Memory in infancy

Conflicting views
Deferred imitation procedures have been proposed to tap declarative memory abilities in non-verbal populations such as infants”  
(Jones & Herbert, 2006, p. 195)

“With development of a nonverbal analogue to verbal report, namely deferred imitation, researchers have found evidence of long-term recall well before they [young children] can talk” (Bauer et al., 2003, p. 629).
Memory in infancy
- a controversial issue?

• How do memory skills emerge during the course of human development?
  – Prospective and retrospective memory (do infants think about the past or plan for the future)
• What memory skills exist at birth?
  – A single system or multiple memory systems?
• When can infants remember events and for how long?
• How can we measure memory processes in preverbal infants and be sure that the outcome is comparable with what we know of memory later on in development?
• Debate focuses on early declarative processes, not implicit memory
<table>
<thead>
<tr>
<th>Memory Systems</th>
<th>Associated Theorist(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>imagery/verbal</td>
<td>Paivio 1971</td>
</tr>
<tr>
<td>episodic/semantic</td>
<td>Tulving 1972, 1983; Kinsbourne &amp; Wood 1982</td>
</tr>
<tr>
<td>memory in the wide sense/memory in the narrow sense</td>
<td>McDougall 1923; Piaget &amp; Inhelder 1973</td>
</tr>
<tr>
<td>specific/general memory</td>
<td>Nelson &amp; Brown 1979; Nelson 1984</td>
</tr>
<tr>
<td>sensorimotor/representational (conceptual)</td>
<td>Mandler 1988, 1990</td>
</tr>
<tr>
<td>habit/memory</td>
<td>Hirsh 1974; Bachvalier &amp; Mishkin 1984</td>
</tr>
<tr>
<td>horizontal/vertical</td>
<td>Honig 1978</td>
</tr>
<tr>
<td>associative/abstract/representational</td>
<td>Wickelgren 1979</td>
</tr>
<tr>
<td>knowing how/knowing that</td>
<td>Oakley 1981, 1983</td>
</tr>
<tr>
<td>procedural/declarative</td>
<td>Cohen &amp; Squire 1980; Cohen 1984</td>
</tr>
<tr>
<td>early-developing/late-developing</td>
<td>Squire 1987</td>
</tr>
<tr>
<td>procedural/semantic/episodic</td>
<td>Schacter &amp; Moscovitch-1984</td>
</tr>
<tr>
<td>semantic/cognitive mediational</td>
<td>Tulving 1987</td>
</tr>
<tr>
<td>event memory/knowledge systems/associative memory priming</td>
<td>Warrington &amp; Weiskrantz 1982</td>
</tr>
<tr>
<td>taxon/locale</td>
<td>Weiskrantz 1987</td>
</tr>
<tr>
<td>declarative/nondeclarative</td>
<td>Jacobs &amp; Nadel 1985; Nadel 1992</td>
</tr>
<tr>
<td>procedural/perceptual representation system/semantic/episodic/short-term (working)</td>
<td>Squire 1992a</td>
</tr>
<tr>
<td>Implicit Memory</td>
<td>Explicit Memory</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>phylogenetically primitive</td>
<td>phylogenetically more advanced</td>
</tr>
<tr>
<td>early maturing</td>
<td>late maturing</td>
</tr>
<tr>
<td>spared in amnesia</td>
<td>impaired in amnesia</td>
</tr>
<tr>
<td>unconscious</td>
<td>conscious</td>
</tr>
<tr>
<td>nonepisodic</td>
<td>episodic</td>
</tr>
<tr>
<td>general</td>
<td>highly specific</td>
</tr>
<tr>
<td>abstract</td>
<td>concrete</td>
</tr>
<tr>
<td>automatic</td>
<td>controlled</td>
</tr>
<tr>
<td>involuntary</td>
<td>voluntary</td>
</tr>
<tr>
<td>direct access</td>
<td>indirect access</td>
</tr>
<tr>
<td>fast access</td>
<td>slow access</td>
</tr>
<tr>
<td>all-or-none retrieval</td>
<td>partial retrieval</td>
</tr>
<tr>
<td>no capacity demand</td>
<td>limited capacity</td>
</tr>
<tr>
<td>weighted for object form</td>
<td>weighted for object function</td>
</tr>
<tr>
<td>perceptually-based</td>
<td>conceptually-based</td>
</tr>
<tr>
<td>context-free</td>
<td>context-dependent</td>
</tr>
<tr>
<td>incidental</td>
<td>intentional</td>
</tr>
<tr>
<td>nonassociative</td>
<td>associative</td>
</tr>
<tr>
<td>temporally persistent</td>
<td>time-limited</td>
</tr>
<tr>
<td>inflexible</td>
<td>flexible</td>
</tr>
<tr>
<td>know</td>
<td>remember</td>
</tr>
</tbody>
</table>
One model of major memory systems and major tasks used with infants and children

(Richmond & Nelson, 2007)
Ideas about early memory processes

• Implicit memory present at birth, explicit memory protracted (Schacter & Moscovitch, 1984; 8-10 m)
  – Early system tasks: habituation, novelty preference
  – Late system tasks: object search, DNMS

• Pre-explicit memory capabilities such as deferred imitation and VPC at 8m (based on hippocampal structures) (Nelson, 1995)
DNMS is a research protocol for testing object recognition memory in experimental animals.

