Cognitive Development 42 (2017) 4–14

Contents lists available at ScienceDirect

Cognitive Development

Plasticity may change inputs as well as processes, structures, and responses

Lisa M. Oakes

Department of Psychology, Center for Mind and Brain, University of California, 267 Cousteau Place, Davis, CA 95618, United States

ARTICLE INFO

Article history:
Received 16 June 2016
Received in revised form 15 February 2017
Accepted 16 February 2017
Available online 1 March 2017

Keywords:
Experience
Plasticity
Input
Infant cognition
Learning to learn

ABSTRACT

Significant work has documented neuroplasticity in development, demonstrating that developmental pathways are shaped by experience. Plasticity is often discussed in terms of the *results* of differences in input; differences in brain structures, processes, or responses reflect differences in experience. In this paper, I discuss how developmental plasticity also effectively changes *input* into the system. That is, structures and processes change in response to input, and those changed structures and processes influence future inputs. For example, plasticity may change the pattern of eye movements to a stimulus, thereby changing which part of the scene becomes the input. Thus, plasticity is not only seen in the structures and processes that result from differences in experience, but also is seen in the changes in the input as those structures and processes adapt. The systematic study of the nature of experience, and how differences in experience shape learning, can contribute to our understanding of neuroplasticity in general.

Contents

1. Introduction

Development during infancy is characterized by a series of changes—the acquisition of new abilities, the refinement of old abilities, the integration of processes, and the reorganization of systems. The first postnatal year, for example, is characterized by the acquisition of independent sitting (e.g., Adolph & Robinson, 2015), a shift from processing faces in a piecemeal fashion to processing faces holistically (e.g., Schwarzer, Zauner, & Jovanovic, 2007), the coordination of visual exploration and reaching (e.g., von Hofsten, 2004), and the emergence of brain responses specific to face processing (e.g., de Haan, Johnson, & Halit, 2003). All these developmental changes reflect, to some extent, neuroplasticity. That is, the

E-mail address: lmoakes@ucdavis.edu

http://dx.doi.org/10.1016/j.cogdev.2017.02.012
0885-2014/

neuroanatomical structures and connections that support these abilities have developed and adapted in response to infants' experiences.

Developmental outcomes reflect a cascade of events, however. Any given milestone or achievement reflects the specific experiences—biological or environmental—that have shaped physical, motor, and cognitive abilities at various points in developmental time. These changes in abilities then lead to different opportunities for new experiences (i.e., different inputs), that then further change the child's developmental trajectory (see Masten & Cicchetti, 2010). Moreover, multiple different factors contribute to the achievement of a given milestone (see Thelen & Smith, 1994). Consider as an example an infant whose first spoken word is "dog." Clearly, the infant's exposure to English contributed to this being the child's first spoken word. However, children's first spoken words also reflect their developing abilities to perceive speech sounds in their "native" language, to articulate specific speech-related sounds, to learn associations between specific objects and specific word forms, as well as their experience with a particular language. Therefore, many experiences through the first year contribute to this milestone. For example, infants' daily exposure to one or more language shapes their developing processing of speech sounds (Dietrich, Swingley, & Werker, 2007; Kuhl, Tsao, & Liu, 2003; Werker & Desjardins, 1995; Werker & Tees, 1984). In addition, infants' early actions on objects—and the resulting influences on their visual object perception—may contribute to their learning of object names (Smith, 2013).

In this paper, I focus on how plasticity changes the inputs that an organism experiences. At least since the time of Dewey, there has been a recognition that input is an integral part of the experience of the world (Dewey, 1896). In the context of development, psychologists have long recognized the importance of input for development as well as how inputs change over development (Gibson, 1982, 1988; Piaget, 1954). However, despite the importance of input for understanding cognitive development, much of the work on cognitive development focuses on the *outputs* or *products* of development—changes in brain organization, strategies, skills, cognitive structures. When constructing programs of research to understand cognitive development, however, we should also consider how the input itself changes over development, and how those changes in the input contribute in important ways to subsequent development. These ideas have much in common with cascade approaches to understanding development (Bornstein, Hahn, & Wolke, 2013; Masten & Cicchetti, 2010), and one goal of this paper is to encourage researchers to think about developmental cascades broadly across domains, timeframes, and areas of development.

In this paper I will consider how differenct developmental outcomes (e.g., structures, processes, responses) translate to differences in the input, and those differences in the input further influence future developmental outcomes. Thus, here I will examine how differences in what information serves as input derive from variations in experience. This paper is organized in three sections. First, I discuss how different levels of variation in the input create different levels of variation in the products of development—i.e., plasticity. This discussion sets the stage for the second section, in which I provide two examples from research findings in two domains of how plasticity is revealed in the input. Finally, I conclude by providing a framework for understanding different ways in which input contributes to plasticity, and posit some goals for future research.

2. Levels of variation in the input and plasticity

There has long been a recognition between input and plasticity. Recognizing that there is considerably variation in the amount of overlap in the input across individuals, Greenough, Black, and Wallace (1987) distinguished between *Experience Expectant Plasticity* and *Experience Dependent Plasticity*. Some inputs are essentially universal—except under very extreme conditions, every human child experiences gravity, a caregiver, exposure to variations in temperature, and so on. These universal inputs lead to what has been referred to as *Experience Expectant Plasticity* (Greenough et al., 1987). Because there is little variation in the input, there is little variation in the structures, processes, and responses that develop, and it can appear that there is no plasticity. For example, there is a significant amount of consistency across individuals in the neuroanatomical organization and structures for representing visual and auditory information. In such cases it is tempting to conclude that those developmental products—e.g., the resulting brain organization—do not reflect plasticity at all. However, extreme examples illustrate that typical development reflects how the system responds to high level of overlap in the input—the lack of variation in the products of development reflects, at least in part, the lack of variation in the input.

Plasticity in these systems is observed when considering cases of extreme deprivation. The brain systems of children born blind or deaf, for example, do not receive the input that is experienced by the vast majority of developing brains. The resulting brain organization illustrates profound neuroplasticity; systems in infants born deaf or blind that would have processed information from the ears or eyes (if that input was available) adapt and develop to process other kinds of information (Bedny, Richardson, & Saxe, 2015; Finney, 2001; Finney et al., 2003; Ptito et al., 2012). The uniformity of the developing structure, therefore, reflects the overlap in the input.

Other inputs vary, resulting in differences in structures, processes, and skills, reflecting *Experience Dependent Plasticity* (Greenough et al., 1987). In these cases, different structures, processes, or skills emerge as a function of the differences in experience or inputs. For example, infants who have previously looked at and learned about dogs and cats will have a different context for learning about new dogs and cats than will infants who have not previously looked at and learned about dogs and cats. In this case, infants form different structures, processes, or representations that reflect different input.

These examples illustrate two extremes—experience expectant plasticity reflects situations in which there is high overlap in the input across individuals and experience dependent plasticity reflects situations in which there is little overlap in the input across individuals. However, there is significant variation in the amount of overlap individuals experience in a