세브란스 SEVERANCE | 용인세브란스병원 YONGIN SEVERANCE HOSPITAL

2021 대한소아재활발달의학회 추계연수강좌

Visuomotor problems in children with CP and DD

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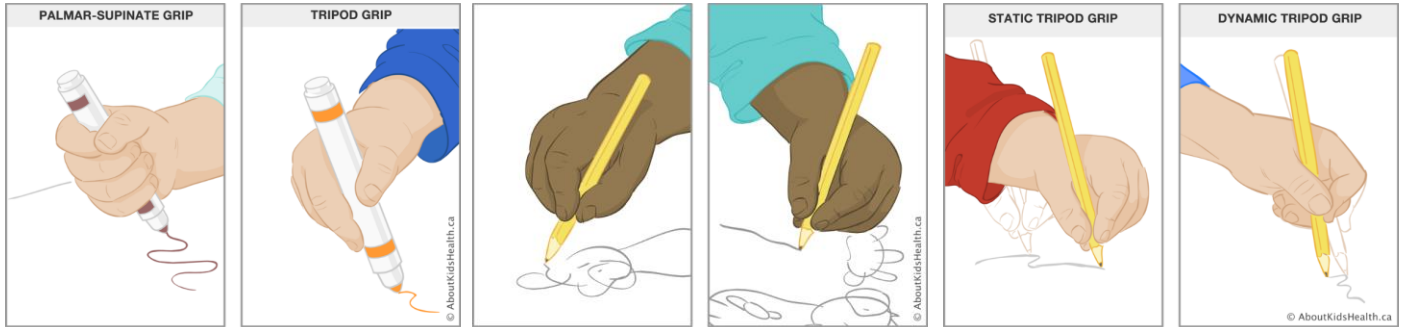
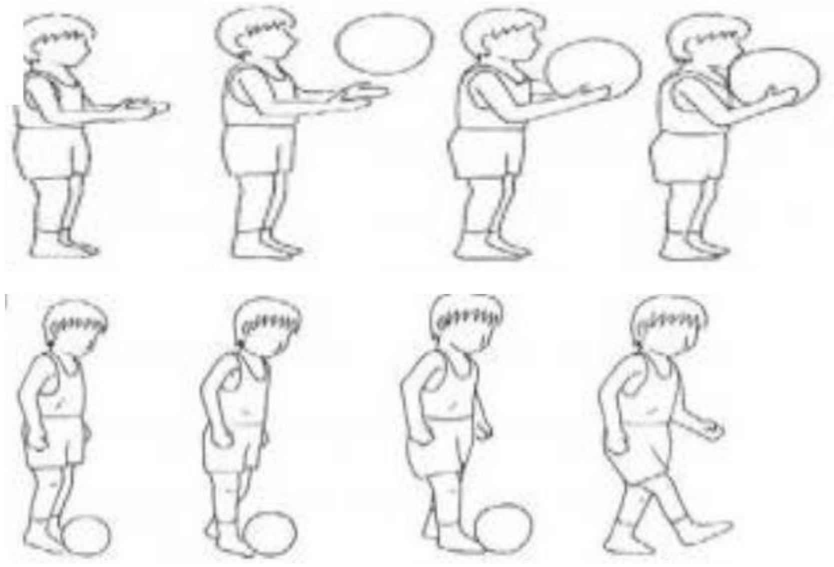
재활의학과

김승기

- 시지각 (visual-perception)
  - 물체의 형태, 색체, 기타 특성을 판별하고, 공간 내에서 물체의 방향과 형태를 파악하고, 물체 사이 혹은 물체와 공간 사이의 관계를 이해하는 능력
    - 물체를 주시하고, 물체의 움직임을 따라갈 수 있으며, 공간 안에서의 배열뿐 아니라 작은 부분들이 어떻게 전체를 이루고 있는지를 파악하고 지각
- 시각-운동 협응 (visuomotor integration; VMI)
  - Visual perception과 motor skill 간의 협응을 통해 시각적으로 입력된 정보를 실제 행동으로 옮기는 능력
  - 감각-반응 통합능력 중 가장 먼저 발달

- Visual motor integration (VMI)
  - the ability to perceive visual input, process the information, and coordinate a motor response
  - VMI skills encompass eye-hand coordination, praxis, visual perceptual skills, gross motor coordination, and fine motor coordination.





Visual developmental milestones

At birth	Primary focus is on objects 8 to 10 inches from their face or the distance to parent's face.
1mo	Eye-hand coordination begins to develop. By 8 weeks, babies begin to more easily focus their eyes on the faces of a parent or other person near them.
2mo	The eyes are not well coordinated and may appear to wander or to be crossed.
3mo	Babies should begin to follow moving objects with their eyes and reach for things
5mo	The eyes are capable of working together to form a three-dimensional view of the world and begin to see in-depth. Babies have good color vision
8mo	Most babies start crawling at about 8 months old, which helps further develop eye-hand-foot-body coordination.
9mo	Babies begin to pull themselves up to a standing position.
10mo	A baby should be able to grasp objects with thumb and forefinger.
12mo	Most babies will be crawling and trying to walk.
24mo	The eye-hand coordination and depth perception should be well developed.

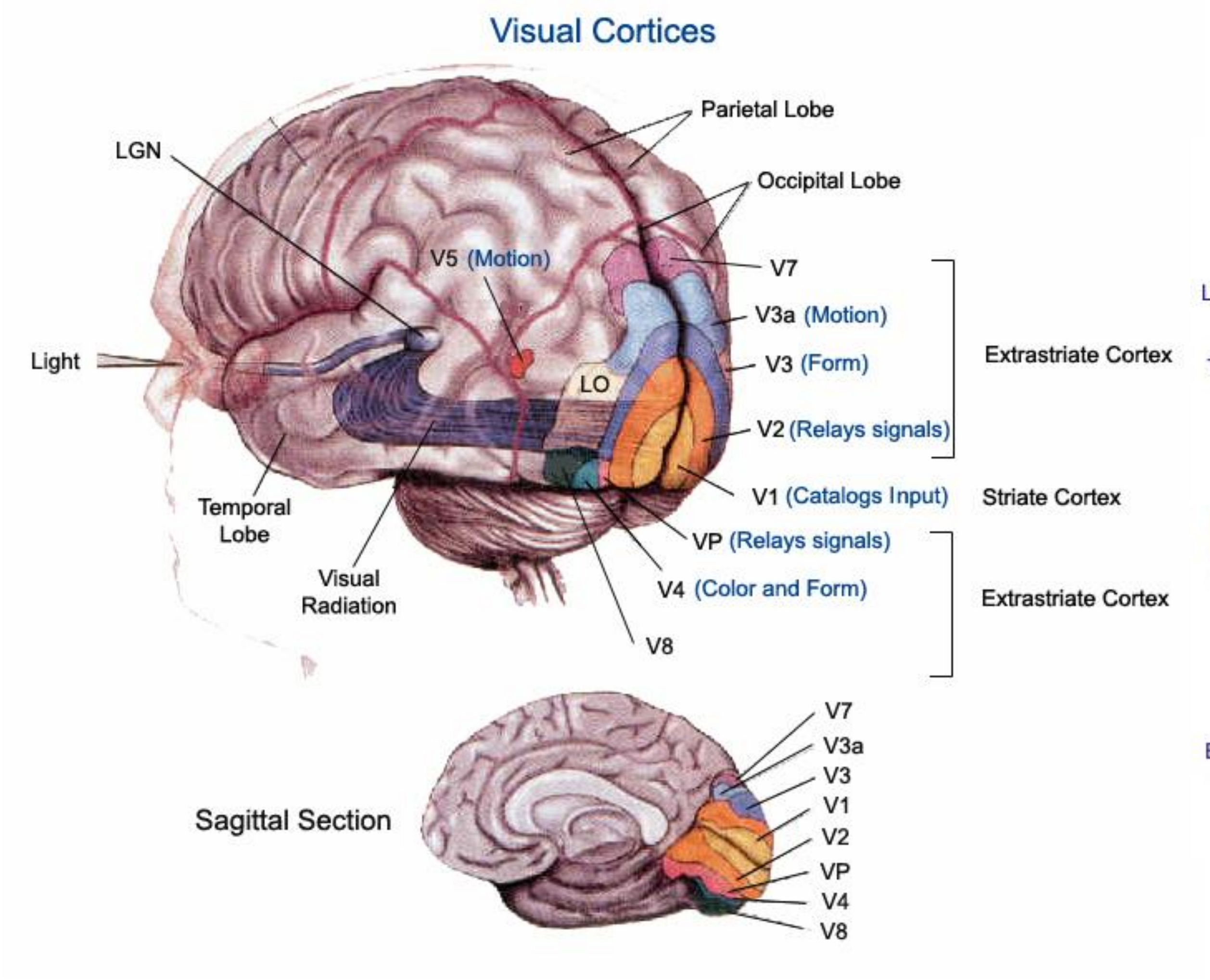
- Visuomotor integration의 발달
  - 낙서하기(scribbling)

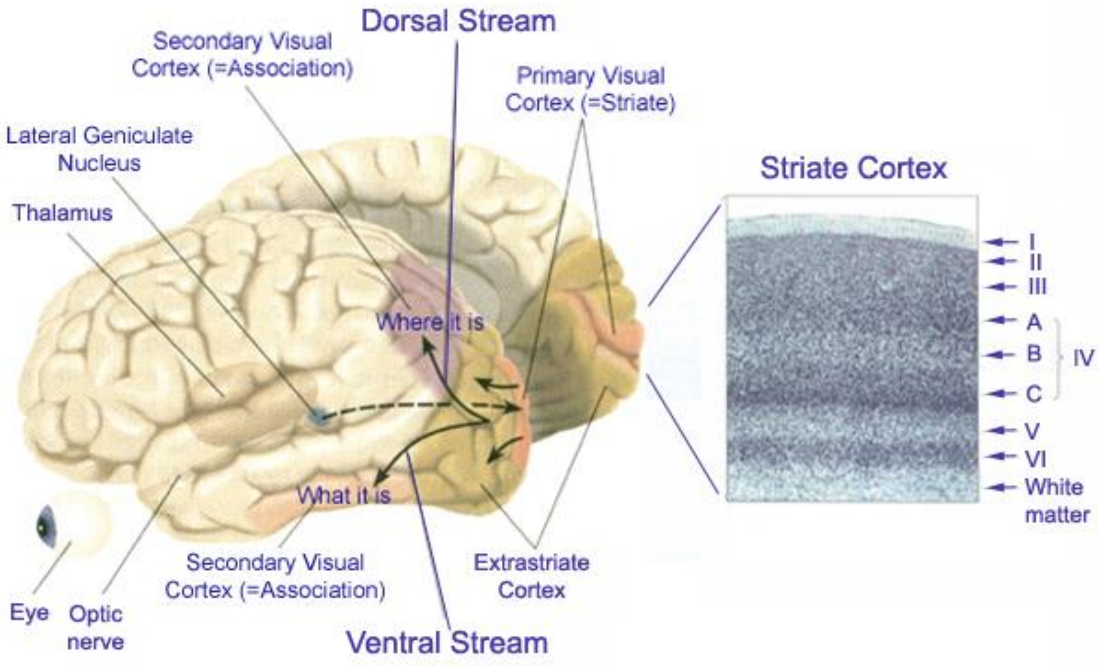
    ↓
  - 모방(imitation) : 시연(rehearsal) 과정

