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Multistage maturation optimizes vision

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1 **Multistage maturation optimizes vision**

2 **Late development of color vision improves object recognition**

3 Pascal Mamassian

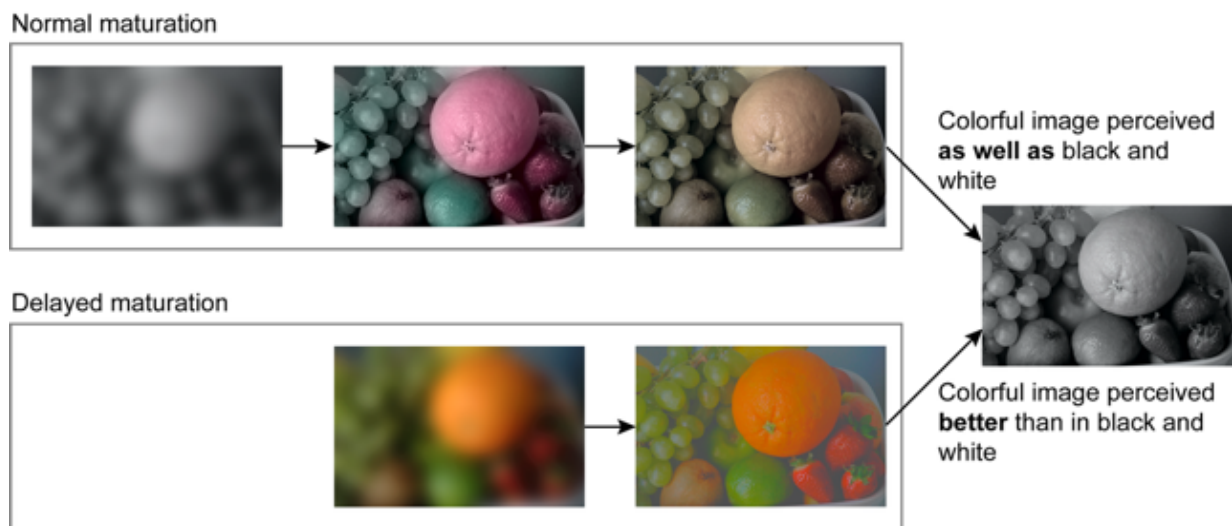
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6 How can humans make sense of the world around them given the complexity and vast
7 amount of information that impinges their senses? This question is particularly critical for
8 newborns as they start to discover their environment, when the simultaneous exposure to a
9 variety of sensory stimuli likely makes the world feel like “one great blooming, buzzing
10 confusion” [(1), p. 488]. This complexity explains in part why perceptual systems (such as the
11 visual system) need time to fully mature, so that, for instance, motion is perceived earlier
12 than color, and motion of the full visual field is detected earlier than motion of isolated
13 objects (2). On page 907 of this issue, Vogelsang *et al.* (3) report the functional benefits of
14 multistage maturation for the visual system, showing that the late development of color
15 vision is important to improve object recognition. This could help to explain why sequential
16 steps in the maturation of perceptual abilities are important.

17
18 Vision develops across various stages. For example, newborn babies are thought to be color
19 blind but can discriminate some objects based on information from the intensity of light
20 reflected from a surface (luminance)—such as their mother’s face— although with a much
21 lower acuity than adults (4). Later in life, infants as young as 2 months of age can
22 discriminate some colors, in particular red versus green, although they are more confused
23 with other color contrasts, such as blue versus yellow (4). However, it is still unclear whether
24 there is any benefit to progressively acquiring the ability to distinguish colors.

