Drawing as a Window into Visual Learning and Plasticity Following Treatment for Congenital Bilateral Blindness

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Background

- Drawing and copying can provide a window into the development of vision and visual-motor integration in childhood (refs).
- 'Project Prakash' is a humanitarian/scientific endeavour to treat children born blind, while exploring their brain development following visual deprivation in the first few years of life.

Goal

- Further developmental research on drawing ability as a window into internal representations by following the emergence of drawing from the onset of vision.
- Isolate the roles of visual- and motor- skill for contributing to the development of basic shape drawing.
- Determine if shape copying can develop past dogmatic critical periods (i.e. with late sight-onset).
- Map the developmental trajectory of shape production from visual versus haptic exploration, as visual experience is gained.

Method

Subjects

- 15 Patients:
  treated for billateral congenital cataracts when 7-22 years old.
  No other co-occuring developmental issues.
  Pre-operative acuities range ~20/500 to Light Perception only.
  Post-operative acuities range ~20/150 to ~20/500.
  Each child performed task at multiple, but not all, timepoints.
- 14 Controls:
  With normal visual development and status.
  Children attend orphanages in Delhi, India.
  Matched for socio-economical background and location.
  No other co-occuring developmental issues.
  Approximately matched for gender and age.
  Acuity matched: performed task with imposed 20/500 visual acuity.

Protocol

Tasks:

1. Tracing - trace outline of single and pairs of shapes.
2. Copying Vision - look at outline of shapes and reproduce.
3. Copying Tactile - with eyes closed, haptically explore emossed outline of shape, then reproduce by drawing on ipad with eyes open.

Conditions:

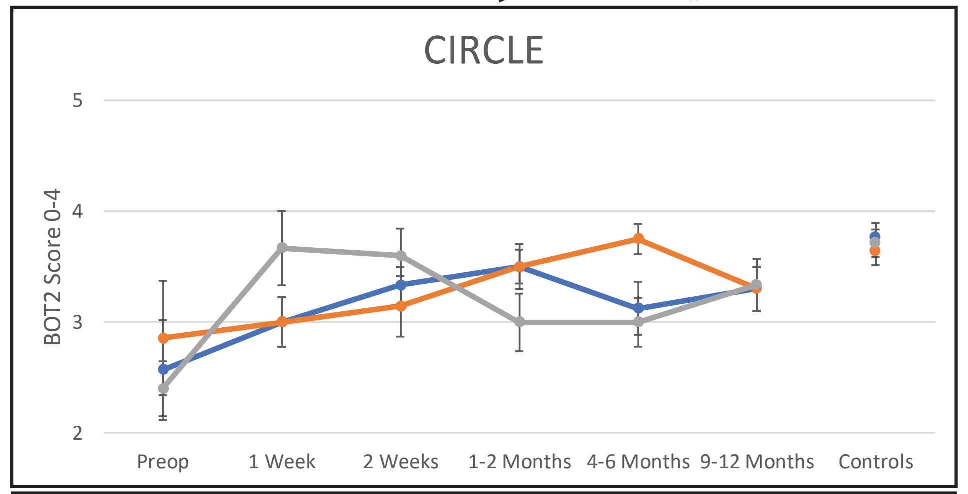
1. Single Shape: Primary, Secondary
2. Dual Shapes: Overlapped, Touching, Side-by-side

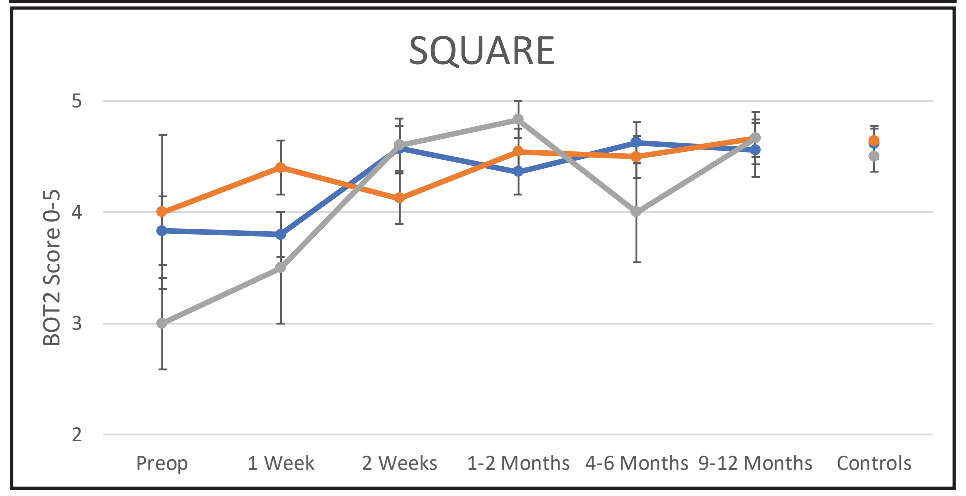
All tasks performed on ipad XX-inch, drawings made with finger, shape sizes kept consistent across conditions, shapes and subject drawings made in high contrast, subjects allowed to correct their shape production in real time.