    ↓
  - 직접 모방(direct copying)

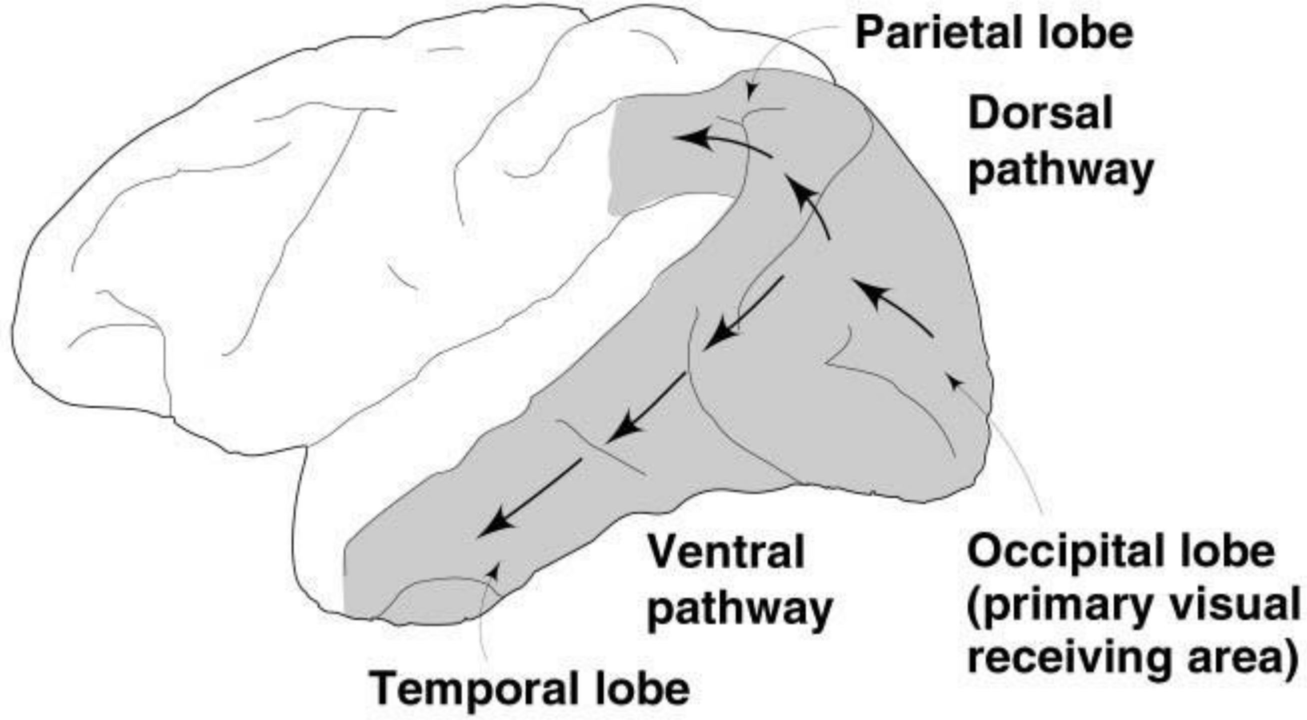
3yr	원 그리기
4yr	십자선 직접 모방, 사각형 모방
5yr	사각형과 사선 직접 모방, 삼각형 모방
7-8yr	마름모 모방
9-10yr	원기둥, 직육면체 등의 입체 도형 모방

Visual area of the human cortex



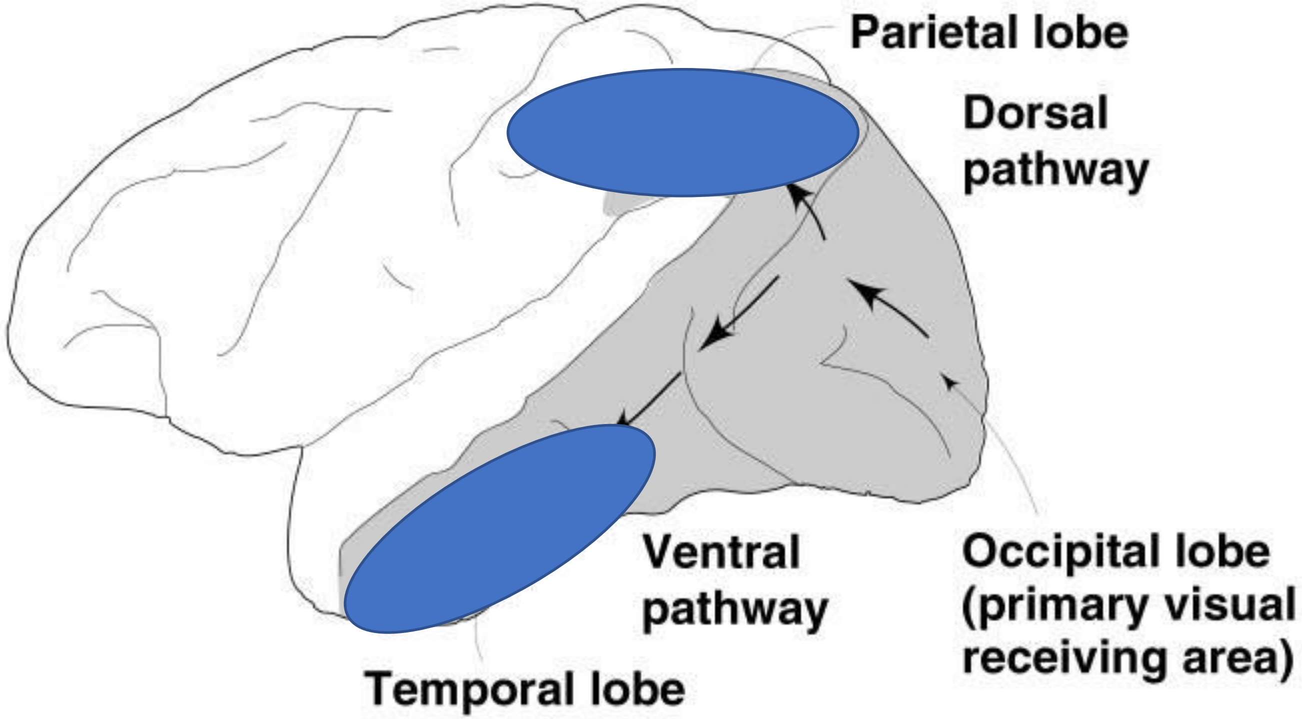


Ungerleider and Mishkin (1982)

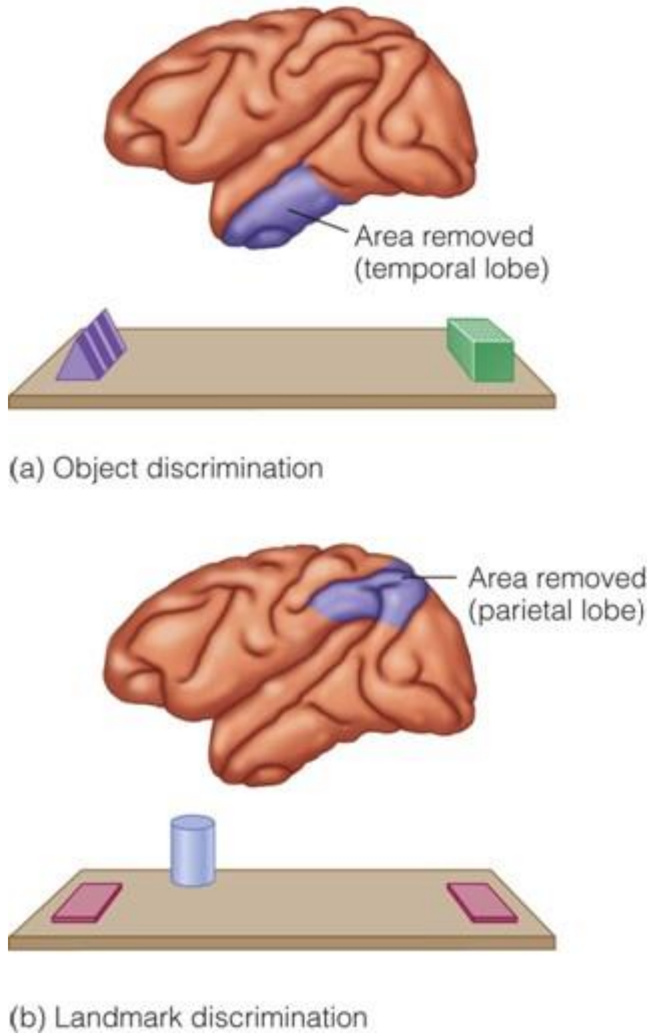


Ungerleider and Mishkin (1982)

