacific Northwest environment may well explain much of the Posner's lasting love affair with Oregon.

At first, Posner tried to meld physics and psychology, studying psychophysics and auditory processing. Reflecting his enduring interest in scientific application, he suggested to Boeing how alteration of the noise frequency spectrum, as opposed to simply reducing intensity, might not only make jet engines less loud but also affect annoyance, reducing it or increasing it, depending on the nature of spectral change. His academic interests took a sharp turn, however, when he left Washington for additional graduate study in the psychology department at the University of Michigan.

Michigan—with such notable faculty as Paul Fitts, Arthur Melton, and Ward Edwards—was in the forefront of a cognitive psychology vigorously reemerging from the shadow of behaviorism. Posner took Fitts as his mentor. Fitts was a pioneer in the area of human factors, and that practical orientation likely attracted Posner. More important for the directions Posner was to take, however, Fitts was intent on developing a stronger theoretical basis for application. He used the tool of reaction time and Shannon's newly developed theory of information to explore limitations of human information processing, themes that played central roles in Posner's career (see Fitts & Posner, 1967).

In those early years at Michigan and shortly thereafter as a young professor at the University of Wisconsin, Posner applied the new, formal metric of information theory to problems such as concept learning and similarity judgment. Along a different line, he developed an "acid-bath" theory of short-term memory (Posner & Konick, 1966). The acid, rather than etching memories into the brain's slate, ate away at already etched memory, the acid concentration depending on similarity. He also explored memory for movements, stimulating a line of investigation on different codes of movement.

After three daunting winters in Wisconsin, the jewels of sea, mountain, forest, and, of course, an outstanding psychology department, attracted Posner and his wife in 1965 to the University of Oregon. The psychology department had a long and storied history. It is the oldest psychology department in the United States west of the Mississippi River. The department's founding in 1895 predated by a year even the famed Würzburg school so prominent in the history of cognitive psychology. The department's founder, Benjamin Hawthorne, declared at initiation that the proper focus of psychological study was the mind, and indeed it initially was called the department of mental science. At Oregon, Posner joined Ray Hyman and Fred Attneave, two others who were playing prominent, pioneering roles in the application of information theory to cognition. The three received a large program grant from the Advanced Research Projects Agency of the Department of Defense, and with it they bought a "battleship"—a huge PDP-9 computer, which filled a room even though it was miniscule in capacity by modern standards. With the aid of Gil Osgood and some enterprising graduate students, Oregon soon had the most outstanding computer-based psychology lab in the country. From that moment Oregon, and Posner, became a Mecca for cognitive psychologists from around the country and from around the world.

One of us joined Posner the next year as a postdoctoral fellow, the first in a long string of fellows. One of our papers (Posner & Keele, 1968) gained some attention. Following Posner's earlier dissertation work, dot patterns were constructed to serve as examples of different concepts—dogs versus cats so to speak (Posner, 1963). Research participants learned to sort patterns into two categories and then were tested for discrimination accuracy. Surprisingly, the prototypes from which concept examples were constructed were categorized as well as or better than the experienced examples themselves—this despite the fact that the prototypes were not previously experienced. Posner thought the dominance of concept prototype settled an argument between the British philosophers Bishop Berkeley and John Locke about the nature of concepts. He chose the title of the paper: "On the Genesis of Abstract Ideas."

Posner's early research included work on human factors, thinking, memory, motor control, and concept representation. He continued over succeeding years to investigate a wide array of problems. At this point, however, after two years at Oregon, he set down the cornerstones for his most enduring contributions to cognitive psychology and its ultimate merger with neuroscience. He began to work out elementary components of reading and to differentiate processes of attention.

