Food and Cognitive Performance

Louise Dye

Human Appetite Research Unit
Institute of Psychological Sciences
University of Leeds

dl.dye@leeds.ac.uk

Overview

Effects of foods on mental performance

• What foods affect cognition?
• How do foods affect cognition?
  • Direct effects (magic ingredients)
  • Glucose regulation - short term or long term – IGT/T2DM
  • Hormone effects (e.g. Soy isoflavones/fibre)
Areas of Interest

• Effects of macronutrients in adults
  • Healthy young students
• Other meals and other groups
  • Change in pattern of eating – large evening meals
  • Preventing/slowing cognitive decline - elderly
  • Increase in obesity - T2DM – IGT
• Other products
  • Novel ingredients, anti-oxidants, isoflavones, flavonoids, vitamins etc

What is Cognitive Performance?

Perception, understanding & action

Complex tasks – operating machinery, driving, learning, making decisions

Evolved to give us control over the environment

We are all using our cognitive abilities all the time

Louise Dye, HARU, Leeds
The shape of things to come?
Perception – attention (vigilance)
Information processing
Learning & memory
  - acquisition
  - storage & retrieval
  - recall & recognition
Problem solving
Motor control
  - reaction time:
  - tracking

Glucose, GI & cognitive function
Human Brain: energy

- 2% of body mass (~3 Ib)
- 20% energy (glucose and oxygen)
- 2-3,000 pints blood/day pass through the brain

Glucose is main fuel for the brain

Glucose and cognitive demand

Intense cognitive processing leads to increased neural Glucose utilization (decrease in peripheral glucose)

Scholey, Harper and Kennedy, 2001
Glycaemic Index & Cognition

Between subjects design
Biscuits or cereals

High GI Breakfast (65)
• SAG: 0.1; RAG: 42.3

Low GI Breakfast (42)
• SAG: 15.8; RAG: 39.5

Verbal memory

Benton et al., 2002

Validation of interstitial glucose against arterialised venous and capillary samples

Dye et al., (2009)
Cognition & continuous blood glucose

Continuous glucose profiles before and after 5 different breakfasts

<table>
<thead>
<tr>
<th>Time (3 min bins)</th>
<th>CT1</th>
<th>CT2</th>
<th>CT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cereal A
Cereal B
Water
Toast & Yogurt
Cereal C

Later in the morning: Cereal B - better recall relative to baseline than water or Cereal C. Toast/Yoghurt better recall than water or Cereal C.
Acute interventions in young healthy adults

- 31 studies
- 134 cognitive outcome measures
- Manipulations – glucose, macronutrients
- Memory
- High demand situations

- 62 measures showed significant effects

Hoyland et al. (2008)
Delay Memory is most sensitive to glucose manipulations

10 studies - 41 measures

Verbal memory (32 measures)
- Free recall
  - Glucose effect in 10/14
- Cued recall
  - Glucose effect in 7/8
- Word recognition
  - Glucose effect in 4/7

Spatial memory (7 measures)
- Glucose facilitation in 4/7

Conclusions so far........

Glucose doesn’t always improve cognition

Effects –
- not immediate
- apparent when blood glucose levels are similar
- not GI dependent
- Glycaemic response & cascade of events

Hoyland et al. (2008)
Louise Dye, HARU, Leeds
Effects of Meals

Breakfast
Lunch & the Post Lunch Dip

Meals, macronutrients and mental performance

<table>
<thead>
<tr>
<th>Meal</th>
<th>RT</th>
<th>Memory</th>
<th>Attention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adults</td>
<td>*</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Children</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Lunch</td>
<td>***</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Evening</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Meal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dye and Blundell, 2002

Louise Dye, HARU, Leeds
Beat afternoon apathy

A new survey among 1,000 British office workers found that many suffer from "afternoon apathy," a severe after-lunch energy slump that affects brain power, output and memory. PETA BEE investigates

LOUISE A - HGI - CHO

B - LGI - CHO

C - HGI - HP

Effect of high & low GI at lunch on Post Lunch Dip

3 meals
cognitive performance, subjective state & appetite in relation to the post-lunch dip

- A - HGI - CHO
- B - LGI - CHO
- C - HGI - HP

Louise Dye, HARU, Leeds
Blood glucose after each meal does not relate to mental performance.

Blood glucose after HGI & LGI meals alters experience of the Post Lunch Dip.

Mental alertness after HGI-CHO, LGI-CHO & HP meals.

Louise Dye, HARU, Leeds.
Effects in children

Cognition throughout life

- Cognitive development
- Prevention of cognitive aging
- Optimization of cognitive performance

infant  child  adult  elderly
**Nutrition for the Growing Brain**

**Basic needs**

A developing child's brain uses 200-300% more energy than that of an adult.

Nutrition should provide **adequate glucose sources** to meet these high demands.

**Micro-nutrients** such as Iron, Zinc, Iodine and B-vitamins are required for key metabolic and control processes in brain development.