Remove parietal lobe
= couldn't identify location "Where" system



Remove temporal lobe
= couldn't identify object "What" system

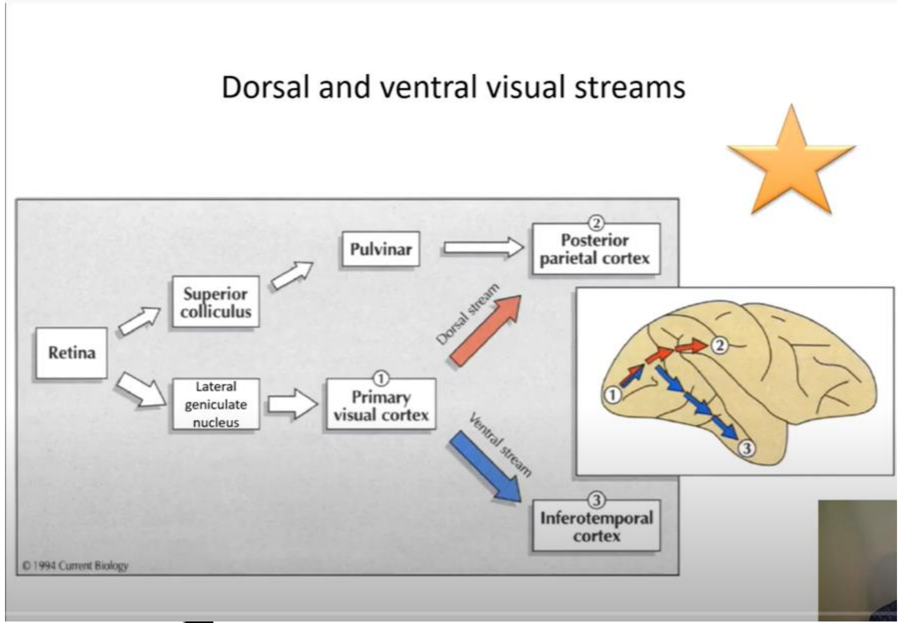


Cortical visual system

Two visual streams

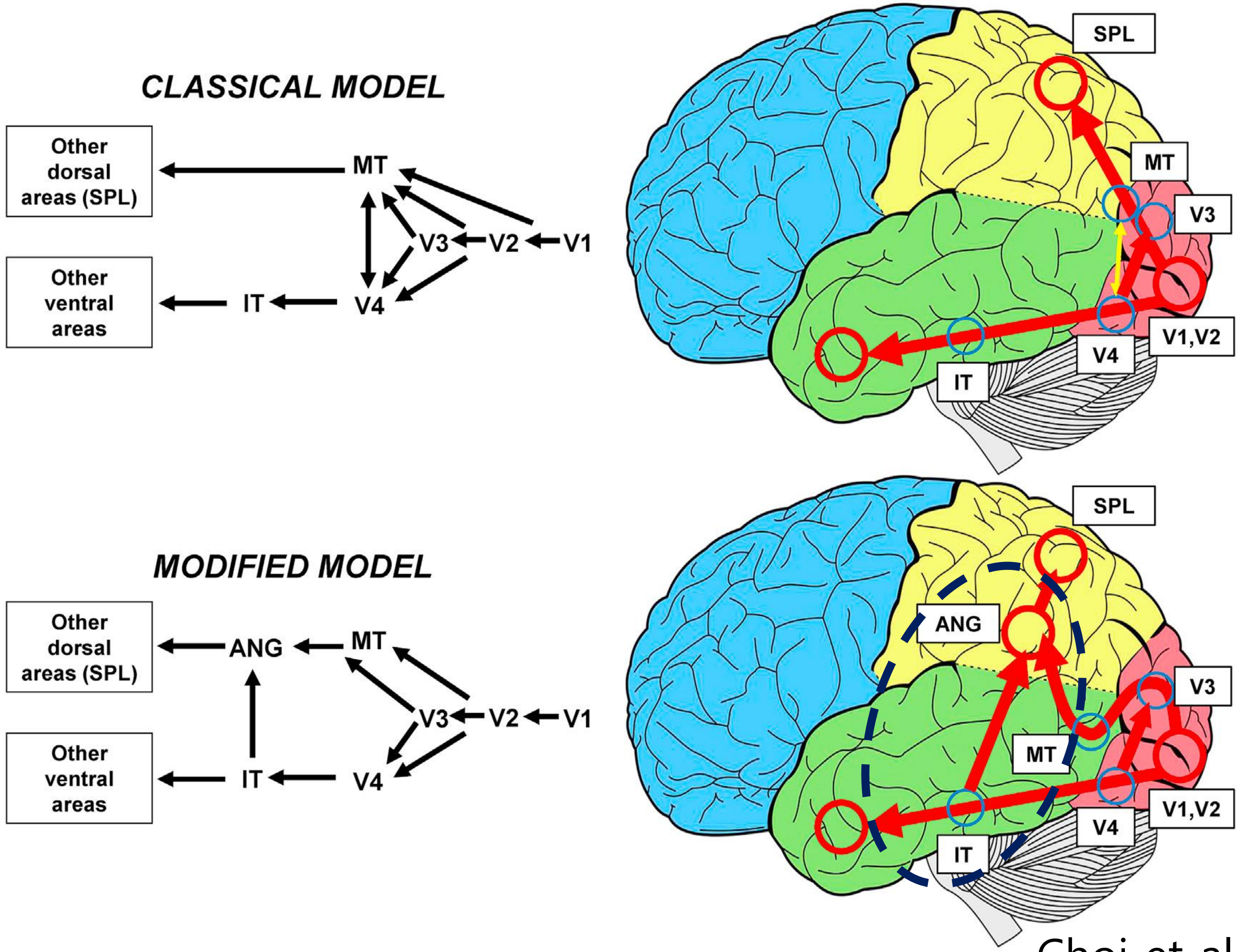
Perception (what) vs. Action (how) visual systems

1. Dorsal stream ending in the posterior parietal cortex
   - Processes “how” information
   - That is, visually-guided action
2. Ventral stream ending in the inferotemporal cortex
   - Processes “what” information
   - That is, conscious perception

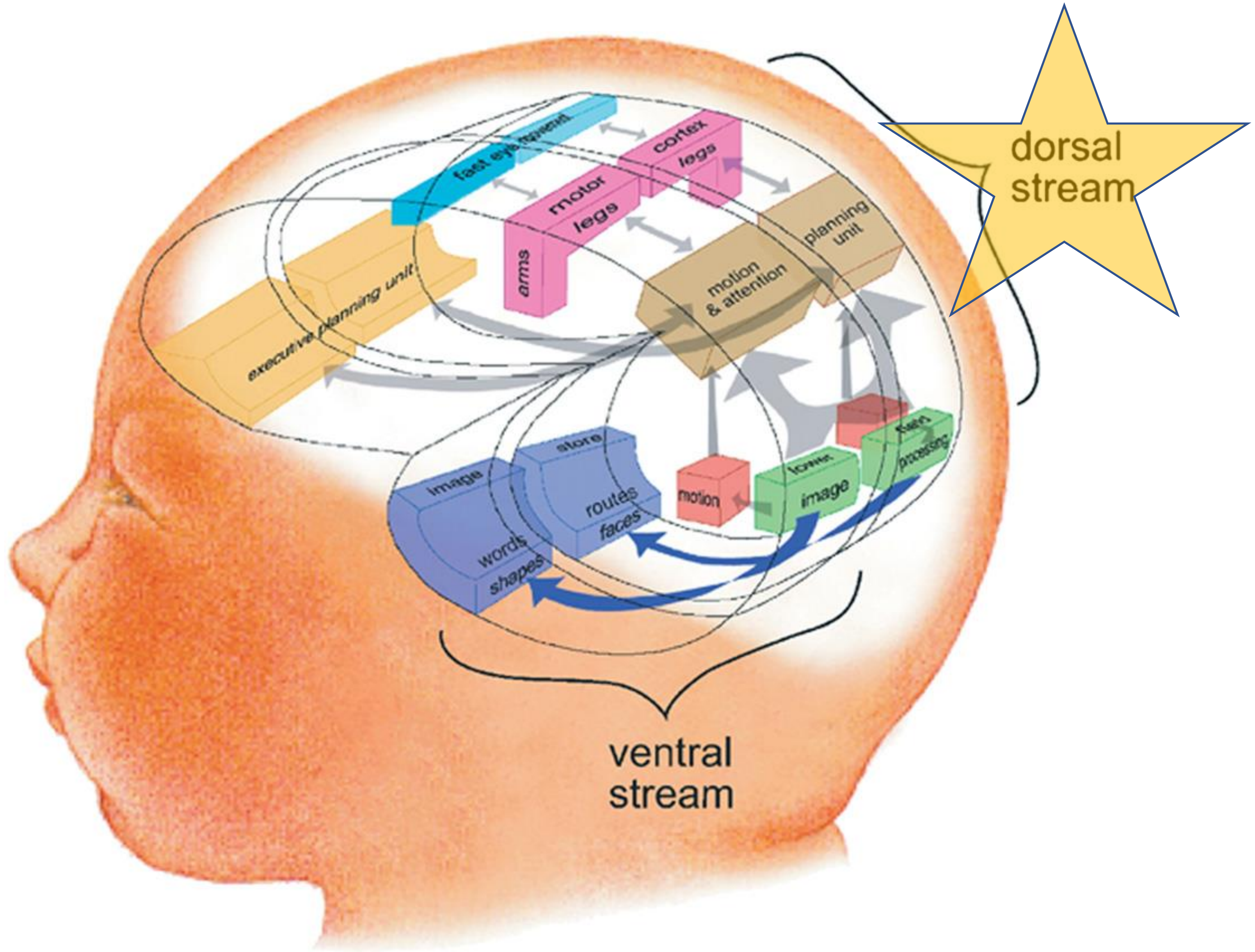


at those objects. Note that this is not the distinction between ‘what’ and ‘where’ (object vision and spatial vision) that was originally put forward by Ungerleider and Mishkin, who proposed that the ventral stream processes incoming information about the intrinsic visual properties of an object whereas the dorsal stream processes information about its spatial location.[10] Our perspective on the division of labour between the dorsal and ventral streams is to place less emphasis on input distinctions (e.g. intrinsic object qualities versus object location) and to take more account of the output characteristics of the two cortical systems. We propose that the intrinsic properties of an object and its spatial location are processed by both streams, but for different purposes: in the case of the ventral stream, for constructing a perceptual representation of the world, and in the case of the dorsal stream, for the visual control of action. This is not to say that the distribution of visual inputs does not differ between the two streams, but rather that the main difference lies in the nature of the transformations that each stream performs on those inputs. Of course,

