Impaired Development of Eye-Hand Coordination in Children with Amblyopia
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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 distance 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.
- Whether binocular stereovision improves eye-hand coordination in children with this condition, in relation to their deficits in visual- and/or stereo-acuity.

Pre-Test Assessments
Established each child’s:
- Dominant (lighting) eye
- Binocular, Dominant & Non-Dominant eye LogMAR VA
- Binocular, Dominant & Non-Dominant eye arm & hand length

Exclusion criteria, normal children:
- Monocular logMAR VA >0.2
- Inter-Ocular logMAR acuity Difference (IOD) >0.1
- Stereovision >100 arc secs
- Ambidexterity
- >20% feov e over a ut

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 anisometropic; 11 strabismic; 3 mixed anisometropia + strabismus
- 16 mild amblyopia (IOD 0.12-0.28); 11 moderate-severe amblyopia (IOD 0.36-1.1)
- 10 coarse stereovision (5.3-360 arc secs); 11 ‘negative’ (undetectable) stereovision

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) in space for contra-operative, with respect to a small (2mm) 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 (ProReflexx, Qualisys). 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 children used a predominantly feedforward/adjunctive (planning) strategy (Fig 2a), spending little time using feedback to correct for errors in executing their grasp
- Whereas the 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. 2a) & more accurate grip sizes at initial contact in the Early age group
  - Reductions in Final Approach Errors (Fig 2a) & Grip Adjustments/Errors (Fig 2c) 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 2a)

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 youngest children with mild amblyopia: 1.6-fold increases in errors & grip sizes in the Non-Dominant compared to the Dominant Eye,
- These latter 2 factors were most evident in patients with moderate (coarse) stereovision, but relatively independent of the severity of other visual deficits of their amblyopia.

Conclusions
1. Binocular stereovision provides advantages for movement programming at all ages studied, and increases in importance as children incorporate ‘sustained’ 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.

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