Impaired Development of Eye-Hand Coordination in Children with Amblyopia

Simon Grant, Dean R Melmoth, Alison L Finlay, John L Sloper* & Catherine Suttle*

Department of Optometry & Visual Science, City University London & Moorfields Eye Hospital*, London, UK

Background & Aims

Normal adults reach and grasp objects with greater speed and accuracy using binocular vision compared to their dominant eye alone (e.g., Watt & Bradshaw, 2000; Loftus et al., 2004; Melmoth & Grant, 2006). These advantages are most marked during the movement end-phase, when binocular feedback concerning on-going changes in hand-target depth is used to control the final approach to the goal object & the application of the grip, but are reduced or absent in adults with persistent moderate-severe amblyopia (Grant et al., 2007) or lacking stereovision (Melmoth et al., 2009). Here we examined:

• Whether binocular stereovision provides similar benefits for normal children at ages spanning the critical period for amblyopia
• And whether performance of these eye-hand coordination skills is impaired in children with this condition, in relation to their deficits in visual- and/or stereo-acuity

Pre-Test Assessments

Established each child's

- **Dominant (sighting) eye**
- **Binocular, Dominant & Non-Dominant eye LogMAR VA**
- **Stereoacuity**
- **Dominant (preferred) hand & arm length**

Exclusion criteria, normal children:

- **Monocular logMAR VA >0.2**
- **Inter-Ocular logMAR acuity Difference (IOD) >0.1**
- **Stereoacuity >100 arc secs**
- **Ambidexterity**

Participants

[1] 36 developmentally normal children, divided into 3 age groups:

- **Early** childhood (**ages 5-6 years; n=11**) = during the sensitive period for amblyopia
- **Middle** childhood (**ages 7-8 years; n=11**) = at the end of the sensitive period for amblyopia
- **Late** childhood (**ages 9-11 years; n=14**) = after the sensitive period for amblyopia

Overall Binocular Visual Acuities were significantly better among the oldest vs. youngest children, but there were no age-related differences in mean IOD or stereoacuity (see below)

[2] 21 children with amblyopia, aged 4-8 years:

- **7 anisometropia; 11 strabismus; 4 mixed anisometropia + strabismus**
- **10 mild amblyopia (IOD 0.12-0.28); 11 moderate-severe amblyopia (IOD 0.36-1.1)**
- **10 'coarse' stereovision (55-3600 arc secs); 11 'negative' (undetectable) stereovision**

Group	Age (yrs)	Sex, Hand	Dom VA	Non-Dom VA	IOD	Stereo (arc secs)
Early (n=11)	6.5	7M, 10R	0.06	0.08	0.05	52
Middle (n=11)	8.1	6M, 10R	0.04	0.02	0.04	55
Late (n=14)	10.1	10M, 10R	0.01	0.03	0.04	52
Patients (n=21)	6.4	13M, 18R	0.03	0.51	0.47	na

References

Grant S et al (2007) Prehension deficits in amblyopia. Investigative Ophthalmology & Visual Science 48: 1139-1148

Hay L (1979) Spatio-temporal analysis of movements in children: motor programs versus feedback in the development of reaching. *Journal of Motor Behaviour* 11: 189-200

Loftus A et al (2004) When two eyes are better than one in prehension: monocular viewing & end-point variance. *Experimental Brain Research* 158: *317-327*

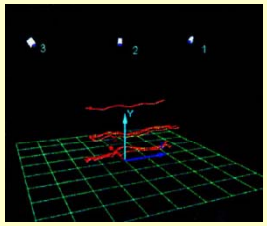
Melmoth DR & Grant S (2006) Advantages of binocular vision for the control of reaching & grasping. *Experimental Brain Research* 171: 371-388

Melmoth DR et al (2009) Grasping deficits and adaptations in adults with stereo vision losses Investigative Ophthalmology & Visual Science 50: 3711-3720

Watt SJ & Bradshaw MF (2000) Binocular cues are important in controlling the grasp but not the reach in natural prehension movements. *Neuropsychologia*, 38:1473-81.

Hand Movement Recordings

Subjects reach for & precision grasped cylindrical household objects of 2 different diameters (24mm, 48mm) placed at 3 different locations (near midline, far ipsi-space, far contra-space) with respect to a standard (midline) starting hand position. They completed separate blocks of these trials in a random order (repeated 2-3 times) using Binocular Vision or just their Dominant or their Non-Dominant Eye – viewing conditions being controlled by liquid crystal (PLATO) spectacles – while their movements were recorded from 3 infra-red reflective markers attached to their preferred hand via a 3D-motion-capture system (ProReflex, Qualysis). Movement kinematics & error rates under each viewing condition were compared within- & between age- or subject-groups employing repeated measures ANOVA.