Cortical visual system

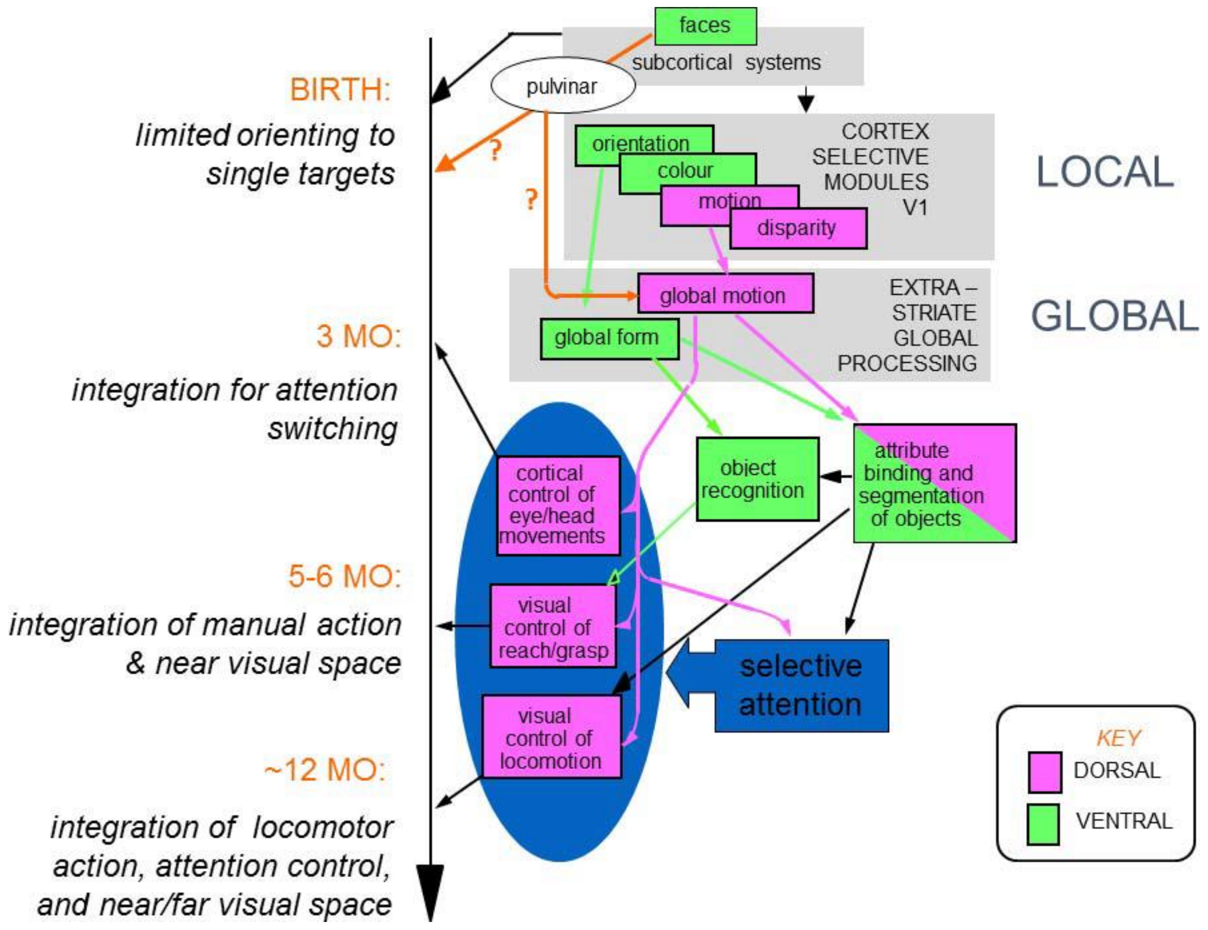


Choi et al., *NeuroImage* 220 (2020)



Dutton GN. *Eye* (2003) 17, 289–304

Model of Visual Development



- Infants show a neural response to coherent motion by around 3 months of age, with sensitivity to global motion developing earlier than sensitivity to static form.
- Global sensitivity for motion was more advanced at 4–5 months of age than for global static form.

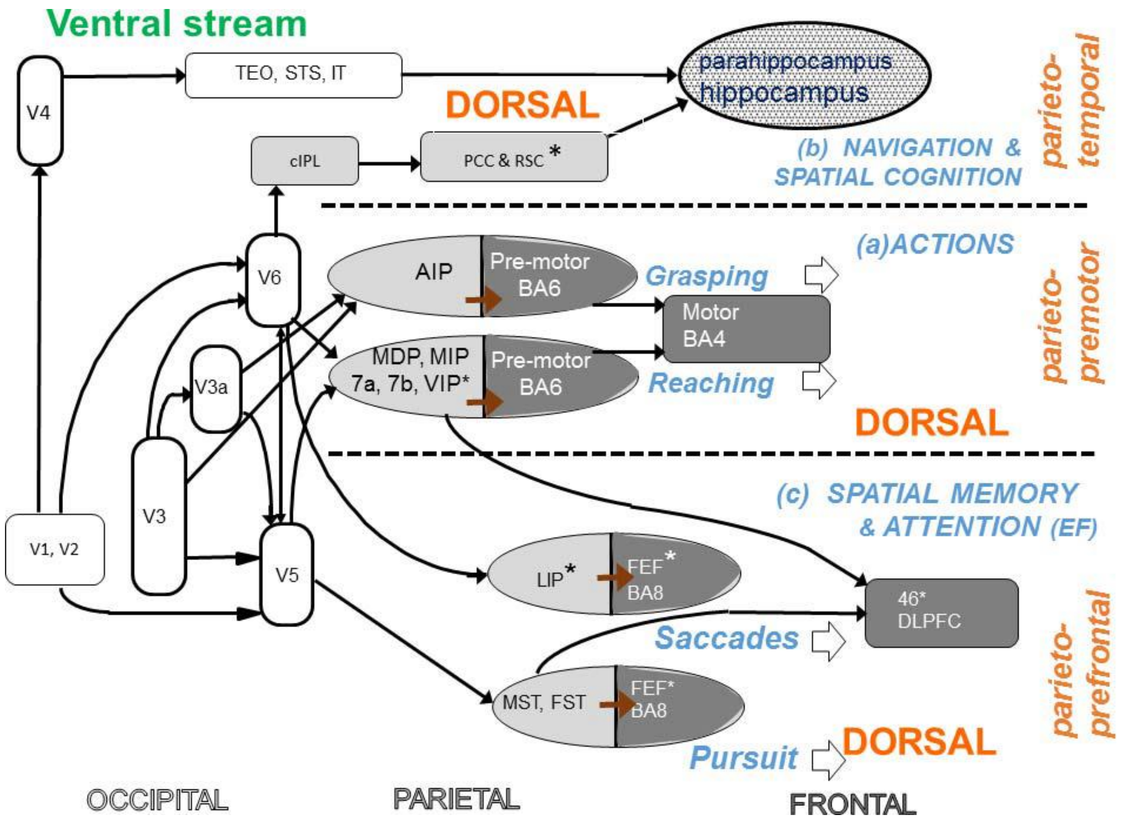
Atkinson. *Journal of Vision* (2017) 17(3):26, 1-24

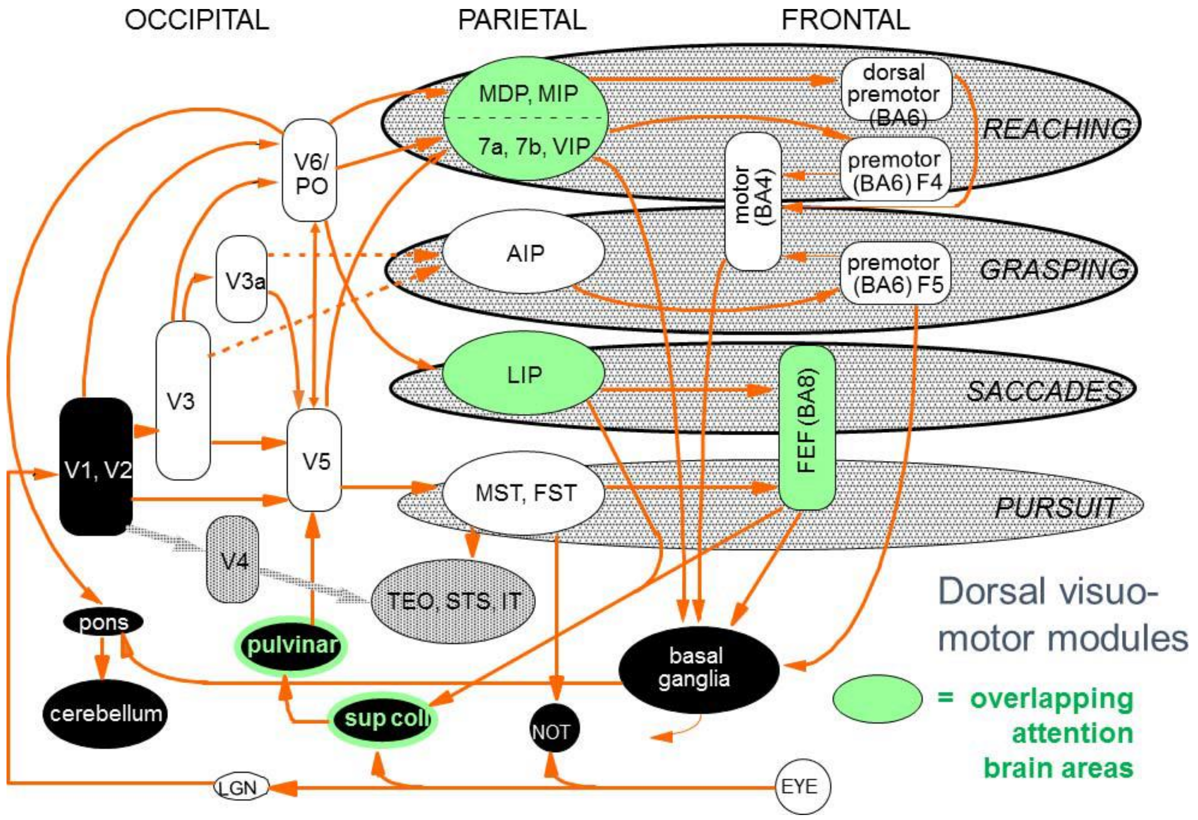
Dorsal and ventral stream development

- Adult levels of form coherence sensitivity were reached for most typically developing children around 7–10 years, but global motion sensitivity showed a slower developmental course, being considerably poorer in 4–5 year olds and not reaching adult levels till around 8–12 years of age.
- Adults generally showed similar coherence thresholds for both form and motion.

