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Editorial

Introduction to Special Issue: "Current Perspectives on Neuroplasticity"

In the past two decades, a wealth of evidence has accumulated that supports a neural constructivist approach to characterizing human development. This approach, in which learning and individual experiences play a central role in constructing mental representations and their corresponding neural changes, is of course one of the central themes of Piaget's theory. This special issue, based on the annual meeting of the Jean Piaget Society held in Toronto in June, 2015, brings together reports from researchers who examine neural plasticity in a variety of ways, across varied domains of development. It provides an overview of the state-of-the-science in examining how experiences and biology interact to shape brain development, and we hope it stimulates discussion of the implications of this neuroscience-based research for the broader understanding of child development.

The importance of neural plasticity has long been recognized (e.g., Hebb, 1949), and the role of expectable environmental input (and its absence) on brain development is well known (e.g., from sensory deprivations studies; Hubel & Wiesel, 1962). An early demonstration of the way in which behavioral adaptations to more idiosyncratic (i.e., experience-dependent) aspects of the environment co-occur with neural adaptations appeared in the work of Greenough and colleagues (e.g., Greenough, Black, & Wallace, 1987), who examined rats raised in "enriched," or relatively complex environments that included other rats and the opportunity to explore and play (see also Rosenzweig et al., 1962). Compared to rats raised in captivity as usual, these rats showed better learning and memory (e.g., on maze learning) as well as effects on brain development, including heavier and thicker cortices, more dendrites per neuron, and more spines per dendrite.

The implications of these and other findings subsequently became more widely appreciated in light of several well-publicized studies with adults. For example, Maguire et al. (2000) examined brain regions related to spatial memory in a sample of taxi drivers in London, England. Taxi drivers, who have to pass a rigorous test demonstrating knowledge of London streets, were found to have larger posterior hippocampi (and smaller anterior hippocampi) than age-matched controls. In addition, the number of years they had been driving a cab was positively related to the volume of their posterior hippocampi and negatively related to the volume of their anterior hippocampi. Although correlational, this finding suggests that engaging regularly in navigation (and relying heavily on spatial memory) leads to the reshaping of relevant regions of the brain.

Similar findings have been obtained for white matter and also for measures of brain function. Elbert et al., (1995), for example, used magnetoencephalography (MEG) to measure cortical representations of fingers in violin players and found larger representations in sensorimotor cortex of the digits of the left (fingering) hand (but not the thumb), as would be expected if experience produced these changes. In addition, the number of hours spent practicing the piano (especially as a child) has been found to be related to myelination, with different neural regions being implicated at different ages (Bengtsson, Nagy, Skare, Forsman, Forssberg, & Ullén, 2005). Findings like these, which are increasingly supported by experimental research involving human beings, suggest that we grow our brains by using them, and that we grow our brains in particular ways by using them in particular ways (Zelazo, 2013).

Our understanding of cognitive development has grown enormously with the advent of new tools and techniques for examining processes operating at many levels of analysis (e.g., for studying complex interactions among genes and environment, for measuring neural activity in young children, and for modeling developmental change using sophisticated computational techniques). This research has made it clear that there is plasticity at all levels of analysis, and in particular it has sharpened out understanding of the influence of specific early experiences on subsequent cognitive and brain development. The current special issue of *Cognitive Development* is designed to provide cutting edge theoretical and empirical contributions on developmental neuroplasticity.

Lisa Oakes provides for this special issue a theoretical piece examining neuroplasticity in development. Rather than using a canonical framework to explore this topic, where plasticity is discussed in terms of the ways in which experience is changed by differences in brain structures, processes or input, this paper discusses the idea that developmental plasticity, itself, also effectively changes input into the system. In this way, plasticity is not only seen in the structures and processes that result from differences in

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experience, but also is seen with respect to changes in the input as those structures and processes adapt. The paper includes examples from research findings across two domains (face processing and the effect of pet experience on infants' processing of animal images) that illustrate how, even when processing the same information, children who have adapted to different experiences will attend to and learn from that information differently, and thus the input to the system will be altered.

In the next article, **Bryan Kolb** presents a masterful review of the effects of various kinds of stress (including preconception, gestational, bystander gestational, and maternal separation) on prefrontal cortex and behavioral development, largely in animal models. Kolb argues that neocortical development represents more than a simple unfolding of a genetic blueprint but rather represents a complex dance of genetic and environmental events that interact to adapt the brain to fit a particular environmental context. As the brain develops it progresses through a series of stages beginning prenatally and continuing through gestation, infancy and childhood, adolescence, and well into the third decade. The developing normal brain shows a remarkable capacity for plastic changes in response to a wide range of pre-conceptual, prenatal, and postnatal experiences. This review examines the many ways in which early experiences alter brain development, including environmental events such as sensory stimuli, early stress, psychoactive drugs, parent-child relationships, peer relationships, intestinal flora, and diet. This sensitivity of the brain to early experiences has important implications for understanding neurodevelopmental disorders as well as the effect of behavioral and medical interventions in children and adolescents.