Elementary Components

In 1967, 2 years after arriving at Oregon, Posner and several graduate students began publishing studies on letter matching (e.g., Posner, Boies, Eichelman, & Taylor, 1969; Posner & Mitchell, 1967). Deciding that two letters of different shape had the same name (e.g., upper case “A” and lower case “a”) took longer than when they had the same visual shape as well as name (e.g., as two lower case “a”s). Letter matching itself has little intrinsic importance. Nonetheless, the technique provided a simple tool for gaining insight into the central properties of the human cognitive system. One and the same external stimulus—letters in this case—gave rise to distinctly different internal representations or codes—visual codes, phonetic codes, and semantic codes. The codes arose in parallel, contrary to a view dominant at that time of human as serial computer. Other investigators, such as Oregon’s Gerry Reicher, discoverer of the famous “word superiority effect,” (Reicher, 1969) and even Posner, together with postdoctoral fellow Tom Carr (see chap. 2), visiting professor Sandy Pollatsek, and graduate student Charles Snyder, made similar points regarding the multiple codes of words (Carr, Posner, Pollatsek, & Snyder, 1979)

In addition to implications for reading per se, the letter-matching studies that began in the late 1960s provided an exceptional meta-theoretical point. They illustrated the power of extremely simple reaction time procedures, dubbed chronometric techniques by Posner, for untangling fundamental components of important, complex tasks, not only of reading but also in domains such as motor control. The studies marked the beginning of a central theme in Posner’s work: elementary codes and processes.

Tom Carr (chap. 2, this volume) begins by describing this idea inherited from Posner during Tom’s postdoctoral years in the late 1970s—that skills are assembled from elementary processes. Using reading as a case example, Carr details the graphemic/orthographic codes that are abstracted from printed word input and translated into phonetic codes. He describes how differences among individual people in their code efficiencies can be deduced using simple measures such as reaction time. He reviews evidence that phonetic mastery correlates with reading success and indeed that phonetic-based schooling programs produce better readers than programs with little phonetic emphasis.

Another outstanding example of the power of componential analysis is provided by Stanislas Dehaene (chap. 4, this volume). Previously Dehaene conducted magnificent studies using reaction time methods to decompose and examine different codes of numeric representation. In this chapter, however, he uses the chronometric method to analyze the activation of semantic codes of words (and numbers), such activation sometimes rising to consciousness and sometimes not. Together Carr and Dehaene provide powerful illustrations of Posner’s idea that decomposition of skill into elementary components yields insight and powerful application to important human endeavors.

The letter-matching studies also revealed another aspect of the human information-processing system (Posner & Boies, 1972). A single stimulus, a letter, not only activated internal codes of various types. It also served as a general alerting signal—telling the brain when it is time to pay attention.

Alerting was shown to operate independently of attention drawn to the information content of the stimulus.

This point regarding separable and independent components of attention became the center of focus in subsequent research. Posner worked with a string of illustrious students and postdoctoral fellows, including Ray Klein, Brian Davidson, Charles Snyder, Mary Jo Nissen, Yoav Cohen, Roger Remington, John McLean, Gordon Shulman, Peter McLeod, John Duncan, and others. One paradigm rose to the top. Research participants were cued in which of two boxes on a screen a signal might occur, the task being to press a key whenever a spot appeared in a box, regardless of which box. This exceedingly simple task was to yield clues about the nature not only of alertness but also of selective attention (e.g., Posner, Davidson, & Snyder, 1980).

A cue at a place where a signal might occur very often pulls eye movement to it. Indeed, later in this chapter we will describe how Posner and Rothbart made use of this pulling tendency to study attention in infants who were so young that verbal instruction could not be given. In the case of infants, eye movement gives an indication of where attention is located. Posner and colleagues were able to show at this earlier research period, however, that even when adult participants inhibit eye movement, an internal process of attention shifts to the place where the signal is expected to occur. The attention shift was indexed by temporary improvements in reaction time whenever the signal occurred at the cued location.

One finding about attention to a location is that it could be dissociated into two forms. The occurrence of a cue automatically and rapidly summons attention to its location regardless of eye movement and regardless of intent. In addition, a symbolic cue such as an arrow at fixation could direct attention to a place different from the cue location, again without eye movement. This less automatic form of endogenous orienting is slightly delayed over the automatic exogenous form. Later work by Posner and colleagues, especially the prominent neurologist Robert Rafal, were to place these two forms of orienting in different brain systems. This dissociation also led to a second discovery. If participants were instructed not only to maintain fixation at a central point but also to keep attention there, a noninformative signal occurring elsewhere unavoidably summoned attention to itself, although attention quickly returned to fixation. If an obligatory signal requiring response subsequently occurred at the previously summoned place, response to it was delayed compared to a case in which attention was not previously summoned. It appeared that attention to a previously attended location was "inhibited" (Posner & Cohen, 1984).