- Sensitivity to pattern properties is apparent earlier in cortical development than to directional motion, but global integration of these directional signals develops in infancy faster and more robustly than for static pattern elements. Through childhood, this relation reverses again and global motion development depends on a relatively delicate, vulnerable system whose disruption is apparent in a range of developmental disorders.

Dorsal stream functions





Atkinson. *Journal of Vision* (2017) 17(3):26, 1-24

Dorsal stream functions

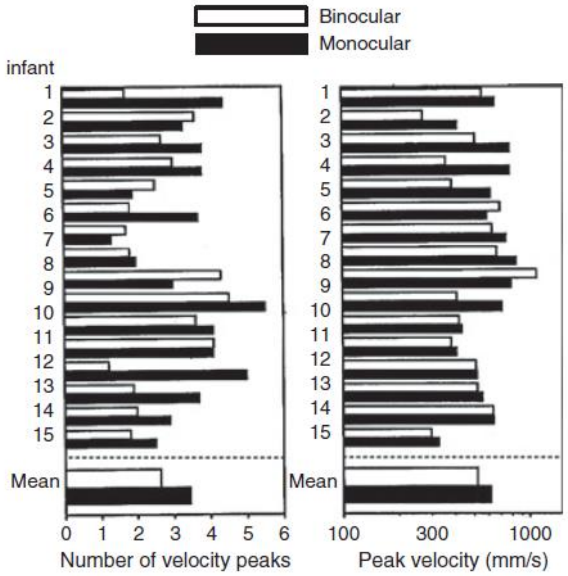
- Dorsal stream
  - Functions
    - reaching and grasping, processing of motion, navigation, spatial memory and spatial attention, and aspects of executive function
  - Different modules
    - Different action systems (reaching, grasping, eye movements, locomotion) require different information in different spatial reference frames → distinct visuomotor modules supporting each of these action systems
  - Attention
    - Many cortical dorsal stream areas overlap with those to be involved in the control of attention

Dorsal stream vulnerability

- 'Dorsal stream vulnerability' has been identified as a raised threshold for global motion coherence relative to static form coherence.
- found across many different developmental disorders
  - including autism, Williams syndrome, fragile X, children born very preterm, children with congenital cataract and dyslexia, hemiplegia, developmental coordination disorder
- Early visual deficit
  - Congenital cataract, amblyope

➔ poor motion sensitivity, visuomotor spatial integration for planning actions, attention, and number skills

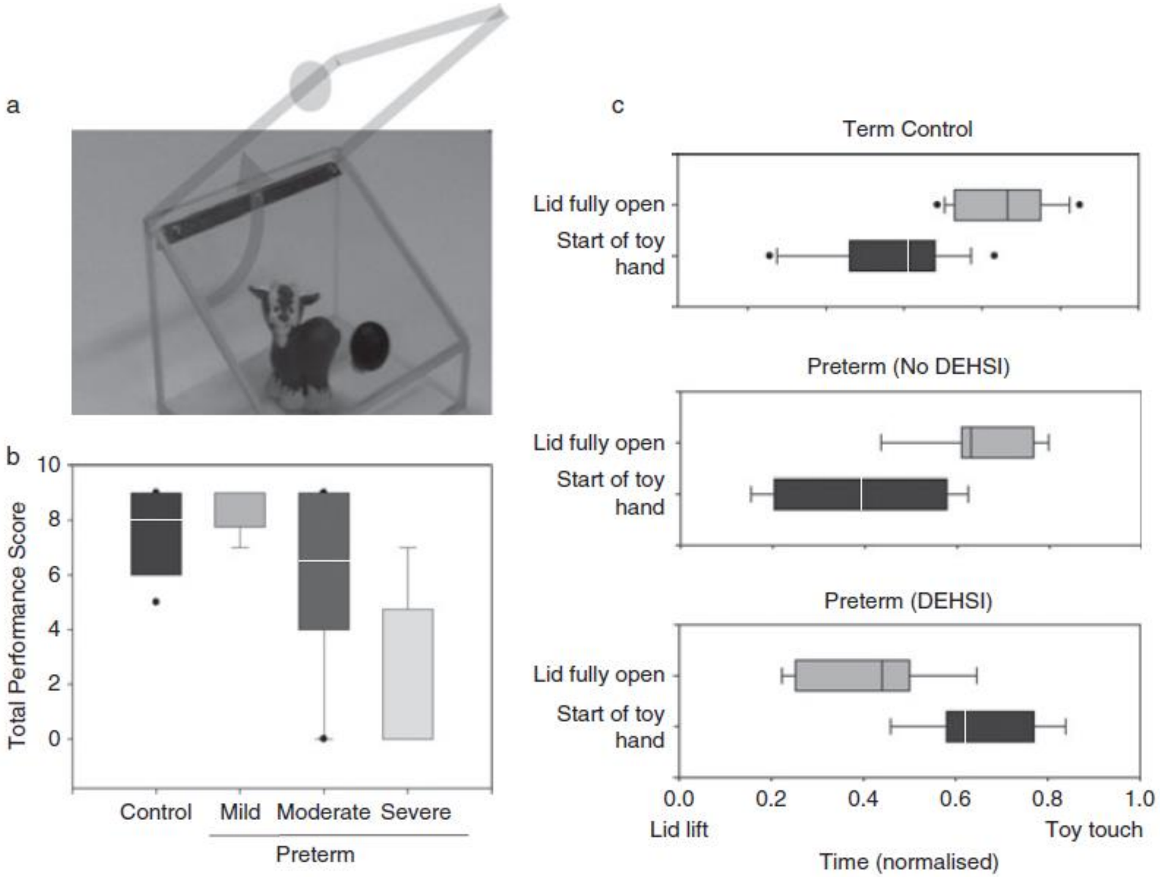
Visuomotor control
- Reaching and grasping



- Infants aged between 5 and 18 months show an almost compulsive response to reach out, grasp, and manipulate any small object placed in front of them.
- 3 component processes of reaching
  - selective attention, visuospatial information, selecting an appropriate motor program
- binocular stereoscopic vision - binocular processing emerges in the infant's visual cortex (typically 3–4 mo)
  - visual 'cues' to distance
- Size
  - Between 5 and 12 months, infants preferred to look first at the larger object of each pair.
  - Between 8 and 12 months, the reaching module uses visual size information that specifies graspability.
  - After 12 months, the two modules become more effectively coupled.

Oliver Braddick & Janette Atkinson, *DMCN* (2013) 55(4); 13-18

Visuomotor control
- Bimanual coordination



- Two hands together symmetrically from an early stage
- Passing an object from one hand to the other - generally observed between 5 and 7 months of age

- one hand held the lid open while the other grasped the toy, was achieved by about 80% of typically developing infants aged 18 to 24 months

- Bimanual coordination is believed to depend on the development of a brain network including the left and right supplementary motor areas and their interconnection through the corpus callosum.

Oliver Braddick & Janette Atkinson, *DMCN* (2013) 55(4); 13-18

Visuomotor control
- Motor planning

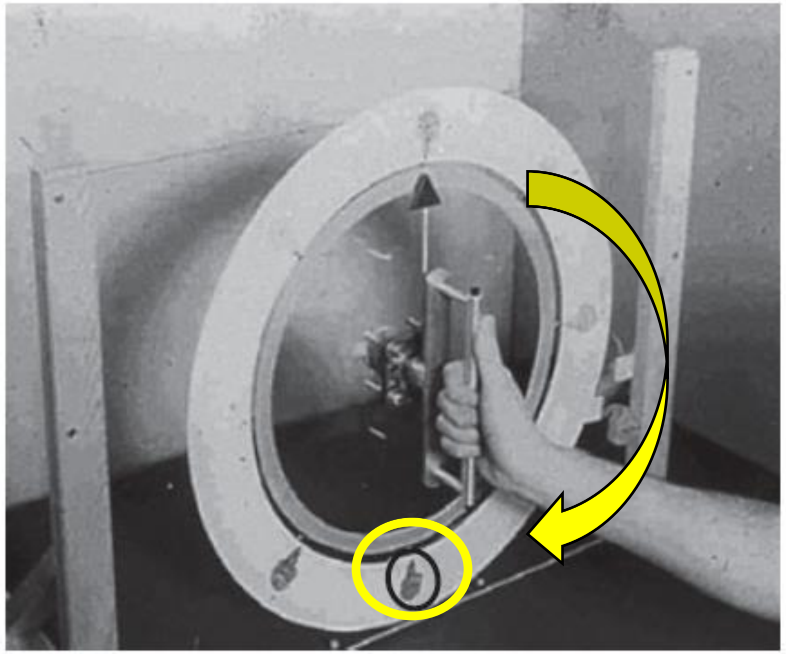
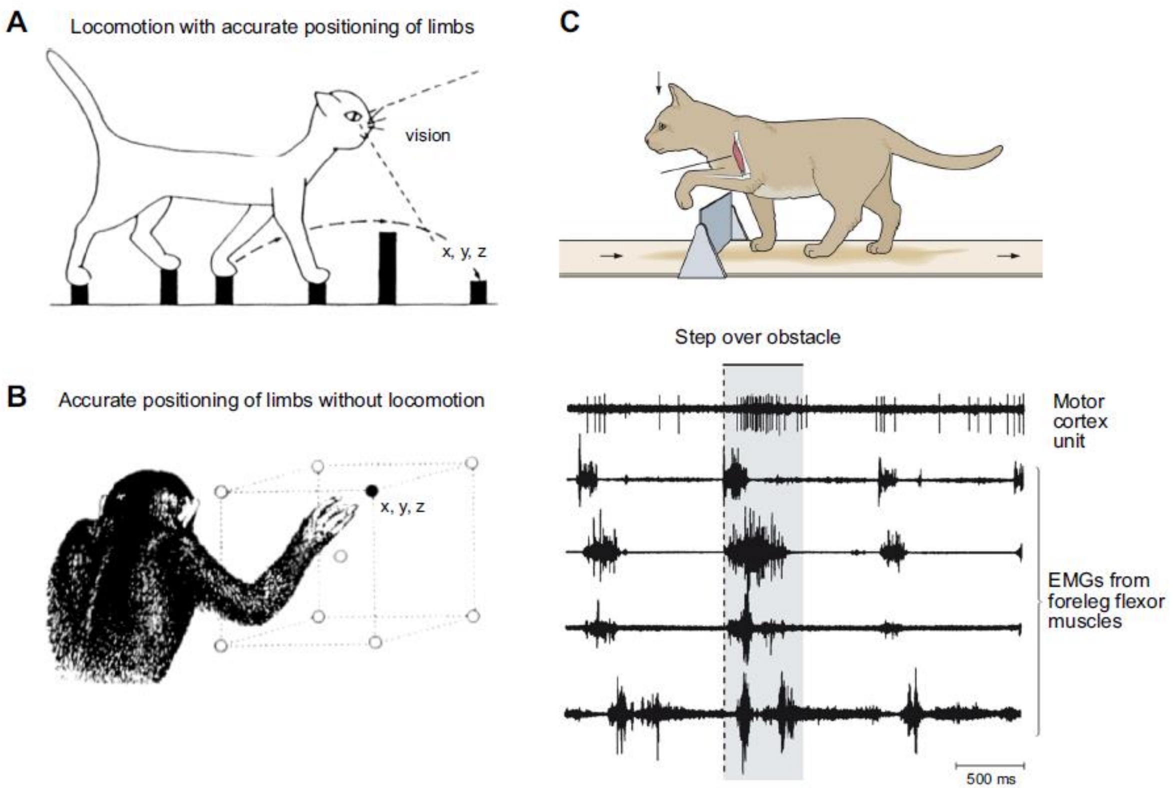


