Cognitive Functioning in Children with Motor Impairments

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Is there a relationship between motor and cognitive ability?

- Two extreme views:
  - Descartes (1596-1650): “Cognitive processes are entirely different from motor processes”
  - Piaget (1896-1980): “Cognitive development relies totally on motor functioning”

(Wassenberg et al., 2005)

Early studies examining the relationship between motor ability and cognition?

- Earlier studies on motor vs cognitive development found:
  - Positive correlation between motor and cognitive development (Wallin, 1916)
  - Correlation between motor skills and language weaker than between motor and intelligence (Faris, 1919)

The Relationship Between Abilities in Children

- 390 children aged between 3 and 12 years
  - 198 girls, 192 boys
- Measured the following:
  - Intelligence (WISC-III) - verbal, performance
  - Language (CELF) - expressive, receptive
  - Motor Coordination (MAND) - fine, gross
  - Attentional Control - Response inhibition, working memory
  - Empathic Ability - Theory of mind, Emotion Recognition, Emotion Understanding

(Dyck et al., 2004)

The Relationship Between Abilities in children

<table>
<thead>
<tr>
<th></th>
<th>IQ</th>
<th>Lang</th>
<th>Motor</th>
<th>Empath</th>
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<td>.22**</td>
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*p<.05, ** p<.01, *** p<.001 (Dyck et al., 2004)

Developmental Differences in the Relationship

- Infancy – Bayleys Scales of Infant Development
  - High correlations between the Mental and Psychomotor measures, particularly at the younger ages
- A strong relationship between motor and language abilities in younger children not observed in older children (Anderson, 1939; Seashore, 1930)
- Very little other research
Are there differences in relationships between abilities as a function of age?

- Based on maturational changes in brain size and structure (e.g., Durston et al., 2001) and on developmental theory (e.g., Piaget, 1976), systematic differences are to be expected.
- We examined 449 children in 4 age bands:
  - 3 – 5 years
  - 6 – 8 years
  - 9 – 11 years
  - 12 – 14 years
- LISREL – revealed that all covariance matrices for each age band differed from each other

Younger Children

<table>
<thead>
<tr>
<th>Children aged 3 to 5 years</th>
<th>PO</th>
<th>VC</th>
<th>ER</th>
<th>EU</th>
<th>ToM</th>
<th>LE</th>
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PO-Perceptual Organization; VC-Verbal Comprehension; ER-Emotion Recognition; EU-Emotion Understanding; ToM-Theory of Mind; LE-Expressive Language; LR-Receptive Language; MCF-Fine Motor; MCG-Gross Motor

Older Children

<table>
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<tr>
<th>Children aged 9 to 11 years</th>
<th>PO</th>
<th>VC</th>
<th>ER</th>
<th>EU</th>
<th>ToM</th>
<th>LE</th>
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<td>.16</td>
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<th>ER</th>
<th>EU</th>
<th>ToM</th>
<th>LE</th>
<th>LR</th>
<th>MCF</th>
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<tr>
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<td>.50**</td>
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</table>

PO-Perceptual Organization; VC-Verbal Comprehension; ER-Emotion Recognition; EU-Emotion Understanding; ToM-Theory of Mind; LE-Expressive Language; LR-Receptive Language; MCF-Fine Motor; MCG-Gross Motor

Results

- At 3-5 years – there was only a single component suggesting performance across domains was largely due to a ‘basic’ ability.
- For all age groups the first component in each analysis is defined by the very high loadings of the receptive/expressive language measures and verbal comprehension.
- When a second component is extracted (for ages 6-8 and 9-11 years), it is clearly defined by the high loadings of the motor scales.
- The motor component is:
  - independent of language in the 6-8 year olds
  - weakly related to it in the 9-11 year olds where it is also defined by the substantial loadings on the perceptual organization and emotion recognition measures
  - not significant in the 12-14 year olds, where it again loads on a single latent variable.

Age needs to be considered

- Although there was a strong relationship between motor and cognitive development in pre-school age children this disappeared at school age.
- Relationships between different domains differ across age cohorts:
  - Implications for children with motor disability?

Comorbidity between Motor Disability and other Disorders

- DCD and ADHD (and Autism) [Gillberg, 1992]
- DCD, ADHD and Learning disorders [Kaplan and colleagues, 1998]
- DCD and all 3 ADHD subtypes [Piek and colleagues, 1999, 2003]
- DCD and language impairment [Hill, 2001]
- Motor, ADHD and autistic symptoms [Reiersen et al., 2008]
- DCD, ADHD, & RD [Sergeant, Piek & Oosterlaan, 2006; Crawford & Dewey, 2008]
Cognitive impairment: Executive functioning

Executive functions - the complex cognitive processes required to perform novel or difficult goal-directed tasks
- the ability to delay or inhibit a particular response
- develop a plan of action sequences
- hold a mental representation of the task through working memory
- Set-shifting fluency

Children with developmental disorders (e.g., ADHD, RD) - consistently score lower on measures of executive functioning

What about executive functioning and motor disability?