Inhibition of return is thought to be a marker of an important control process in attention. The real world is exceedingly complex. Extracting information relevant to a current endeavor requires not only scanning with eye movement but also scanning with attention throughout the visual field. Whatever is in the field pulls attention hither and thither. Inhibition is thought to prevent repeated rescanning of an area already deemed irrelevant. Indeed during a postdoctoral mid-1990s stint with Posner, one of us (Mayr) was inspired to explore a similar mechanism that inhibits previous task sets thereby relinquishing their control over action once they no longer are relevant (Mayr & Keele, 2000).

Despite its apparent simplicity, the search for a full understanding of how exactly inhibition of return operates has been a surprisingly difficult endeavor. Ray Klein has been intricately involved in this attempt, ever since his graduate-student years with Posner in the mid-1970s. He gives a comprehensive account (chap. 4) of a line of research that serves as a model case of how the componential method can be used to characterize attention to locations. He shows us how inhibition-of-return arises from the interaction between endogenous and reflexive systems and how with this framework in mind, we can begin to reexamine individual and developmental differences in basic attentional functioning.

Much of Posner's midperiod work, ranging from the mid-1960s up to the late 1970s, is covered in his influential book, *Chronometric Explorations of Mind* (Posner, 1978). The book laid down a conceptual framework for his work on mapping cognition to brain that was to follow.

Mapping Cognition to Brain

In the early 1980s, Posner put forth a new idea, one that proved to be enormously influential in the merger of cognitive analysis with neuroscience. Elementary components, he suggested, might be the correct grain for mapping mental function to the brain. At first, one might not appreciate the boldness of this proposition. The phrenologists more than a century ago divided the brain into regions responsible for arithmetic, language, motor control, emotions, personality and social traits, and so on. We now find their divisions humorous. But have more "modern" views progressed greatly beyond the phrenologists' view? Many still argue that Broca's and Wernicke's brain areas are for language, cerebellum, and basal ganglia are for motor control, and the like—large brain areas for specific, complex-task domains. Posner raised the possibility that brain regions instead were specialized for elementary processes. Although in some cases, particular, localized processes might be devoted primarily to particular task domains, Posner's analysis opened a search for localized elementary processes accessible by a variety of different kinds of tasks.

The arrival of world-renowned Oscar Marin as chief neurologist at Good Samaritan Hospital in nearby Portland, Oregon, provided the opportunity to test Posner's notion of localization. From the University of Oregon, Posner soon was commuting more than 100 miles to Portland, where he and Marin formed a research and training program. The program attracted talented young neurologists and cognitive psychologists—Fran Friedrich, Avishi Henik, John Walker, Rich Ivry, Alan Wing, David Margolin, Bob Rafal, and others, each of whom have since left their deep marks on what was then an embryonic cognitive neuroscience.

Posner and his colleagues used the same reaction-time techniques they had used for isolating components of attention—techniques such as brightening a box or cueing with an arrow to pull or to drive attention. By examining how damage in one part of the brain affected reaction time, they were able to localize different components of attention to different brain regions (e.g., Posner, Cohen,

& Rafal, 1982; Posner, Walker, Friedrich, & Rafal, 1984). Not only were exogenous and endogenous forms of orienting of attention found to emanate from different regions of the brain, even more elementary components such as disengaging from previous focus, moving to and reengaging a new focus were associated with different brain regions and assembled into a network.

Posner's point about using neurological patients to localize fundamental cognitive components to specific brain regions was firmly established, and he moved to a new approach. He left behind a powerful idea and a cadre of colleagues who continue to this day to make important discoveries about the elementary cognitive functions of cortical and subcortical brain regions.