Main Findings

1. Normal Development, Visuomotor Control Strategies Change with Age:

- The **youngest** subjects relied on a predominantly feedforward (programmed or 'ballistic') strategy (Hay, 1979), spending little time using feedback to guide their hand in the Final Approach to the object (~20% of the overall movement duration, Fig.1).
- Whereas the **middle & oldest** children employed more balanced feedforward/feedback (adult-like) control of their Final Approach

2. Normal Development, Binocular Advantages Change with Age:

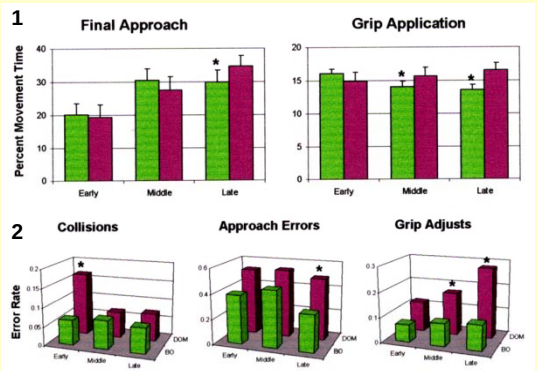
Binocular vision provided few advantages in the younger children, being confined to:

- Reductions in the rate of premature Collisions with the object (Fig. 2) & more accurate grip sizes at initial contact in the **Early** age group
- Reductions in the Grip Application times (Fig 1) & Grip Adjustments (Fig 2) in the **Middle** age group
- But the **Oldest** children exhibited the full range of binocular advantages to those of normal adults, including reduced Approach Errors (Fig 2)

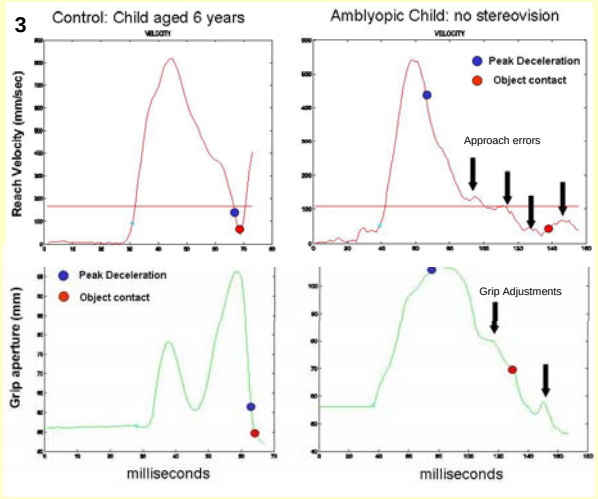
3. Abnormal Development, Children with Amblyopia

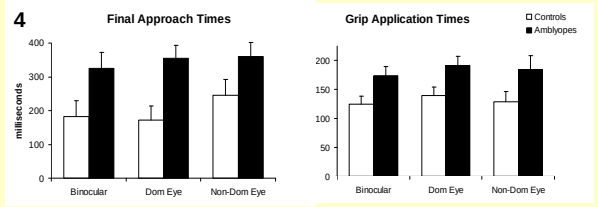
Showed impaired reaching & grasping performance under all viewing conditions compared to age-matched normal subjects (Fig 3), even for the dominant (better) eye, with much longer Final Approach & Grip Application ***times*** (Fig. 4) and many (1.5-3 times) more ***errors*** in executing their grasp

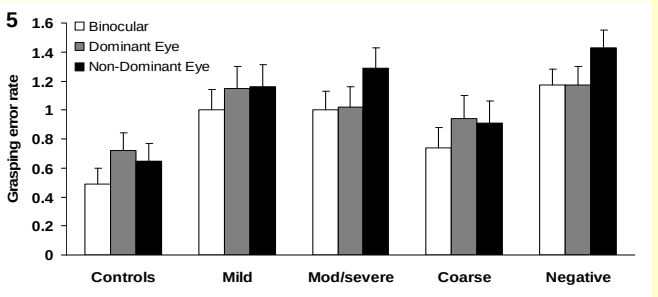
- These latter (Fig 5) were least evident in patients with residual (coarse) stereovision, but relatively independent of the severity of their VA loss or the cause of their amblyopia.



Binocular vs Dominant Eye performance in Normal Development







Conclusions

1. Binocular stereovision provides advantages for movement programming at all ages studied, and increases in importance as children incorporate 'on-line' visual feedback (e.g., about changes in hand-target depth) to guide the progress of their reach and grasp.

2. Restoring functional binocular vision may significantly improve the poor eye-hand coordination abilities of children with amblyopia.

Supported by The Wellcome Trust. Thanks to the children of Hugh Middleton School & patients of Moorfields Eye Hospital