Recent Research

- Wassenberg et al (2005) - found no GLOBAL relationship between motor and cognitive performance in 5-6 year olds once cognitive tasks with a motor component were removed. However there was a relationship between specific tasks, namely:
  - Working memory
  - Verbal fluency
  - Visuo-motor integration

- Roebers and Kauer (2009) - examined 7 year olds and found weak but significant relationship between cognitive executive functioning tasks and motor tasks tasks.

Evidence that early motor development predicts cognitive executive functioning tasks

  - Infants with poorer postural control at 6 months had more difficulty with a problem reduction task measured at 6, 12 and 24 months.

- Murray et al. (2006)
  - Found that children who were able to stand earlier than their peers in infancy scored higher on tests of adult categorization and categorization with working memory once they reached 33-35 years of age.

Longitudinal Study

- Hierarchical regression analyses were conducted to investigate the relationship between early motor performance (4 months-4 years) and specific areas of cognitive performance at school age:
  - Once SES was controlled for, the Gross Motor trajectory did not add to the prediction of:
    - Verbal comprehension
    - Perceptual Reasoning
  - But there was a significant finding for:
    - Working Memory (p = .039).
    - Processing Speed (p = .003)

- Piek, Dawson, Smith & Gasson (2008)

Executive Functioning and DCD

- 76 control and 28 children at risk of DCD
- Choice RT measure
- Three measures of EF
  - Goal neglect task – goal-directed planning and working memory
  - Go/No go task – response inhibition
  - Trailmaking/ memory updating – working memory and response inhibition

Results

- DCD group poorer on RT task
  - Consistent with earlier studies (e.g., Piek & Skinner, 1999)
- No evidence of problems with:
  - go/no-go task (response inhibition) or
  - goal neglect task (goal directed planning).
- A weak but significant effect for the trailmaking/memory task (working memory)
  - but only for the timing measure.

Pick et al., 2004
**Study 2: Executive Functioning in children with DCD or ADHD**

**AIM:** To investigate the neuropsychological processes of:
- Response inhibition
- Working memory
- Set-shifting
- Processing speed

in clinical samples of children diagnosed with DCD or ADHD

Piek, Dyck, Francis & Conwell, 2007

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**Participants**

**Age and sex**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
<th>Age Range</th>
<th>Mean Age</th>
<th>SD</th>
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<td>163</td>
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<td>20</td>
<td>6.50-13.08</td>
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<td>22</td>
<td>7.00-14.58</td>
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<td>1.96</td>
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<tr>
<td>ADHD-C</td>
<td>18</td>
<td>6</td>
<td>24</td>
<td>6.90-14.08</td>
<td>10.57</td>
<td>2.00</td>
</tr>
</tbody>
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**Results – Go/no-go task (response inhibition)**

- No difference on the Go-No-Go task for any condition
  - Supports our previous finding for DCD (Piek et al. 2004)
  - Does not support other previous research arguing for a response inhibition deficit in ADHD

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**Results – GNT (Planning and working memory)**

- A significant Group effect
  - F(3,223)=4.844, p=.003
- DCD group performed more poorly than all other groups
- Does not support our previous finding and suggests children with DCD have difficulty with working memory/goal directed planning.

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**Results - TMM (Working Memory)**

- Significant Group effects.
- DCD group performed more poorly than control and ADHD – C on all timing measures.
- Provides support for our previous findings that timing is affected but not ability to accurately perform the task.
- ADHD-C did not perform significantly poorer on ANY task.
- ADHD-PI was not significantly different than the DCD group for the mean of trial 2. But, for the standard deviation on trial 2, like the DCD group, the ADHD-PI group was significantly larger than the control group.
Results – VIT (Set Shifting)

- Significant group effects
- As in other tasks the DCD group was significantly slower than other groups.
- No other significant group differences

Summary

- The poorer timing and variability in children with DCD - linked to the overall timing deficit found in children with DCD.
- This may be associated with their poorer visuo-spatial ability – require longer to process the information initially but can then successfully perform the task (may be linked to Baddeley’s model of working memory – re the ‘visuo-spatial sketchpad’).
- No evidence of EF deficits in children with ADHD-C
- A poorer performance by ADHD-PI in the second trial compared with the first suggests that attention to the task may have been a factor, as would be expected in this group.