In 1985, Posner, bringing Gordon Shulman with him, joined Marc Raichle at Washington University in St. Louis. Their goal was to use PET scan neuroimaging to map elementary process to brain. In 1987 to 1989, Posner, Raichle, and Shulman—with Petersen, Fox, Mintun, Sandson, and Dhawan—published a series of landmark studies in *Nature, Science,* and the *Journal of Cognitive Neuroscience* (Petersen, Fox, Posner, Mintun, & Raichle, 1987, 1989; Posner, Petersen, Fox, & Raichle, 1988). Much of Posner's direct contributions and influence regarding the use of neuroimaging in mapping cognitive component to brain is presented in Posner and Raichle's book *Images of Mind* (Posner & Raichle, 1994).

These landmarks were based on much the same logic as Posner's seminal studies of letter matching. Whereas Posner's earlier studies examined change in reaction time as a result of change in elementary process, these neuroimaging studies looked at change in blood flow. While the brain was being scanned for amount of blood flow in different brain regions, participants (a) viewed fixation points, (b) viewed words, (c) named words, or (d) made a semantic translation (e.g., shovel to dig), naming the translated word. Each change in elementary operation altered blood flow in different brain regions, thereby allowing identification of mental component with the brain region. In later studies, the team further clarified the nature of internal codes supported by each targeted brain region. Although simply viewing words activated one region in the posterior cortex, it was not clear whether this region provided a visual word code or whether it merely responded to strings of complex shapes. Additional analysis found that nonwords—that is, letter strings without semantic content whose constituent letters nonetheless fit the spelling rules of English—activated the same posterior region of visual cortex as did real words. Letter-string nonwords without orthographic regularity failed, however, to produce activation, supporting the contention that this decidedly visual area of the human brain had learned the visual properties of English words. In essence, the function of an area of the human visual cortex was altered in response to instruction in reading. Among other things, this seminal study provided groundwork for exploring plasticity of function in the human brain.

These studies of the St. Louis group set a gold standard for research on cognitive to brain mapping, showing as they did how one elementary code or process could be isolated from others and providing the correct grain for understanding brain function. Nowadays extensions of the method frequent all aspects of cognitive neuroscience.

The enormous influence of neuroimaging technology for mapping cognitive function to brain structure is represented in this volume in already mentioned chapters by Carr (chap. 2) and Dehaene (chap. 4). Carr's chapter, describing elementary reading codes and instructional strategies for teaching reading, closes by laying out neuroimaging evidence for two distinct routes from visual graphemic representation to pronunciation. Dehaene, in his chapter, presents among other things a series of neuroimaging experiments that uncover the emergence of word-level understanding in terms of an increasingly abstract cascade of functions along a posterior–frontal axis within the word-form area originally discovered by Posner. Dehaene also shows how researchers can use clever combinations of behavioral, imaging, and computational work to make progress in one of the toughest problems in the neurosciences—namely how, when, and why information processed in the brain enters consciousness.

An important theoretical advance in 1990 by Posner and Steve Petersen was triggered through the integration of results from patient studies on spatial orienting with results from brain imaging studies. The theory proposed distinct attentional networks with each having distinct functional and neuroanatomical properties. A posterior network within the parietal cortex was associated with change of attention from one place to another—disengagement from a former location, movement, and reengagement at another location. An anterior network, specifically associated with the anterior cingulate and related prefrontal cortical areas, becomes active whenever conflict between goal-directed actions and interfering response tendencies need to be resolved. Important elaboration and advance of these early propositions can be found in the chapters of B. J. Casey (chap. 8, this volume) and John Duncan (chap. 5, this volume). Casey presents a detailed analysis about how frontal cortical regions and subcortical regions (basal ganglia) cooperate in regulating different kinds of conflicts, and how different developmental disorders can be characterized in terms of alteration in each of these subfunctions. Duncan provides a somewhat more general claim about prefrontal cortex as the site that represents the currently relevant task model. He proposes that the degree to which this task model contains only relevant aspects while suppressing irrelevant aspects may be at the core of what in psychometric research is associated with general intelligence (g). In this regard, he travels a long way on Posner's journey from characterizing a simple processing component to understanding a fundamentally important, real-world phenomenon.