Figure 3: Apparatus for the handle task. Coloured mouse figures define target locations at 45° intervals around the circle. An illuminated LED indicates the current target (here marked by a circle around the bottom target position). The thumb towards grip shown here would lead to an uncomfortable wrist posture at the end-state when the arrow points to the target.

- An even more complex aspect of motor planning is the goal of 'end state comfort'.
- This behaviour develops slowly in childhood: only by age 8 years do children vary the grasp appropriately.
- Younger children tend to adopt a 'thumb-towards' grip for all target positions, suggesting behaviour that is driven by the immediate visual properties of the pointer rather than translation of visual positions into future motor states.

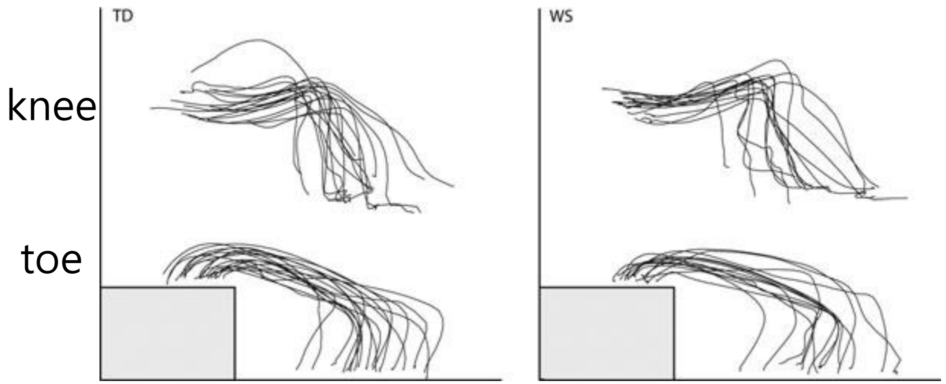
Oliver Braddick & Janette Atkinson, *DMCN* (2013) 55(4); 13-18

Visuomotor control - Locomotion



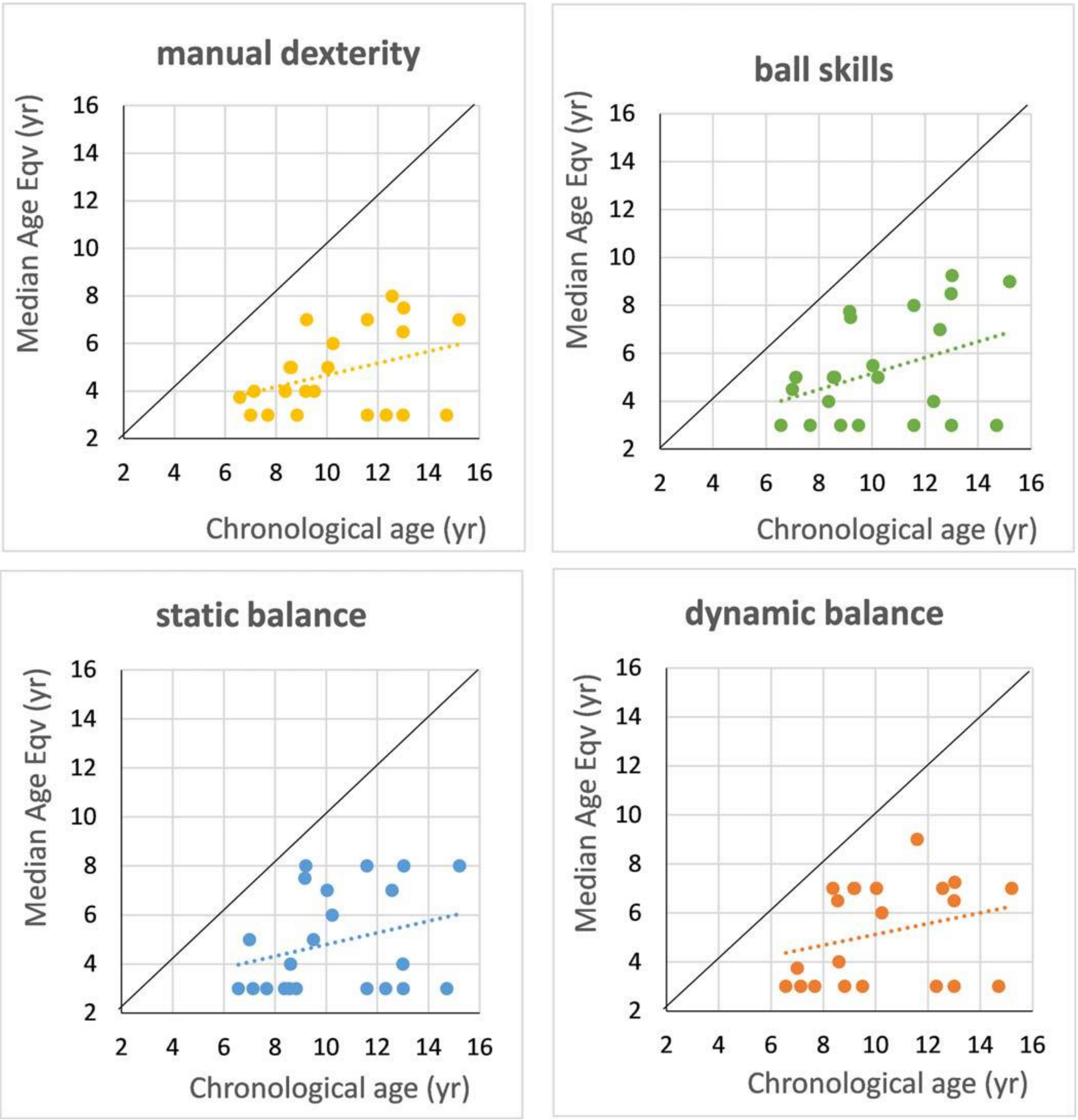
Sten Grillner and Abdeljabbar El Manira, *Physiol Rev* 100: 271–320, 2020

- Locomotion is a further domain where visual information is required to prepare safe and accurate motor responses.
- the action sequence of the leg while descending stairs is determined by advance visual information about the step height, in children as young as 3 years old, but that this linkage is seriously disrupted in WS.



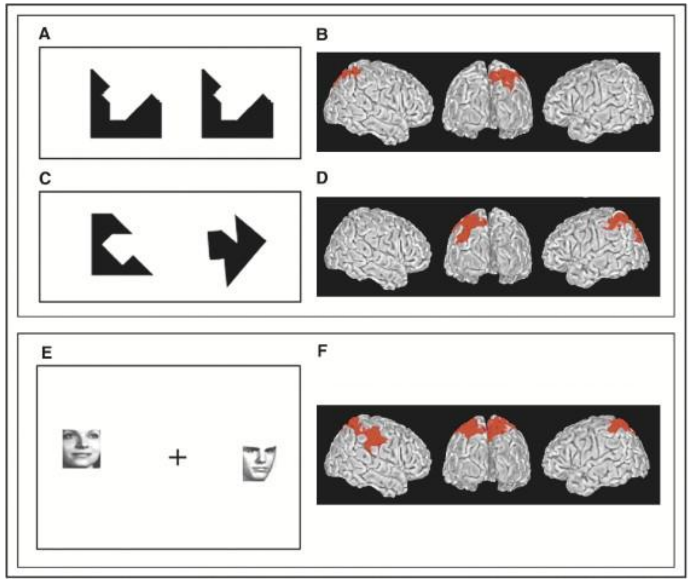
Willams syndrome

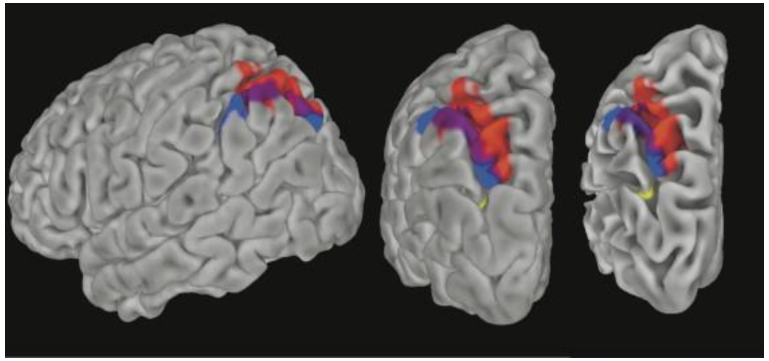
- a specific deletion on chromosome 7
- very uneven cognitive profile, with relatively strong expressive language abilities
- good face recognition and object recognition in line with their mental age, but very poor performance on visuospatial and visuomotor skills such as drawing and block construction
  - persistent deficits in global motion coherence sensitivity, relative to static form coherence, compared to typically developing children

