*Neuroscience* 255 (2013) 99–109

# BINOCULAR PATTERN DEPRIVATION WITH DELAYED ONSET HAS IMPACT ON MOTION PERCEPTION IN ADULTHOOD

**M. ZAPASNIK AND K. BURNAT** *

*Laboratory of Neuroplasticity, Department of Molecular and Cellular Neurobiology, Nencki Institute of Experimental Biology, Pasteur 3, 02-093 Warsaw, Poland*

**Abstract—The quality of motion perception depends on visual input during early development. Even 1 month of binocular deprivation (BD) from birth impairs motion coherence thresholds when tested in kittens; conversely BD with a 1-month delayed onset does not impair it (Mitchell et al., 2009). We showed that 6 months of BD applied from birth induces a selective impairment in a Global Motion Detection task, but not in global form perception, when tested in adulthood (Burnat et al., 2002, 2005). In these animals cell counts of the retinal motion-sensitive alpha ganglion revealed a lifelong increase in OFF-type ganglion cell (Burnat et al., 2012). Here we examined in adult cats the effect of BD on global motion perception using an array of tasks with gradually increasing perceptual difficulty. Two conditions of BD were applied: from birth, lasting for 1, 2, 4 or 6 months, and with a delayed onset with first 2 months of normal vision followed by 2 months of BD. Cats deprived from birth for a 6-month period had Global Motion Detection impaired, as compared to the normal group. Velocity and low contrast-defined motion processing was impaired when BD was applied exclusively in months 3–4 of life. The cats deprived from birth for 1 or 2 months were not impaired in any of the tested motion tasks. Motion coherence thresholds, when tested at the end of a long motion training were not affected by BD and did not differ from those obtained for the normal group. Impaired extraction of low contrast-defined motion signal was found in cats deprived solely in months 3–4 of life. Surprisingly, binocular pattern deprivation during the first 2 months of life did not weaken motion sensitivity, revealing the occurrence of a critical period for motion perception later in development than previously suggested.**


**Key words: visual development, velocity perception, low contrast motion perception, cataract, critical period, cat.**

## INTRODUCTION

The significance of the quality of the visual input during development is undisputable. Early stimulation shapes the circuitry of the visual system as functionally assessed with acuity, form and motion processing (Maurer et al., 2005; Wattam-Bell et al., 2010). Importantly, the development of these visual attributes does not occur simultaneously, as each attribute develops at its own individual pace and reaches adult levels at different times (Lewis and Maurer, 2005). During visual development form and motion processing develop separately, with motion perception having early onset and a long maturation and form perception showing a later onset and faster maturation (Maurer et al., 2005; Wattam-Bell et al., 2010).

Binocular deprivation (BD) from birth, such as congenital cataract and pattern deprivation leads to severe visual impairments in motion perception but only mild deficiencies in form perception (Burnat et al., 2002, 2005; Ellemberg et al., 2002; Lewis et al., 2002). In mammals, early BD impairs orientation and direction selectivity of cortical neurons and reduces the number of responses of motion-sensitive retinogeniculate inputs to the visual cortex (Sherman and Spear, 1982; Crawford et al., 1991; Gordon and Stryker, 1996; White et al., 2001). The time-frame for the establishment of motion perception is not yet well described. Studies on children treated for congenital binocular cataracts showed global motion perception impairment, whereas this function was intact in children with later onset of cataracts that developed after a few months of normal vision (Ellemberg et al., 2002). We showed previously in BD cats that the sensitive period for establishing the global motion perception occurs within the first 6 months of life (6BD, Burnat et al., 2002). Notably, relative motion detection was normal when tested using a moving versus a stationary square, whereas division of the square into two parts impaired motion detection, proving that perception of global features of the motion stimuli is reduced in 6BD animals (Burnat et al., 2002). In contrast, global form perception proved to be affected solely at the threshold level in 6BD cats (Burnat et al., 2005), confirming that exclusively global features of motion perception are impaired by long-lasting (for 6 months from birth) pattern deprivation.

Mitchell et al. (2009) showed that the establishment of global motion perception in kittens measured with coherence thresholds occurs very early in life, as BD applied during the first month of life impaired the detection of motion coherence, while 1 month of BD applied after the first month of normal visual input did not. These results lead to the assumption that the global motion-sensitive period occurs during the first month of life. However, visual training – "as soon as was practical

*Corresponding author. Tel: +48-225892371; fax: +48-228225342.
E-mail address: k.burnat@nencki.gov.pl (K. Burnat).
*Abbreviations:* 1BD, 2BD, 4BD, 6BD, first 2, 4 and 6 months of life of binocular deprivation, respectively; 2N2BD, first 2 months of life of normal vision followed by 2 months of binocular deprivation; ANOVA, analysis of variance; BD, binocular deprivation; RDP, random dot pattern.

0306-4522/13 $36.00 
http://dx.doi.org/10.1016/j.neuroscience.2013.10.005

once the deprivation ended" (Mitchell et al., 2009), i.e. during the most plastic period of visual development in the cat, e.g. starting from the second month of life, most likely has influenced their visual performance. Therefore, the following queries remain unsolved: (1) When does the motion-sensitive period close? (2) How does visual experience subsequent to BD influence the establishment of motion perception?