Sampling:

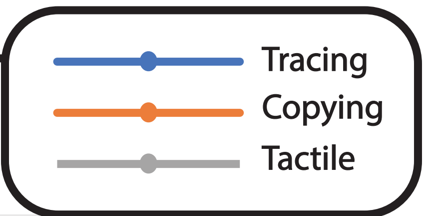
- Data collected at multiple timepoints before and after treatment, upto one year after treatment.
- Also recorded visual acuity, contrast sensitivity, age, education level.

Primary Shape

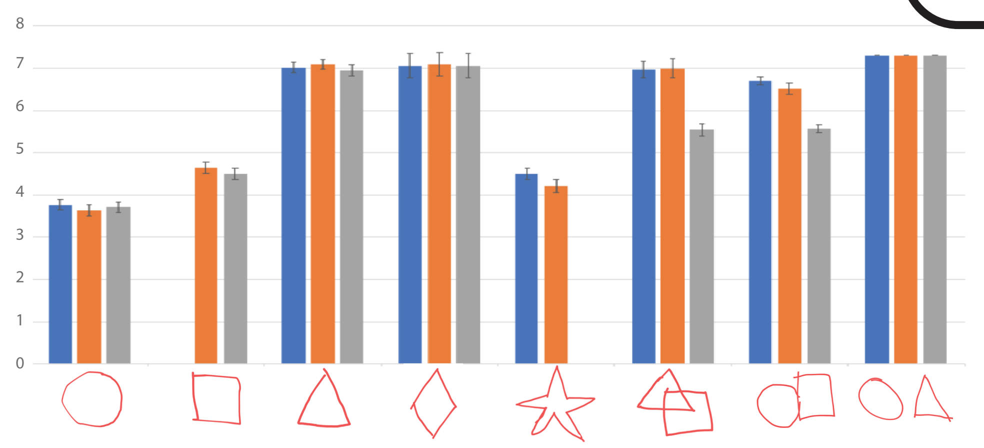




1. Patient group begins w/ lower than control performance, and much lower than children their biological age on all 3 tasks.
2. However, they improve rapidly w/ only 2 wks of visual experience to the level of controls on all stats.
3. Increased visual experience results in descrease in "between subject variability" for tracing & vision copying only.