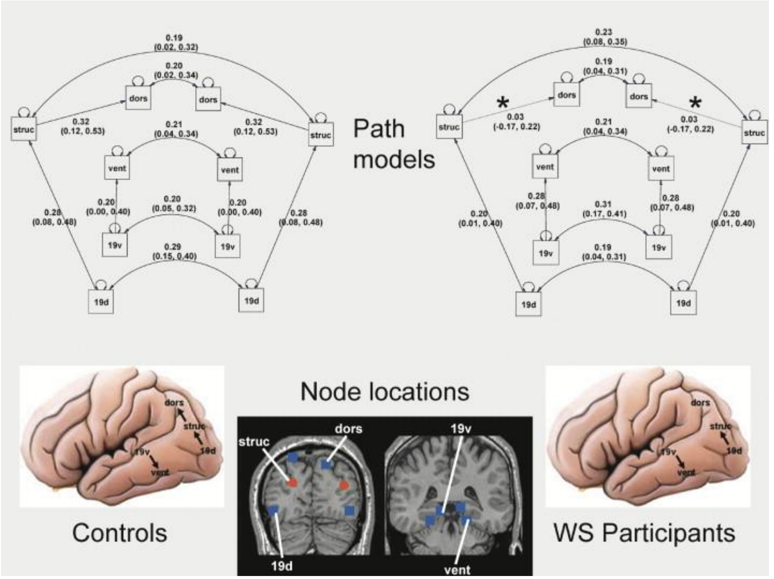


Atkinson. *Journal of Vision* (2017) 17(3):26, 1-24

- MRI
  - anomalous fiber tract development within the centrum semiovale, together with abnormal cerebellar structure
  - Hypoactivation in the parietal portion of the dorsal stream, gray matter volume reduction in the immediately adjacent parietooccipital/intraparietal sulcus, lack of a path from the structurally altered area into the dorsal stream







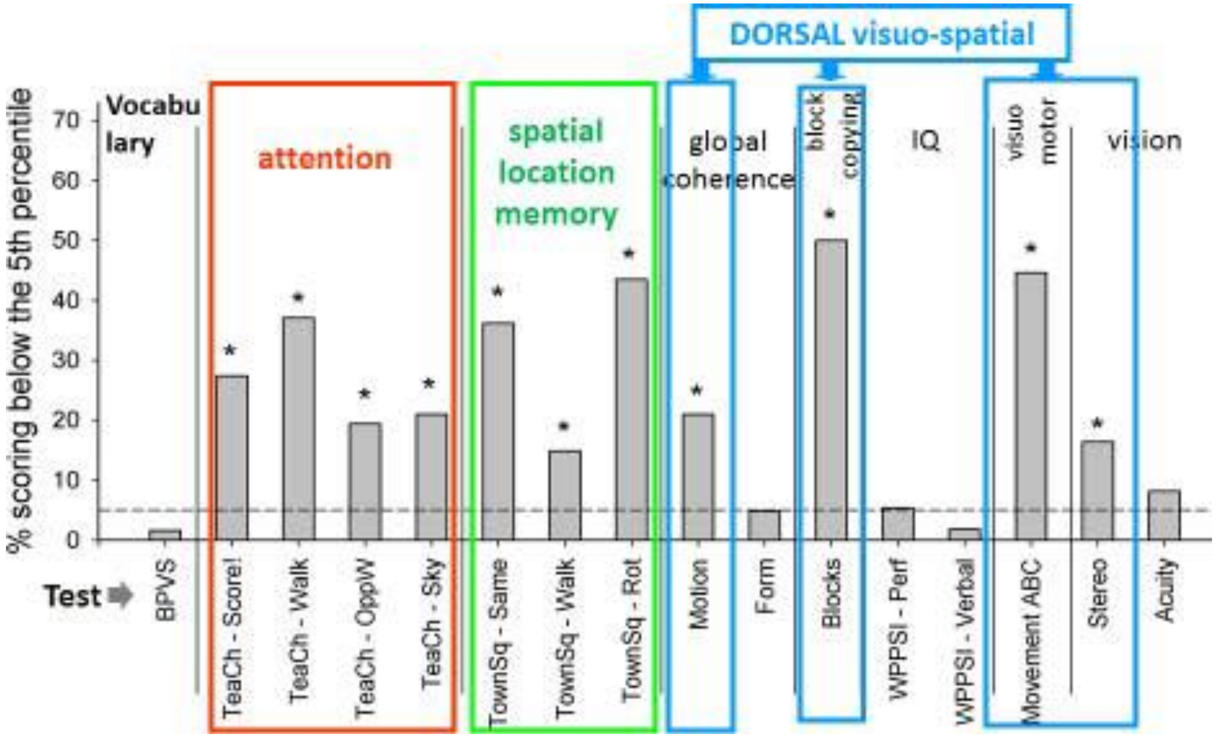
Meyer-Lindenberg et al., *Neuron* 2004(43) 623-631

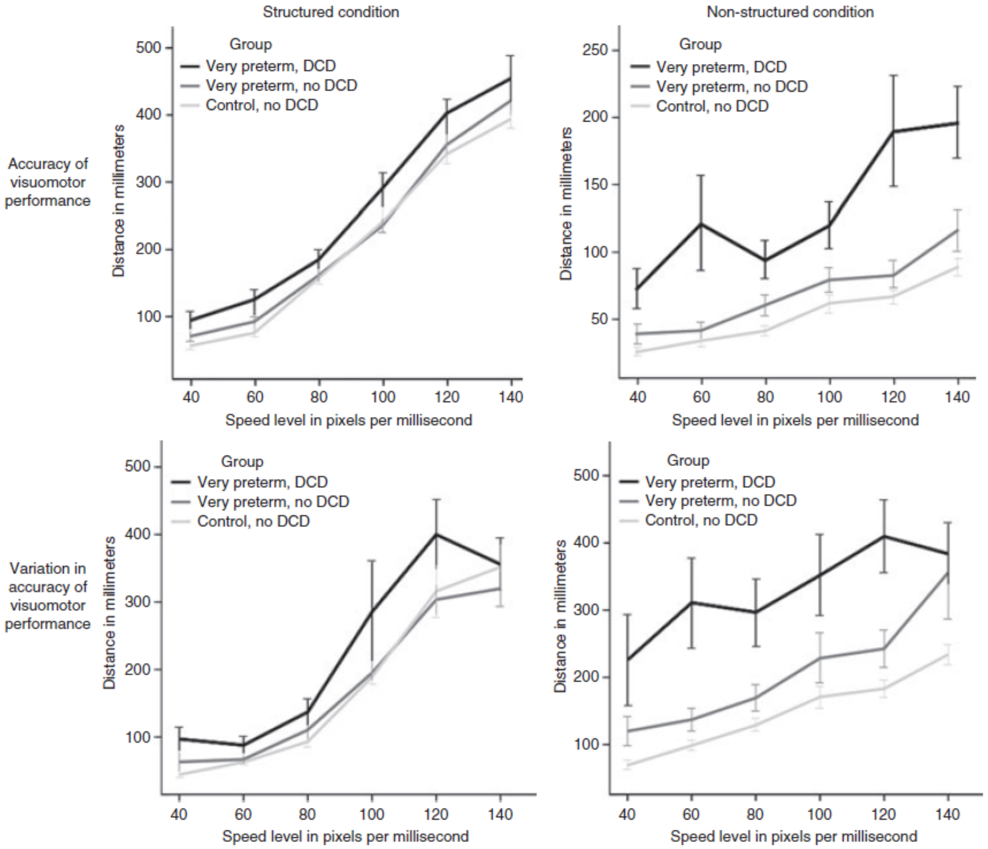
- Fragile X syndrome
- ASD, developmental dyslexia
    - Poor visuo-motor control
- DCD

- amblyopia and deficits in binocularity
    - abnormalities in hand-eye coordination in reaching and grasping for objects
- hyperopic refractive errors in infancy
    - deficits based on the visuo-motor and spatial tasks from the ABCDEFV

Preterm

- Preterm
  - *The preterm-born infants showed similar activation to term-born for the simple VEP pattern-reversal stimulus and for global static form.*
  - *The term-born infants and preterm-born infants, with very mild or normal neonatal MRI findings, showed a greater activation in this VERP response to global motion than that seen for the group of preterm infants with brain injury categorized as "severe" from neonatal MRI.*
  - *the preterm infants categorized as having "mild" or "moderate" perinatal brain injury appeared to show a more immature configuration, compared to term-born infants, in terms of lateralization of the activation, which changes from infancy to adulthood.*
  - *in preterm infants, even those without major brain injury, the development of the dorsal stream underpinning motion coherence sensitivity is already delayed compared to term-born infants.*





Atkinson. *Journal of Vision* (2017) 17(3):26, 1-24

Jorrit F de Kieviet et al., *DMCN* (2013)

Cerebral Palsy

- Visual-perceptual impairment ranged from 40% to 50%
- the mean visual perception quotient from 70 to 90
- None of the studies reported a significant influence of CP subtype, IQ level, side of motor impairment, neuro-ophthalmological outcomes, or seizures.
- The severity of neuroradiological lesions seemed associated with VPI.
- a lower gestational age was more often associated with lower visual motor skills than with decreased visual–perceptual abilities.

Anne Ego et al., Visual–perceptual impairment in children with cerebral palsy: a systematic review. *DMCN* (2015)

Cerebral Palsy

- Periventricular leukomalacia on MRI was found to have a strong association with CVI in all 30 studies.
  - More than half of the children with CP due to white matter damage showed abnormalities of dorsal stream function, namely visual field defects (79 %), impaired ability to perceive motion (79 %), difficulty in navigation (73 %) and difficulty in handling complex visual scenes (61 %).
  - damage typically occurs more often in the white matter adjacent to the posterior parietal cortex than in the occipito-temporal cortex.