---

**Breakfast and cognition in children**

**Systematic review**

**Two aims:**

- Does breakfast per se confer benefits?
- Is breakfast type important?
- 45 studies

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute effects in well-nourished children</td>
<td>21</td>
</tr>
<tr>
<td>Acute effects in children of differing nutritional status</td>
<td>7</td>
</tr>
<tr>
<td>Long-term effects of school breakfast programs and breakfast clubs</td>
<td>13</td>
</tr>
<tr>
<td>Effects of habitual breakfast intake</td>
<td>4</td>
</tr>
</tbody>
</table>

Louise Dye, HARU, Leeds

Review findings

- Few studies
- Generally +ve effects of BF
- Small effects
- Difficult to determine optimal breakfast

- Most convincing effects for school breakfast programs
  - but these increased school attendance
- More demonstrable in nutritionally vulnerable children

- Predominance of younger samples or large age range
- Poor range of cognitive tests
  - concentration on memory and attention performance


Breakfast vs No Breakfast

- BF vs No BF
- 29 children aged 11-12 years
- IQ controlled for
- Large range of tests (9)

Benefit of BF for psychomotor performance & memory
Higher IQ protective

Dye, Hoyland & Lawton (in prep)
Effects in the elderly

Louise Dye, HARU, Leeds
Epidemiological studies: dietary intake & cognitive function

<table>
<thead>
<tr>
<th>Dietary component</th>
<th>Cognitive impairment risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty Fish</td>
<td>↓</td>
</tr>
<tr>
<td>Omega 3 PUFA</td>
<td>↓</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>↑</td>
</tr>
<tr>
<td>Sat Fat</td>
<td>↑</td>
</tr>
<tr>
<td>Homocysteine</td>
<td>↑</td>
</tr>
</tbody>
</table>

- Rotterdam Study - 45-70 year old (Kalmijn et al., 2004)

Fish consumption is negatively related to the risk of dementia

Fish meals per week

Trend: p<0.01

Cases per 100 person-years

(Barberger-Gateau, 2002)
Mechanism of Action

Ingested Dietary component → Physiological change in central process → Improved Health e.g. Reduced BP, Obesity, improved Glycaemic control → Cognitive Function

Known?
Biomarkers - potential vs known Time course of action Age/gender dependent effects - soy IF

Effects of glucose on cognition in relation to glucose regulation

Epidemiological studies of IGT–clear association with impaired cognitive function (Kalmijn et al., 1995)

Systematic review

NGT – Normal glucose tolerance
- Clear effects on cognition
- Memory – worse specific tests
Only in poor regulators in the normal range

IGT – Impaired glucose tolerance
- Pre Diabetic state – losing regulation
- Unaware, not on treatment
- Middle aged
- Few effects on cognition
- Poor range of insensitive tests (e.g. MMSE)

Louise Dye, HARU, Leeds
Dietary fibre, exercise & cognition in elderly with IGT / T2DM

• 2 year intervention: exercise 2-4/wk + Dietary fibre >30g/day

<table>
<thead>
<tr>
<th></th>
<th>NGT (n=74)</th>
<th>IGT (n=36)</th>
<th>T2DM (n=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPG</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2hr OGTT</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HOMA</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MMSE</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Dementia scale</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Block design</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

Dietary fibre & exercise improved cognitive function via improved glucoregulation

• Yamamoto et al., 2009

Soy - naturally high in fibre

Plant

Produce

Structure

Louise Dye, HARU, Leeds
Habitual Soy consumption & cognitive function

Dementia – lower in Japan
Honolulu Asia Aging Study- cross-sectional
males 71-93yrs
Tofu - poorer cognitive function
1% variance in cognitive function explained

Kame project - longitudinal
• Rate of cognitive decline not related to tofu consumption

SWAN – cross-sectional
IF consumption not correlated with cognitive function

Soy effects

Naturally high in fibre
Effects on satiety
Positive effects of glucoregulation
Effects on symptoms
Effect on cognitive function
Mechanisms:
Phytoestrogens +
High fibre

Effect of IF on Planning Ability

Hill et al., submitted
Novel foods/ingredients

Lots of interest in:
• Blueberries
• Isomaltulose
• Gingko biloba
• Ginseng
• Flavonoids
• Soy
• Curcumin
• Goji berry
• Red wine!!

And many others……….

Blueberry Supplements reverse deleterious effects of ageing on motor behaviour

prevent behavioural deficits in mice
-antioxidant effect
(Joseph et al., 2003)

Reading study - first in humans
Acute - no effects

Louise Dye, HARU, Leeds
Rats are not little humans & humans are not big rats.
A recent Cochrane review does not support a preventive role of n-3 PUFA in cognitive impairment or dementia. "There is no evidence that dietary or supplemental omega 3 polyunsaturated fatty acid (PUFA) reduces the risk of cognitive impairment or dementia in healthy elderly persons without pre-existing dementia."


Future Directions

- Changing nature of diet, health & population
  - Understand effects of altered eating patterns
  - Effects of under & overnutrition
- Cognitive benefits could be conferred directly – specific nutrients or overall intake
- Or via other effects on health e.g. better gluco-regulation, reduced triglycerides or other markers
- Important to preserve cognitive capacity in ageing
Thank You!

BioPsychology Group
Clare Lawton
Alexa Hoyland
Dan Lamport
Fiona Croden
Diana Camidge
Neil Boyle
Iria Myrissa
Claire Hill
Maria Bryant