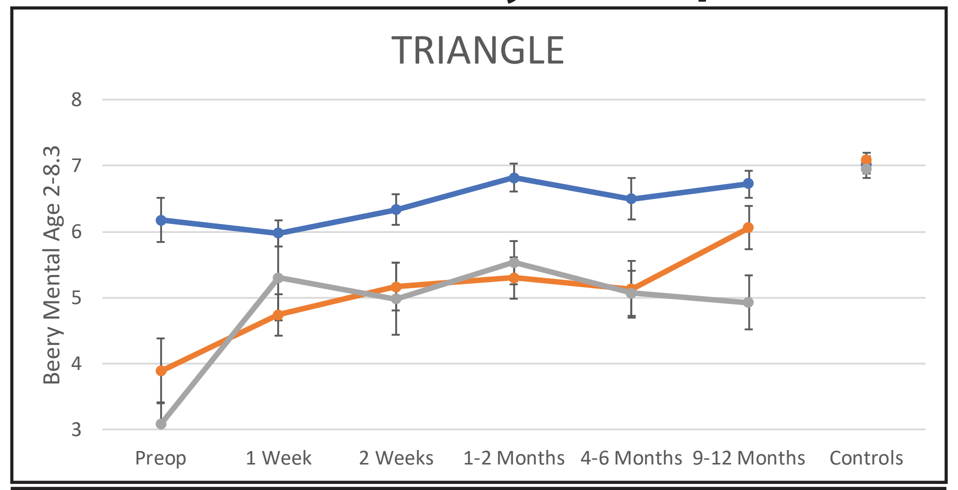


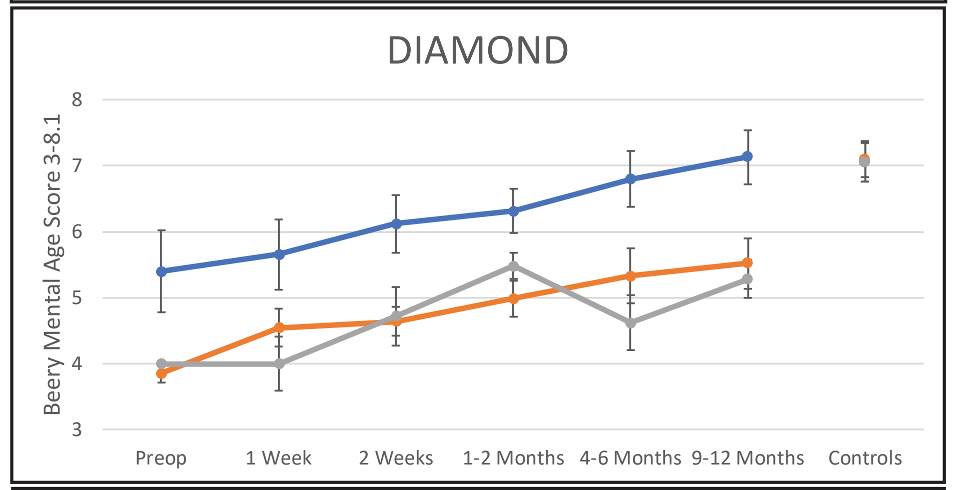
Controls

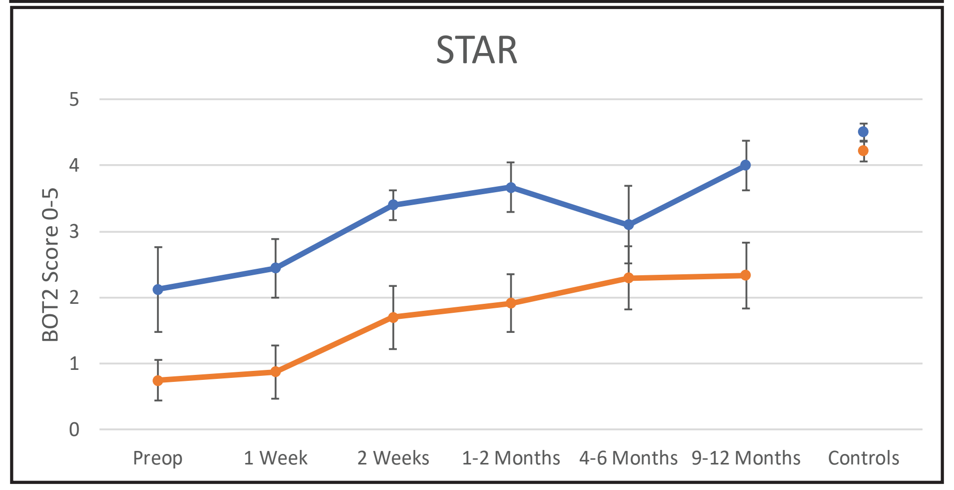


1. Despite imposed low visual acuity, controls' performance is not affected, indicating that impairments found in patients after treatment are due to atypical visual development but not to persisting acuity impairments.
2. Performance on tactile task is comparable to vision task on all conditions except when multiple shapes are interacting (overlapping and touching), suggesting they have developed robustVM integration when visually exploring and encoding an input, whereas VM integration remains poor when haptically exploring an input.
3. Controls' tend to draw the relationship of all three shape-pair conditions as side-by-side shapes.