Mapping cognitive components to brain regions by no means indicates how a brain region accomplishes its computation. Nonetheless, establishing a function of a brain region is a necessary precursor to understanding the mechanism of function. Posner's early behavioral paradigms for decomposing processes of attention have been influential not only in mapping but also in understanding their neurochemical underpinnings. Single-neuron recording using behavioral tasks similar to those Posner had developed for humans already had indicated regions of the monkey brain involved in spatial cueing. Oregon colleagues of Posner, Rich Marrocco, and associated graduate students, were able to register neurochemical responses in local regions around small complexes of neurons receptive to attentional cueing. In addition, they were able to manipulate the time course of the deployment and shifting of attention in response to manipulation of neurotransmitter agonists and antagonists (e.g., Davidson, Cutrell, & Marrocco, 1999; Davidson & Marrocco, 2000). Such studies provide a critical step in understanding physiological mechanisms whereby localized brain regions instantiate their elementary computations.

As mentioned earlier, the neuroimaging revolution in cognitive neuroscience began to a large degree in the influential program initiated by Posner and Raichle. The idea was to relate changes in cognitive activity to changes in regional blood flow. Raichle's chapter 6 in this volume points out a puzzle, however, and in so doing it establishes a new agenda in the search for basic mechanisms that relate brain to function. Most elementary functions, such as activation of word codes or switching the focus of attention from one location to another, take at most a few hundred milliseconds. The spiking of principle neurons that accompany such a function is not only short in duration but also narrowly localized. The overall energy cost of such operation is small compared to the energy reflected in blood flow changes, such changes lasting longer and involving broader areas. This discrepancy in energy costs presents a serious disconnection between concepts. Do blood flow changes reflect specific internal processes such as code activation or attention switching, or do they in some manner reflect a larger, more energy intensive context in which the processes are embedded? Raichle's chapter alerts us to an exciting new challenge regarding our understanding of the link between brain function and cognitive function.

The successes of Posner and his many colleagues, as well as those of numerous others who have now applied his ideas in other task domains, provides a strong case: The elucidation of elementary functions that make up tasks appears not only to provide an appropriate grain for understanding the functional architecture of the human brain but it also provides a beginning foundation to understanding the mechanisms themselves.

Development and Individual Differences

Although few would doubt that genetics, development, and experience contribute to human variation in intelligence and temperament, progress in forging strong links has been limited by their complexity. The analysis of association between brain regions and the elementary functions they support might offer an entry point, providing also an appropriate grain of analysis for understanding the developmental time course of cognitive function, its variation across individuals, and genetic versus experiential contributions. In more recent years, Posner has focused on these themes.

Studies along this line had their origin at the University of Oregon in a series of collaborative studies beginning in 1990 by Posner, long-time faculty colleague Mary Rothbart, then-postdoctoral fellow Mark Johnson, and notable students including Anne Boylan Clohessy, Shaun Vecera, Johannes Rothlind, Cathy Harman, and Lisa Thomas-Thrapp. Some of their initial efforts were reported in a special issue of the *Journal of Cognitive Neuroscience* in fall 1991. About this time, Posner also established the first of a series of collaborations with Jim Swanson, ultimately leading to a revised understanding of attention deficit disorders of children (Swanson et al., 1991).

By examining eye movements as modulated by stimuli and training, Posner and his colleagues were able to map out development of attention and control in infants (e.g., Johnson, Posner, & Rothbart, 1991). An infant of only a few months of age naturally fixated on an interesting, moving shape. Following fixation, two shapes were added, one on each side of the fixated shape. Infants of 2 and 3 months of age had great difficulty in disengaging from initial fixation as long as the initial object remained in view. By 4 months of age, however, the young child could disengage from a persisting object to look at another, suggesting that a critical component of attention had matured. This point in time was consistent with maturational changes in parts of the brain thought from neurological studies to serve disengagement. Moreover, infants for whom the disengagement was first achieved preceded other infants in achieving temperamental aspects of self-control, such as the ability to be soothed by a distracting stimulus.

