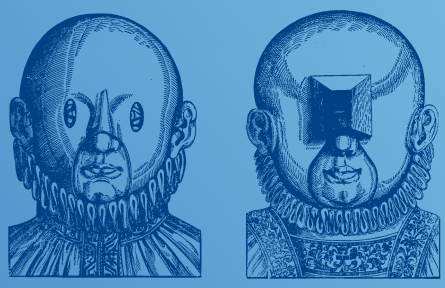
Nigel W. Daw

Visual Development

Third Edition

Springer



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Preface

Research in the area of visual development has become a multidisciplinary affair. Students who acquire an interest in the field therefore need to understand several different aspects of the subject. The development of acuity measured by psychophysicists is the concern of optometrists and ophthalmologists, and depends on changes in the anatomy of the retina and the physiology of cells in the visual pathway. Scientists working on the cellular, molecular, and biochemical mechanisms lean on anatomical studies, physiology, and psychophysics in designing and interpreting their experiments. Indeed, the laboratories of the leading scientists working on the subject now all use a large variety of techniques in their studies.

Because the study of visual development is pursued by workers in many disciplines, from medicine to basic science, I have tried to write this book at a level at which it can be understood by a variety of students: graduate students in neurobiology and psychology, as well as optometry students and ophthalmology residents. The text assumes some knowledge of basic terms such as acuity, but a glossary is provided should the reader find some words that are unfamiliar. The emphasis is on facts and conclusions, rather than on methods and procedures. Many details are left out.

However, I hope that the experts will also read the book. The subject has become so wide-ranging that not many people have the time to read literature in all aspects of it. The book is also intended for experts in one area to get a grasp of the basics of the subject in other disciplines that are not their primary discipline.

To write a book covering such a wide variety of disciplines, I have had to simplify. The book does not go into controversies in detail. Instead, it provides my summary of what seems to me to be the best evidence. Not everybody will agree with my synthesis. Some experts will read it and be outraged at some of my statements. However, my outrageous statements were intended to be constructive: I hope that they will provoke thought and point the way to more experiments that will carry the field forward.

I am grateful to Colin Blakemore for inviting me to write this book. The process has been an educational one for me, and led to a number of insights which may have been apparent to others, but not to me. A number of friends and colleagues have helped me in the preparation of the book. Grace Gray in particular read the entire text twice, and improved it throughout. Robert Hess went through the whole section on Visual Deprivation, and made

many valuable comments. John Lisman did the same for the section on Mechanisms. Janette Atkinson, Marty Banks, Oliver Braddick, Jan Naegele, Pasko Rakic, and Josh Wallman read individual chapters in their area of expertise and made many corrections and improvements. Several of my colleagues in the Department of Ophthalmology—Ethan Cohen, Jonathan Kirsch, Thomas Hughes, Colin Barnstable, Silvia Reid and Helen Flavin—gave comments on various portions of the text, and Marc Weitzman read two whole sections. I would like to thank them all. However, I did not adopt all of their suggestions, and the errors and omissions are mine. I would also like to thank Janet Hescock and Bob Brown for help in the preparation of the text and figures, together with support from the Core Grant to Yale University from the National Eye Institute.

Branford, CT, USA Nigel W. Daw

Preface to the Third Edition

It is almost 20 years since the first edition of this book was written, and considerable research has been done in that time. The development of vernier acuity and contour discrimination have been more carefully defined. Genes that play a role in myopia have been localized. New techniques using Gabor patches in various configurations have enabled scientists to define amblyopia in more careful terms, particularly the concept of spatial uncertainty, and whether it is due to undersampling or distorted sampling. Amblyopia was never simply a matter of a deficit in acuity, but it has taken careful experiments to show exactly what it is beyond that.

Ten years ago, the molecules that govern the crossing of the optic nerve fibers in the chiasm, and which project to the contralateral side, and which to the ipsilateral side were completely unknown. So were the molecules that govern the topography of the projections within the visual system. Today, we know some molecules involved in both these developmental events, as well as some that mark the boundaries of the visual cortex.

The technique of optical imaging of the visual cortex has enabled scientists to visualize the ocular dominance and orientation columns. Scientists can now use this technique to study the development of these columns, and the effect of various forms of visual deprivation on them, in a way that was not possible with single unit recordings.

It has also become increasingly apparent that there are many critical periods in the development of the visual system. The critical period for the effect of a particular form of visual deprivation in many cases lasts longer than the period of development of the property affected, and the period during which recovery can be obtained lasts longer still. Moreover, there are different critical periods for different properties. Properties handled at a higher level of the system have a later critical period. In addition, the critical period can be affected by the previous visual history of the animal, and by the technique used to evaluate it. For all these reasons, the chapter on critical periods has become much more involved.

Twenty years ago, quite a lot was known about mechanisms of long-term potentiation and long-term depression, and not much about plasticity in the visual cortex resulting from monocular deprivation. Today, a considerable amount is known about mechanisms of ocular dominance plasticity, and what is known about LTP and LTD does not add a great deal, so the chapter on the latter has been eliminated.

The subject of the effect of out-of-focus images on the size of the eyeball has also been a very active area of research. We still do not know how the signal gets from the neural retina to the choroid and sclera, but there are a few molecules known that increase in response to plus lenses and decrease in response to minus lenses, or vice versa, that may be candidates for the signal.

Moreover, the best treatment for amblyopia has become much better known, as therapists concentrate on properties other than acuity. Basic scientists have quantified the improvements that can be made by not patching the amblyopic eye all of the time, and working with both eyes to improve binocular vision at the same time as the acuity in the amblyopic eye. Use of perceptual learning and video games has helped by increasing activity and attention as the therapy is done. Many of the principles have been employed by pediatric vision therapists for some time, but the publicity generated by "Stereo Sue" and others has helped to broadcast them.

For all these reasons, it is high time that this book should be revised. The aim of the book is the same as it was in the first edition—to provide a short summary of findings in the field that can be used by ophthalmology residents, optometry students, graduate students in neurobiology and psychology, senior undergraduates, and, since the field is so diverse, for experts to read chapters outside their area of expertise.

For this third edition, there is a Web site, www.visual-development.net, with links to various videos that illustrate points and procedures discussed in the book. See also the list of useful videos after the table of contents.

I am most grateful to Paul Harris for reading the whole book and providing a number of suggestions for clarification, as well as for professional guidance on the new chapter on "Treatment of Amblyopia." I am also very grateful to Terri Lewis, Len White, Mike Crair, Eileen Birch, Dennis Levi, Donald Mitchell, John Lisman, Takao Hensch, and David Troilo, who provided comments on individual chapters and hopefully caught most of my errors, but I am sure that some remain. I also thank Simina Calin, my editor at Springer, for all her help and guidance.

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