Secondary Shape

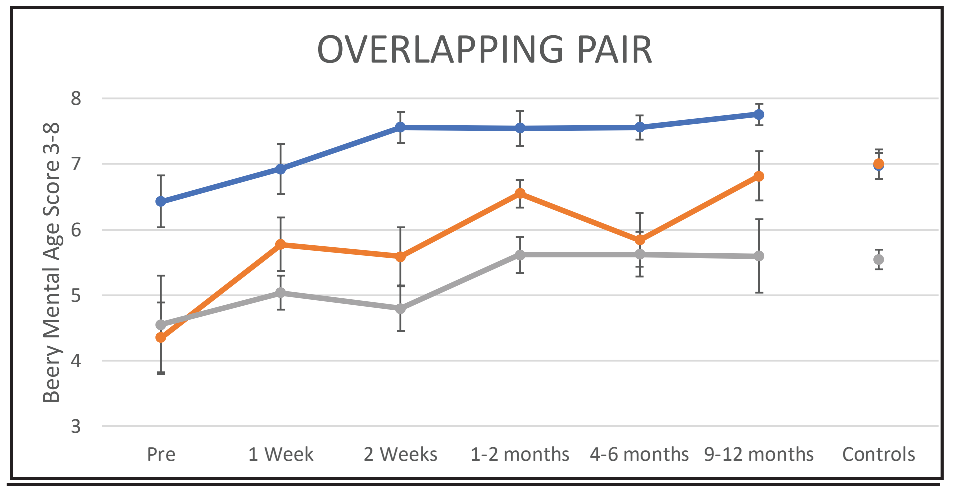


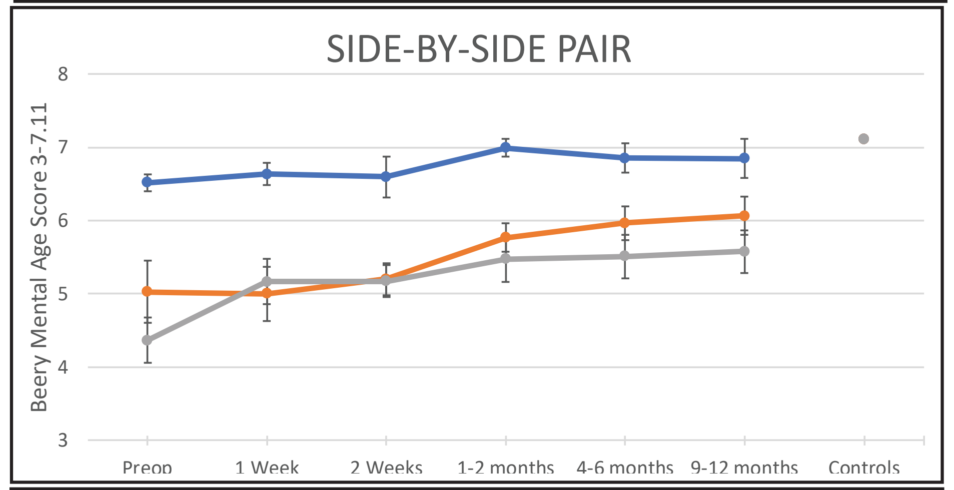


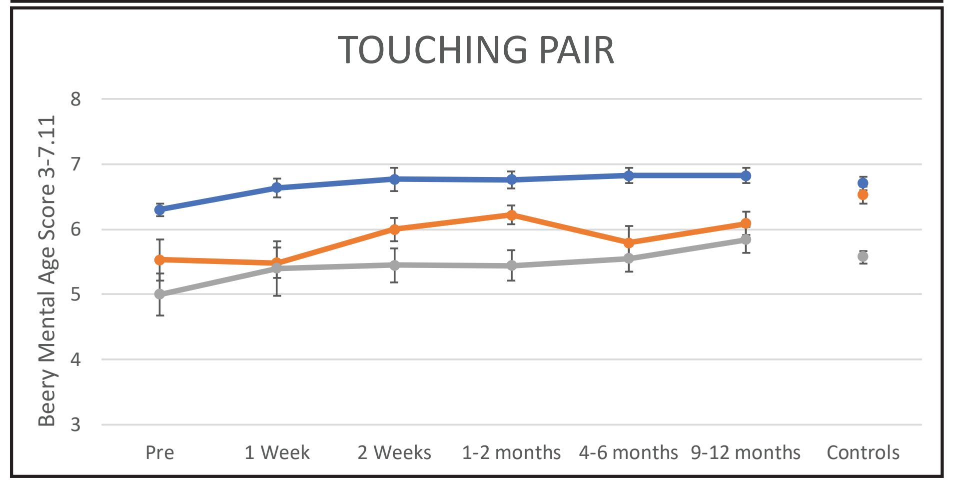


1. Triangle copying improves within first week, consistent with sudden onset of form production in NT's, suggesting early emergence of basic visual-motor integration immediately after sight onset.
2. Tracing performance begins high and rapidly reaches NT level:
   Possibly reflects reliance on component-based strategies, which remain effective for tracing, even with minimal vision.
   Indicates that their drawing skills are not limited by fine motor control.
2. Reproduction of shapes (ie copying) begins worse than tracing, regardless of modality of input, but improve rapidly with just 1yr of visual experience.

Paired Shapes







1. Overlapping shapes (with clear interaction): patients improve over the first year of recovery, ending up with the same profile as controls (vision > tactile), suggesting they also develop integration for visual but not haptic encoding.
2. Side-by-side (no interaction): patients improve on both vision and tactile, which is comparable to controls. Overall, performance has not yet reached controls'.
3. Touching (single point of interaction): patients' pre-op performance on tactile and vision is comparable to NT tactile performance, suggesting NT'd tactile encoding is not impaired, but hadn't developed beyond a certain level while visual encoding continued to mature.
4. After 1 year of visual experience patients have yet to develop the vision>tactile encoding advantage for touching shapes that they already developed for overlapping shapes.

Questions

1. How does copying performance with standardized assessments compare to performance based on computational image-similarity or deep neural nets analyses?
2. Does emerging ability to copy simple geometric shapes predict emerging ability to draw real/comlex known objects from memory (e.g. "draw a person").

References

1. Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2): Beitel, P., & Mead, B. J., Perceptual and Motor Skills, (1980).
2. Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI): Beery, K.E. and Beery, N.A., Pearson (2010).