At about the same 4-month time point, other aspects of attention came into play. If shape of the central stimulus predicted where the next stimulus would occur, infants began to make anticipatory eye movement toward the forthcoming stimulus. Although each of these three indicators of attention—disengagement, anticipation, and correct choice—developed on average at about the same time, their onsets were not correlated, different infants achieving them in different order. It appeared that, as in adults where components such as disengaging, moving, and selecting depend on different brain regions, the infant regions mature independently as well. These features of attention that depended on external cues developed much earlier than ability to spontaneously alternate attention between places in space, a type of internal control. The latter did not develop until sometime between 6 and 18 months of age (Vecera, Rothbart, & Posner, 1991). These differences were thought to depend on differential maturation periods of posterior and anterior cortical components of Posner and Petersen's (1990) attentional network.

This type of work raises fundamental questions about what makes brain systems develop. Johnson (chap. 7, this volume) describes a framework (interactive specialization approach) of how to think about these issues, and he applies it to the case of the emergence of a network of cortical regions that he refers to as the social brain. For example, by providing a detailed analysis of what serves as face cues during different developmental periods, he can show how rather general brain networks through experience can become selectively tuned to prefer certain types of information. In general, by this view, neurocognitive development should be seen not so much as the maturation of specific brain areas but as the experience-driven emergence of functionally adequate interactions between several brain areas.

Following these initial investigations of development and individual difference, Posner was asked to found a new center at Cornell Medical School, the Sackler Institute for Developmental Psychobiology. The institute's intent is reflected closely in the theme of this volume. The center is to study the emergence of fundamental components of cognition in the context of brain development and educational environment. One theme, pursued by Bruce McCandliss—a former graduate student of Posner's—and other colleagues, examines the development of processes of reading, the role of educational variation on normal and impaired reading, and the influence of reading instruction on brain function. This important societal theme clearly extends the earlier research themes pioneered by Posner and thoroughly reported in this volume by Carr (chap. 2).

Another theme of the Sackler Institute derives from Posner's analysis of anterior and posterior attention networks and associated methods for disentangling elementary components. This theme has moved in two remarkable, interrelated directions. Posner, Swanson, Casey, and others at the Sackler Institute have made a case that childhood disorders—attention deficit disorder, Tourette's syndrome, childhood schizophrenia, obsessive–compulsive disorder—can be related to deficiencies in conflict resolution (or executive control) components of the anterior attention network. Recent evidence suggests that some of these disorders depend on alteration in one or a few specific genes. The linkage of disorder to elementary component in turn allows linkage of genetic variation to variation in attentional components (see, e.g., Fan, McCandliss, Sommer, Raz, & Posner, 2002; Fan, Wu, Fossella, & Posner, 2001; Fossella et al., 2002). Thus, the idea of elementary components as conceptualized by Posner some decades ago is providing fundamental insight in yet another domain. Details about these ideas are provided both in Posner's chapter 12 (this volume) and in chapter 8 by B. J. Casey, who is Posner's successor as director of the Sackler Institute.

Three additional chapters in this volume by Rothbart and Rueda, Farah, and Neville relate to the developmental themes that form part of Posner's most current interests, including an emphasis on training in the light of understanding elementary components. Rothbart and Rueda (chap. 9) examine individual differences in effortful control in children, showing how it can be measured with laboratory conflict tasks and related to the frontal cortical components of the Posner-Peterson anterior network of attention that support executive function. They present preliminary results indicating that deficiencies in effortful control may be remediable by concentrated cognitive training targeted specifically at executive function.