In the article that follows, **Daphne Maurer** describes lessons from her research on children treated for cataracts. She and her colleagues have taken advantage of a natural experiment: children born with cataracts that blocked all patterned input until the cataracts were removed and the child fitted with compensatory contact lenses. Their longitudinal studies indicate that early visual input sets up the neural architecture for later refinement. When it is absent, there are sleeper effects: damage to visual capabilities that develop long after birth. Later deprivation has no such effects, a result indicating that there are critical periods during which visual development is damaged. Yet even in adulthood some recovery is possible.

The issue of timing of experiences is also addressed by **Janet Werker** and colleagues, who present a series of experiments that tested infants' detection of content congruence (the matching of speech sounds to their corresponding mouth movements) in non-native audiovisual speech and whether sensitivity to congruence declines predictably with the trajectory of perceptual attunement previously established in auditory perception studies. They further explore whether the addition of congruent visual information alters subsequent auditory discrimination of these same speech contrasts, possibly constituting a shift in the timing of the sensitive period for auditory speech perception. They found that only infants younger than 11 months old detected content incongruence even in an unfamiliar language and that familiarization to audiovisual speech changed six-month-olds' later auditory discrimination, but did not affect the discrimination of nine- and 11-month-olds, indicating that prior to the closing of the sensitive period for non-native speech discrimination, auditory discrimination of speech sounds may be changed with the addition of visual information.

Next, **Stephen Lomber** provides a review article examining the overarching question: What is the function of auditory cortex when it is deprived of normal acoustic input? Lomber reviews the literature suggesting that auditory cortex of the deaf may be recruited in the service of vision and that the visual abilities of the deaf may in fact be enhanced. Further, using the elegant paradigm of reversible cooling deactivation of auditory cortex in the congenitally deaf cat, he considers whether these functions are distributed uniformly across deaf auditory cortex, or if specific functions are differentially localized to distinct portions of the affected cortices, and concludes that the neural bases for enhanced visual functions in the deaf can be localized to distinct regions of deaf auditory cortex. Finally, he demonstrates that crossmodal compensatory effects are specific and appear to enhance those functions that the deprived and replacement modalities hold in common.

In the next article, **Marla Sokolowski** and colleagues again take a cross-species approach and examine gene-environment interplay in behavior primarily in the fruit fly, Drosophila melanogaster. Her main focus is the foraging gene, a cGMP dependent protein kinase which influences naturally occurring behavioral variation including the rover/sitter polymorphism. This gene plays a role in food-related behaviours, learning and memory and social behaviors in many organisms including social insects and mammals. Sokolowski and colleagues have used foraging and its interactors as a model to study pleiotropy, how a gene accomplishes its multiple and varied functions. They address questions about the ways in which DNA sequence variation interacts with epigenetic modifications to affect behaviour, and how early behavior gets under the skin to affect later life fitness and behaviour.

The next article, by **Charles Nelson** and colleagues, explores neuroplasticity through the lens of one of the most fundamental developmental processes, that of face perception. In this paper, the authors explore the developmental consequences of having limited racial experience versus exposure to a diverse racial environment with regard to infants' looking preferences to different race faces. A leading account has been that face processing undergoes a process of perceptual narrowing such that the perceptual window through which faces are perceived is "broadly tuned" early in life and narrows with experience. This account would predict that if infants are exposed to multiple face categories during infancy, they would develop a more broadly-tuned perceptual system and be able to recognize a broader array of faces. In contrast, their data shows that racial exposure to caregivers has little influence on face preference among infants and that face preferences tend to disappear over time, contributing to our understanding of the settings in which environmental input impacts cognitive specialization.

In the final review article, **Eric Nelson** provides an overview of neuronal maturation from the perspective of neuroplasticity and adaptation and further provides examples of these developmental learning principles that stem from the neurobiology of social development. He discusses several examples of acquisitions that might constitute times of heightened plasticity, both ones occurring early in postnatal life such as the filial imprinting observed in avian species as well as mammals, face processing, and language acquisition, as well as ones occurring later in social development such as peer integration and romantic behavior. Overall, the review emphasizes the numerous ways in which brain development is influenced by environmentally specific social experiences.

While this collection represents only a sample of the contemporary research on the topic, the selections were carefully chosen to provide a meaningful survey of the range of questions being addressed.

References

Bengtsson, S. L., Nagy, Z., Skare, S., Forsman, L., Forssberg, H., & Ullén, F. (2005). Extensive piano practicing has regionally specific effects on white matter development. *Nature Neuroscience*, *8*, 1148–1150.

Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B., & Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science*, *270*, 305–307.

Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development*, *58*, 539–559.

Hebb, D. O. (1949). *The organization of behavior.* New York: Wiley.

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S. J., et al. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Science USA*, *97*, 4398–4403.

Rosenzweig, M. R., Krech, D., Bennett, E. L., & Diamond, M. C. (1962). Effects of environmental complexity and training on brain chemistry and anatomy: A replication and extension. *Journal of Comparative Physiological Psychology*, *55*, 429–437.

Zelazo, P. D. (2013). Developmental psychology: A new synthesis. In P. D. Zelazo (Ed.), *Oxford handbook of developmental psychology (Volume 1: Body and mind; Volume 2: Self and other)* (pp. 3–12). New York: Oxford University Press.

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