25
26 The importance of color for object recognition has been a long-debated topic (5). Now,
27 Vogelsang *et al.* show that one of the possible benefits of late color development is to
28 improve the ability to recognize different commonplace objects. The results were obtained
29 as part of the humanitarian and scientific Project Prakash, which provides sight-restoring
30 treatments for teenage children in India, including through cataract surgery (6). Testing 10
31 children who were born blind and underwent surgery later in life (called late-sighted
32 individuals), they found that these individuals had more difficulties at recognizing grayscale
33 images of commonplace objects than colored ones, as compared with a control group of

34 normal-sighted children, who were equally good at recognizing colored images (see the
35 figure). Because the late-sighted children had normal color vision immediately after the
36 restoration of their sight, Vogelsang *et al.* hypothesized that late color development, as is
37 the case for normal-sighted individuals, is essential for the robustness of object recognition
38 against color variations. This hypothesis was explored further using deep convolutional
39 neural networks trained under different regimens. These experiments showed that training a
40 model first with grayscale images and then with colored ones leads to more robust
41 performance against color variations compared with training a model immediately with
42 colored images. Although caution is needed when relating the insights provided by these
43 models to human brain processing (7), these experiments are nonetheless useful in
44 providing additional support for the model proposed by the authors on the advantages of
45 multistage maturation of color vision to improve object recognition.



46

47 **Figure. Multistage maturation improves object recognition.** In normal maturation,
48 an infant's vision is thought to be heavily blurred and colorless; then, gradually
49 luminance details sharpen, and red-green color contrasts can be discriminated; and
50 ultimately, a high-resolution, colorful image is perceived that strongly relies on the
51 luminance information similar to the black-and-white image. By contrast, when the
52 maturation of the visual system is delayed as a result of late cataract surgery,
53 luminance and color information develop simultaneously, thereby producing an
54 interpretation that overly relies on color and is better perceived than the
55 corresponding black-and-white image. [Depicted images are for illustration only and
56 do not pretend to accurately represent what observers actually perceive. CREDIT:
57 ORIGINAL PHOTOS BY K. GEGENFURTNER, MODIFICATIONS BY P. MAMASSIAN]

58 The idea that perceptual systems take time to develop is not new. Seventy years ago, the
59 psychologist Jean Piaget emphasized that visual perception is exceptionally impoverished at
60 birth and that it takes months or even years to reach full maturation (8). Indeed, some
61 perceptual abilities appear to develop very late. For instance, even though infants as young
62 as a few months old can perceive the world in three dimensions from different cues in an
63 image, an optimal integration of these signals occurs only when children are almost
64 teenagers (9). Similarly, the fusion of the different senses, such as vision, audition, and
65 touch, also occurs in adolescence (10). The reasons explaining these very late maturations of
66 perceptual systems have remained a mystery, and the multistage hypothesis of Vogelsang *et*
67 *al.* could prompt new interpretations of previous studies.

68

69 Presenting visual properties in multiple stages may also help to treat some visual disorders
70 in adults. It is often stated that some visual functions can no longer be learned past a so-
71 called critical period (11). For example, if the two eyes are misaligned at birth and the
72 misalignment is not corrected within the first 6 months of life, observers will have great
73 difficulties at using binocular vision to see in three dimensions (12). Recent strategies to
74 patch one of the two eyes offer some promising avenues to help cure some binocular
75 deficits, such as amblyopia, at the adult stage (13). The multistage maturation hypothesis
76 offers an interesting prediction, whereby the presentation of selected information in
77 stages—rather than all at once—should further increase the efficiency of learning some
78 visual functions in adulthood. This hypothesis also offers a new perspective on the notion of
79 critical periods, suggesting that what is critical is that a processing stage should be mature
80 before another stage can begin.

81

82 The importance of temporal stages could also be at the origin of synesthesia, a condition
83 that is commonly described as a blending of the senses (14). For instance, in grapheme-color
84 synesthesia, an observer will systematically see some numbers and letters of the alphabet in
85 a specific color. Future studies should consider the possibility that this condition may arise
86 from a temporal irregularity in the maturation of sensory properties.