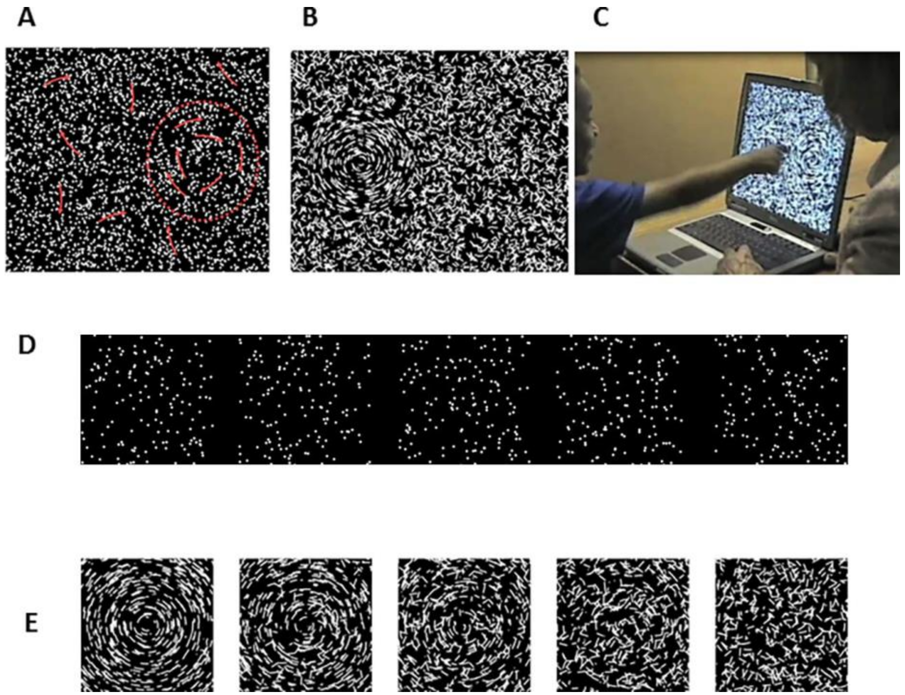
  → as a consequence, the dorsal stream of visual processing tends to be more compromised than the ventral stream
- The overall level of evidence correlating different patterns of CVI and CP (based on GMFCS, motor type and distribution) and MRI was low.

S.S. Philip et al., *Research in Developmental Disabilities* 99 (2020)

Assessment

- Beery VMI-6 (Beery-Buktenica Developmental Test of Visual-Motor Integration, 6^{th} ed) (Beery & Beery, 2010)
- Movement ABC (Movement Assessment Battery for Children) (Henderson & Sugden, 1992)
  - In all four components of this battery—manual dexterity, ball skills, static balance, and dynamic balance
- ABCDEFV battery (Atkinson Battery of Child Development for Examining Functional Vision) (Atkinson et al., 2002)
  - a set of functional visual subtests of sensory, perceptual, and cognitive vision which we had normalized for typically developing children from birth to 5 years of age
- CVI Range (Roman-Lantzy, 2007)
  - Is used to measure visual functioning in children with CVI
- PreViAs (Preverbal Visual Assessment qeustionnaire) (Pueyo et al., 2014)
  - Assessment of visual functions and early detection of abnormal visual behavior in infants aged <24 months

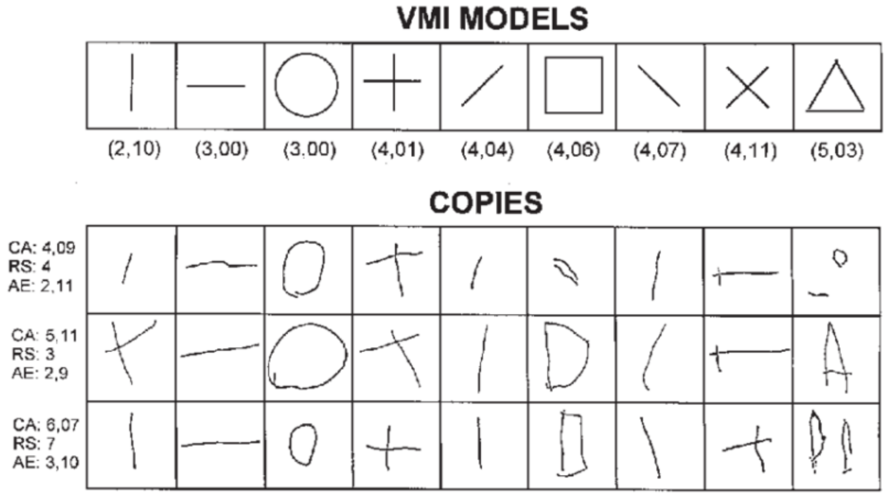
Function	Test	Appropriate age	References
Visual control of bimanual motor planning	Bimanual box test	18 months onwards	Birtles et al. (2011) *[t]*; Birtles et al. (2012) *[p]*; and Braddick and Atkinson (2013) *[t, p]*
Visual planning of manual actions	Atkinson Battery of Child Development for Examining Functional Vision (ABCDEFV) tests—block constructions, shape matching, envelope	1–5 years	Atkinson, Anker, Rae, Hughes et al. (2002) *[t]*; Atkinson et al. (2001) *[ws]*; Atkinson et al. (2007) *[h]*; and Atkinson and Braddick (2007) *[p]*
On-line visual planning of manual actions	Postbox task	> 4 years	Atkinson et al. (1997) [ws]
Planning for end-state comfort	Handle and bar tasks	3 years onwards	Smyth and Mason (1997) *[t,d]*; Newman (2001) *[t,ws]*; Braddick and Atkinson (2013) *[ws]*; and Simermeyer and Ketcham (2015) *[a]*
On-line locomotor planning	Leg kinematics in stair descent	3 years onwards	Cowie, Atkinson, & Braddick (2010) *[t]*; and Cowie et al. (2012) *[ws]*



- Ball in the Grass test

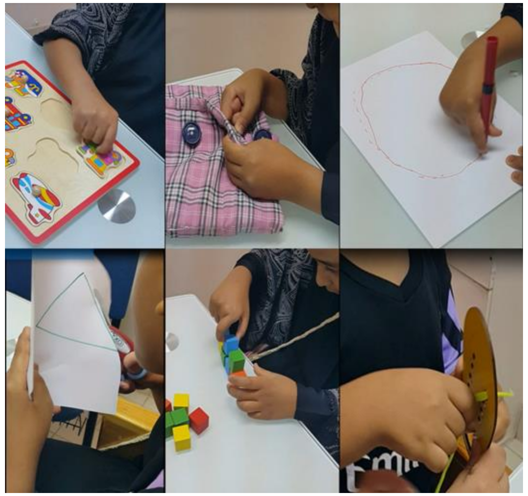
- To measure children's thresholds for global coherence of motion and form

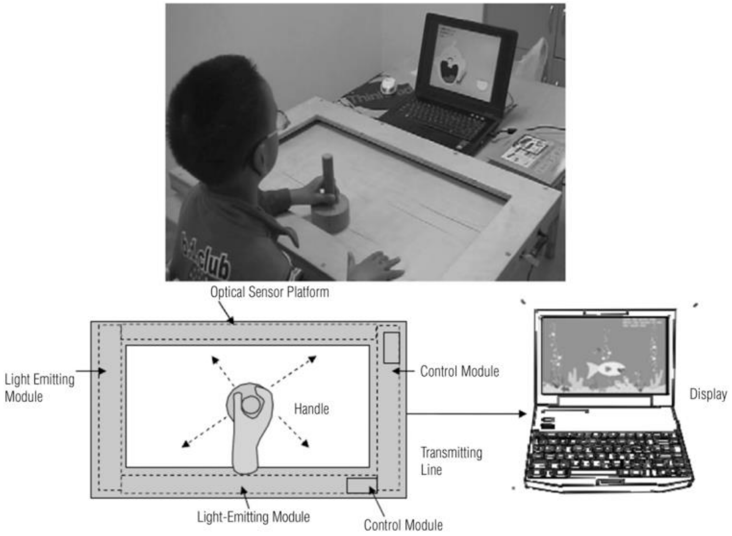
- Beery-Buktenica Developmental Test of Visual Motor Integration (Beery VMI)
  - a pen and paper assessment that requires the patient to imitate and later copy forms of increasing difficulty
    - 시각-운동통합 검사(Visual-Motor Integration Test)
    - 시지각 보충검사(Visual Perception Test)
    - 운동협응 보충검사(Motor Coordination Test)
  - starting at two years of age



Treatment

- Augmented biofeedback with traditional physical therapy significantly improved VMI in spastic hemiplegia compared to control. (Reem M. et al., 2020)
- Visual perceptual intervention had a positive influence on the VMI and ADL performance in children with CP. (Cho et al., 2015)
- An adaptive joystick video game significantly improved on the Beery VMI and the PDMS–2 in children with DD. (Hsieh et al., 2015)





Treatment

감각통합과 감각기반 치료	sensorimotor		-
	classical sensory integration therapy		+
	Interactive Metronome(IM) training		+
발달적 기술기반 프로그램	computerized training	visual-motor coordination of the nonspecific training	+
	fine motor activity	graphomotor intervention program(playful fine motor activity and pencil-and paper activities)	+
		school based occupational therapy	+/-
	Neurodevelopmental approach	facilitation normal postural control and movement synergies	+/-
	perceptual motor approach	fine(cutting, pasting, mazes) and gross motor(jumping jacks, skipping) training	+
부모의 직접적 또는 간접적 접근	sensory diet therapeutic listening	the author gave each family strategies to implement at home	+
	Optometric Vision Therapy(OVT)	program of a visual attention and a visual decision	+
집중행동 치료	modified Constraint-Induced Movement Therapy(CIMT)	restraint of the unaffected upper limb	+

Hong et al., *The Journal of Korean Academy of Sensory Integration* 2010

Treatment

- *Rehabilitation strategies must recognize that 'motor' problems in neurodevelopmental disorders are not purely failures of the motor system, but represent much broader failures to select and attend to the visuospatial cognitive information relevant to a goal, and translate it into appropriate planned sequences of manual actions.*

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With the Love of God, Free Humankind from Disease and Suffering

Thank you for your attention