To address these questions we raised cats under BD condition and tested global motion perception in adulthood, first to see if an early visual deficit affects adult perception and second to allow plastic compensations to occur in the context of restoration of vision upon different periods of early BD (Fig. 1A). In order to describe stable levels of perceptual deficits, the increasing perceptual difficulty in global motion tasks was introduced gradually. We know from our previous work that slow implementation of perceptual difficulty to the visual task is beneficial for deprived animals (Burnat et al., 2002, 2005). Attributes of global motion perception were tested using motion tasks based on Direction Discrimination and velocity, as well as a Coherent Motion Detection task. Since we showed recently in adult BD cats that their global motion impairment correlates directly with malformation of the motion-sensitive OFF-type alpha retinal ganglion cells within the temporal sectors of the retina (Burnat et al., 2012), we also decided to adapt and implement the low contrast-defined form-from-noise detection task after Edwards and Badcock (1994) described for humans as functionally separating ON and OFF channels.

Four groups of cats pattern deprived from birth for the first (1BD), first 2 (2BD), 4 (4BD) or 6 (6BD) months of life were tested. In a delayed onset group, the first 2 months of normal vision were followed by 2 months of BD (2N2BD). At the time of testing, all cats had reached adulthood and had normal visual input restored for at least 2 months before the behavioral experiments started, which permitted maturation of the visual system to occur based upon high quality visual input. Consequently, we aimed to examine if and what kind of permanent visual global motion deficits can be detected in adult cats as a result of the loss of pattern vision in restricted periods of early life, as an animal model of patients with early cataracts.

## EXPERIMENTAL PROCEDURES

### Subjects

The animals were binocularly deprived of pattern visual experience by double-thickness linen masks covering their eyes (Fig. 1B). This procedure reduces retinal illumination to a similar level as lid suturing, but is less traumatic (Kossut et al., 1978). The masks were replaced daily in a normally lit animal facility room where the kittens were housed. The changing procedure lasted no longer than 1 min per day for each cat, which is not sufficient to maintain normal vision (Schwarzkopf et al., 2007; Mitchell et al., 2011). The size of the masks was adjusted to the growing head. In the cats binocularly deprived from birth, the masks were put on from eyelid

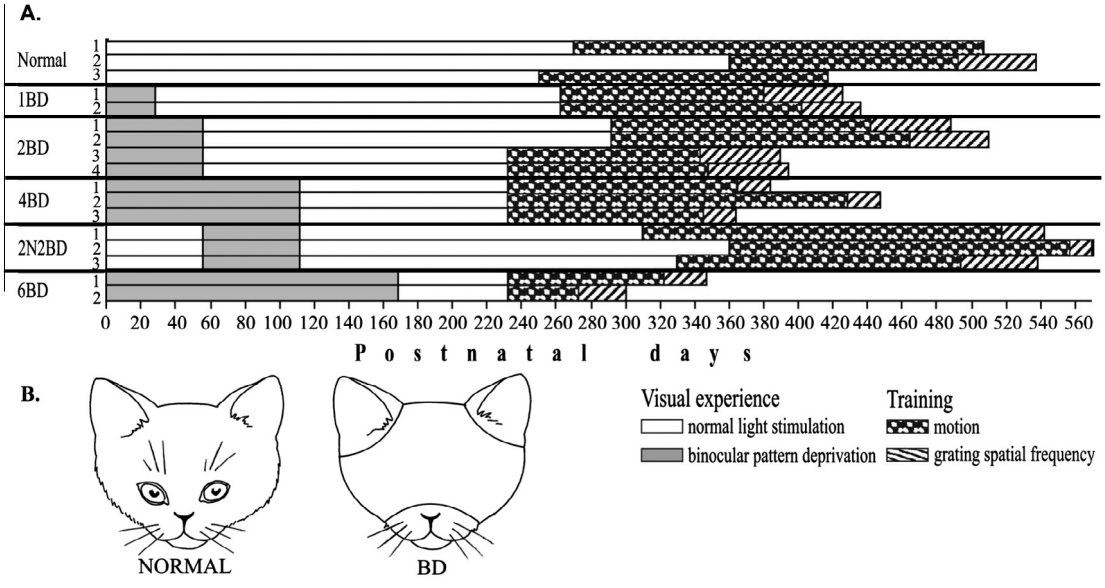


**Fig. 1.** Summary of the deprivation and training paradigms for all groups of cats. (A) Visual experience and training. The type and duration of visual experience (groups and individual cat numbers are depicted on vertical axis) and training are plotted as a function of postnatal days of life (horizontal axis). Normal cats had normal light stimulation. Binocular deprivation from the day of eye opening lasted for the first (1BD), first 2 (2BD), 4 (4BD) or 6 (6BD) months of life. A delayed onset group was deprived in the third and fourth months of life, after an initial 2 months of normal visual experience (2N2BD). All BD cats experienced normal visual input for at least 2 months prior to the motion training. Training duration is a summary of all the motion training which cats experienced during experiment and it does not reflect the overall learning rate. Learning duration of each motion task tested is presented in Table 1. Note the short motion training in 6BD cats, which failed to reach the criterion in motion tasks following the initial Global Motion Detection task. Cats from 2BD and Normal groups, after completing all motion tasks presented here, were further tested on motion tasks which are not described here. (B) Illustration of a normal and a mask-reared kitten.