87

88 Given the blooming, buzzing confusion coming from the many senses at birth, it is no small
89 feat that infants manage to make sense of their environment and can even evaluate the
90 validity of their own perception when they are only a few years old (15). The study of
91 Vogelsang *et al.* illustrates the benefits of developing these senses in sequential steps—
92 showing how late color development improves object recognition—and provides new robust
93 learning strategies for artificial neural networks. Future studies exploring the importance of
94 sensory maturation in multiple stages are likely to offer new insights into numerous other
95 perceptual phenomena.

96

97 **References**

- 98 (1) James, W. (1890). *Principles of Psychology*. New York, NY: Henry Holt.
- 99 (2) Vital-Durand, F., Atkinson, J., & Braddick, O. J. (Eds.). (1996). *Infant Vision*. Oxford, UK:
100 Oxford University Press.
- 101 (3) Vogelsang, M., Vogelsang, L., Gupta, P., Gandhi, T. K., Shah, P., Swami, P., Gilad-Gutnick,
102 S., Ben-Ami, S., Diamond, S., Ganesh, S., & Sinha, P. (2024). Impact of early visual
103 experience on later usage of color cues. *Science*, *384*(6698), 907–912.
104 <https://doi.org/10.1126/science.adk9587>
- 105 (4) Teller, D. Y. (1997). First glances: The vision of infants. The Friedenwald lecture.
106 *Investigative Ophthalmology & Visual Science*, *38*(11), 2183–2203.
- 107 (5) Bramão, I., Reis, A., Petersson, K. M., & Fáisca, L. (2011). The role of color information on
108 object recognition: A review and meta-analysis. *Acta Psychologica*, *138*(1), 244–253.
109 <https://doi.org/10.1016/j.actpsy.2011.06.010>
- 110 (6) Sinha, P. (2013). Once blind and now they see. *Scientific American*, *309*(1), 48–55.
- 111 (7) Wichmann, F. A. & Geirhos, R. (2023). Are deep neural networks adequate behavioral
112 models of human visual perception? *Annual Review of Vision Science*, *9*(1), 501–524.
113 <https://doi.org/10.1146/annurev-vision-120522-031739>
- 114 (8) Piaget, J. (1954). *The Construction of Reality in the Child*. New York, NY: Basic Books.
- 115 (9) Dekker, T. M., Ban, H., van der Velde, B., Sereno, M. I., Welchman, A. E. & Nardini, M.
116 (2015). Late development of cue integration is linked to sensory fusion in cortex.
117 *Current Biology*, *25*(21), 2856–2861. <https://doi.org/10.1016/j.cub.2015.09.043>
- 118 (10) Gori, M., Viva, M. D., Sandini, G. & Burr, D. C. (2008). Young children do not integrate
119 visual and haptic form information. *Current Biology*, *18*(9), 694–698.
120 <https://doi.org/10.1016/j.cub.2008.04.036>
- 121 (11) Kiorpes, L. (2015). Visual development in primates: Neural mechanisms and critical
122 periods. *Developmental Neurobiology*, *75*(10), 1080–1090.
123 <https://doi.org/10.1002/dneu.22276>
- 124 (12) Barry, S. R. (2009). *Fixing my Gaze: A scientist's Journey into Seeing in Three Dimensions*.
125 New York, NY: Basic Books.
- 126 (13) Lunghi, C., Sframeli, A. T., Lepri, A., Lepri, M., Lisi, D., Sale, A. & Morrone, M. C. (2019). A
127 new counterintuitive training for adult amblyopia. *Annals of Clinical and Translational*
128 *Neurology*, *6*(2), 274–284. <https://doi.org/10.1002/acn3.698>
- 129 (14) Newell, F. N., & Mitchell, K. J. (2016). Multisensory integration and cross-modal learning
130 in synaesthesia: A unifying model. *Neuropsychologia*, *88*, 140–150.
131 <https://doi.org/10.1016/j.neuropsychologia.2015.07.026>
- 132 (15) Baer, C. & Odic, D. (2020). Children flexibly compare their confidence within and across
133 perceptual domains. *Developmental Psychology*, *56*(11), 2095–2101.
134 <https://doi.org/10.1037/dev0001100>
- 135