Prospects for training-based improvement in executive function could have considerable importance for some segments of society. Martha Farah, in chapter 10, shows that children of low socioeconomic status perform more poorly than children of higher status on executive function measures (e.g., performance on a go–no-go conflict task) also known to depend on the anterior attentional system. The low socioeconomic status children also exhibit impairment on language–verbal measures but not at all or to a lesser degree on memory, spatial, and perceptual measures. Given the differential pattern of Farah's results, given the Rothbart-Rueda preliminary evidence for training effects on executive function, and given the likelihood that differences in language and verbal abilities are highly dependent on experiential differences, one might hope that early educational intervention tailored from knowledge of cognitive process might successfully intervene with low socioeconomic status children.

These hopes that education based on knowledge of cognitive components would pay off in improved intellectual performance rests on a premise that representational function of rather broad regions of cortex are modifiable by experience. In this regard, chapter 11 by Helen Neville, a leading investigator of brain plasticity, provides some critical hints. Her main theme is that different functional brain systems display markedly different degrees of plasticity. For example, deafness and blindness per se have highly specific effects on some but not other subsystems within the remaining modalities. Knowing the neural systems and related plasticity profiles relevant for specific cognitive subsystems puts us in a good position to target interventions for particular functions and particular time periods. Neville describes intervention programs that are underway to facilitate language development in both typically developing and language-impaired individuals. In the long run, linking the interaction between environmental input and genetic predisposition will contribute to one of Posner's current foci: working to optimize human development.

Conclusion

When we examine Posner's work over a period now exceeding 30 years, it provides inspiration for students and young researchers. For the layperson, it provides an avenue of understanding into the workings of the human mind. The simple procedures, such as reaction time tasks, that researchers use to decompose the mind into its constituents often seem exceedingly abstract and far removed from the real world. To find that small regions of the brain are dedicated to particular elementary functions; to find that variation in such function underlies disorders of executive function; to find genes that influence the function—finding these kinds of things provides a powerful validation of basic psychological research. Posner's examination of elementary processes has truly moved researchers toward a fundamental level of understanding human cognition. All indications are that such basic understanding will have enormous influence in dealing with problems of cognitive development that derive either from deficiency of experience or from genetic differences.

This introduction makes abundantly clear the unbounded respect the contributors of this book have for Posner's contributions to cognitive psychology and its merger with neuroscience. We hope it also is abundantly clear the great affection we hold for Posner for his impact on our individual careers and our personal lives. The respect and honor are not, however, from this group alone. Dozens and dozens of people, of whom we have mentioned only a sample in this introduction, have felt Posner's touch. An extraordinarily large number of honors have been bestowed on him, from the beginnings of his career through to the present. These honors emanated from local (University of Oregon), to regional, to national, and to international organizations. We list a smattering of honors that correspond with the evolution of Posner's research themes in Exhibit 1.1.

Exhibit 1.1. Honors

American Institute for Research, Dissertation award in the area of learning, perception and motivation, 1962
Editor, *Journal of Experimental Psychology: Human Perception and Performance*, 1974–1979
Ersted Award for Distinguished Teaching, University of Oregon, 1975
APA Distinguished Scientific Contribution Award, 1980
Elected to U.S. National Academy of Sciences, 1981
Fellow, American Academy of Arts and Sciences, 1986
Howard Crosby Warren Medal of the Society of Experimental Psychologists, 1988
Distinguished Scientific Lecture, American Psychological Association, 1992
Invited Presidential Address, Society for Neuroscience, Washington, DC, 1993
Scientist of the Year Award, Oregon Academy of Sciences, 1995
Dana Foundation Award for Pioneering Research in Medicine (Neuroscience), 1996
John T. McGovern Medal and Lecture, American Association for the Advancement of Science, 1998
Honorary Doctoral Degree, University of Padova, Italy, 1998
Karl Lashley Award, American Philosophical Society (joint with M. E. Raichle), 1998
Honorary Doctoral Degree, University of Granada, Spain, 1999
Pasarow Foundation Award in Medical Research (Neuropsychiatry; joint with M. E. Raichle), June 2000
Grawemeyer Award for Psychology Contribution (joint with M. E. Raichle and S. E. Petersen)
Honorary Degree, University of Nottingham, 2002
Honorary Degree, University of Paris, 2002
International Science Prize, Fyssen Foundation (France), 2003

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