Motor ability and Working memory

- Evidence of a link in typical development
- Evidence of a relationship between early motor development and working memory in older children and adults.
- Evidence of deficits in working memory in children with motor disability that cannot be linked with other disorders.
- Other researchers have also identified this link (e.g., Alloway and colleagues, 2007, 2008)
- What is the implication in terms of academic outcomes?

Motor ability and academic achievement

- Examined this relationship in 91 adolescents aged 12-17 years.
- Verbal skills (verbal comprehension, narrative memory) have a significant role in predicting Word Reading, Spelling and Numerical Operations.
- Non-verbal skills (manual dexterity, aiming and catching, balance, perceptual reasoning, arrows, memory for designs) have a significant role in predicting Word Reading and Numerical Operations.
- In particular, ‘aiming and catching’ and ‘perceptual reasoning’ were significant predictors of Word Reading, and particularly Numerical Operations.
- This relationship is now being investigated in relation to Working Memory

Conclusions

- There is a complex relationship between motor and cognitive ability that changes with age.
- The cognitive executive functioning skills, particularly working memory, appear to be related to motor ability and disability.
- Academic abilities, particularly maths skills, are also linked with motor ability.
- We need to understand more fully the interrelationship between movement, academic ability (maths) and executive functioning (working memory).

Acknowledgements

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National Health & Medical Research Council
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Curtin University of Technology
Goal-Neglect Task

Adapted from Duncan, Emslie, & Williams (1996)
Assesses goal-directed planning and working memory.
Task consists of multiple presentations of pairs of numbers or letters on the right and left of a set fixation point on the computer screen.
Children initially requested to verbally identify the stimuli presented on either the left or right of the fixation point.
Switch trials (indicated by a '+' symbol) - start reading stimuli presented on the opposite side of the computer screen.
Stay trials (indicated by a '-' symbol) - continue reading stimuli from the current side.
Six 'stay' and six 'switch' trials are presented during the task, consisting of ten pairs of stimuli, followed by a '+' or '-' symbol, followed by the presentation of three additional pairs of stimuli.
To pass a trial, the participant must identify more stimuli presented on the 'correct' side, both before and after the presentation of the switch/stay symbol, than those on the incorrect side.

Trail-Making/Memory Update

A simplified version of that of Rabbit (1997)
Assesses behavioural inhibition and working memory.
Task consists of the presentation of a 'target set' (i.e., the letters A, B, C, and D), with the actual 'target' presented being an ordered rotation of these four letters (i.e., A presented first, followed by B, then C, then D, then back to A again).
Children differentiate if
- a) the letter presented on the computer screen is a member of the 'target set' (i.e., A, B, C, or D) and
- b) if it is the current 'target' (e.g., 'B' if 'A' has just previously been presented).
Response is pressing the blue button when 'target' stimuli are presented and the red button for all other stimulus presentations.
Two trials comprised of 120 stimulus presentations, including 20 presentations of the 'target' stimuli.
Scores include the mean time (MN), standard deviation (SD) and the number correct out of 20 (NC).

Go/No-Go Task

Assesses simple motor inhibition
modified from the Go/No-Go task of Shue and Douglas (1992)
Letters are designated either as 'go' (respond) or 'no-go' (do not respond) stimuli, and are presented at 1-second intervals.
GO stimulus presented - child is required to press a response key as quickly as possible.
NO-GO stimulus presented - no response is required.
Two trials of the task (GNG1 and GNG2), each consisting of 120 stimuli (60 'go' and 60 'no-go').
Responses to the 'no-go' stimulus - scored as commission errors.
Failures to respond to the 'go' stimulus - scored as omission errors.

Visual Inspection Time Task (VIT)

A line-length discrimination task designed to assess processing speed and set-shifting (Anderson, 1988)
Visual inspection time - the shortest exposure time required by a participant in order to correctly discriminate the stimulus (Jensen, 2000).
The child presses, as quickly as possible, a blue key if two lines are the same length, and presses a red key if they differ in length.
120 stimulus presentations, and two trials (CRT1 and CRT2). The second trial - the set-shift trial where commands are reversed and the child presses blue key if lines and different and red key if they are the same length.
Three scores for each trial:
- VIT,
- the reaction time to correct responses only (RTcr),
- and the reaction time to incorrect responses (RTicr).
Longer latencies are anticipated in the second trial as a result of the 'switch cost' (Collette & van der Linden, 2002).