The test relies on the innate preference of all animals for novelty and consists of 3 phases:

**SAMPLE** - The subject is shown 2 identical objects.

**DELAY** - …

**CHOICE** - The subject is shown 2 objects, one of which was shown in the sample phase and one of which is novel. The time the subject spends with the new and the old object is recorded.
Ideas about early memory processes
(Rovee-Collier, Hayne & Colombo, 2001)

• No sudden improvement around 8m
• Operant conditioning assumed to be implicit
  – more similar to declarative memory
  – affected by
    • Study time
    • Retention interval
    • Context
• OC, NP and DI are all related to early explicit/declarative memory processes
Declarative memory

- Amnesia filter
  - Temporal lobe amnesia:
    - Fail declarative tasks
    - Pass procedural tasks

- Parameter filter
  - Declarative memory affected by
    - Changes in study time
    - Retention interval
    - Context change

- Key test of episodic memory according to Tulving:
  - Mental time travel
Declarative/explicit memory in infancy?

• Many different methods used to study “explicit” memory processes:
  – Most common:
    • VPC: Visual Paired Comparison/Novelty Preference
    • CRP: Conjugate Reinforcement Paradigm
    • DI: Deferred Imitation
Memory in infancy
- still a controversial issue

• Many different methods used to study “explicit” memory processes:
  – Most common:
    • VPC: Visual Paired Comparison/Novelty Preference
    • CRP: Conjugate Reinforcement Paradigm
    • DI: Deferred Imitation

Despite the fact that all of the methods…are used to measure infant memory, there is often heated debate about the kind of memory that each task measures.
(Hayne, 2004)
(1) VPC [Visual paired comparison] Novelty preference

- Linked to devl of hippocampus
- Similar pattern on key parameters as declarative memory

(Fagan & Detterman, 1992)
Predicts cognitive development

- Birth-weight
- Neonatal optimality
- NP
- Joint attention
- SES

IQ 8 år

10%

56%
(2) Operant conditioning
The conjugate reinforcement paradigm

-Linked to devl of hippocampus
-Similar pattern on key parameters as declarative memory
Deferred imitation

• Why imitation?
  – Tool for overt and covert observational learning for infants (& chimpanzees)

• Criteria for imitation
  – Novel behavior or response changes
  – DI = imitation of novel actions with objects
  – DI of facial im not included
  – Conservative estimate
Deferred imitation

• Two versions:
  – Observation only (Andy Meltzoff)
  – Elicited imitation (Patricia Bauer)
In classic developmental theory deferred imitation (DI) was regarded as a landmark cognitive achievement that emerged during stage 6 of the sensori-motor period, at about 18 months of age, in synchrony with a host of other cognitive and linguistic milestones.
Deferred imitation

• Two versions:
  – Observation only (Andy Meltzoff)
  – Elicited imitation (Patricia Bauer)
Using deferred imitation as a vehicle to explore early memory
14 months: 1 week delay

Table 2
Proportion of Subjects Producing Each Target Act as a Function of the Test Condition

<table>
<thead>
<tr>
<th>Target act</th>
<th>Test condition</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline ((n = 12))</td>
<td>Adult-manipulation ((n = 12))</td>
<td>Imitation ((n = 12))</td>
<td></td>
</tr>
<tr>
<td>Head touching</td>
<td>.000</td>
<td>.000</td>
<td>.667</td>
<td></td>
</tr>
<tr>
<td>Object pulling</td>
<td>.167</td>
<td>.250</td>
<td>.833</td>
<td></td>
</tr>
<tr>
<td>Button pushing</td>
<td>.667</td>
<td>.750</td>
<td>.833</td>
<td></td>
</tr>
<tr>
<td>Egg shaking</td>
<td>.083</td>
<td>.083</td>
<td>.250</td>
<td></td>
</tr>
<tr>
<td>Hinge folding</td>
<td>.333</td>
<td>.417</td>
<td>.750</td>
<td></td>
</tr>
<tr>
<td>Bear dancing</td>
<td>.000</td>
<td>.167</td>
<td>.083</td>
<td></td>
</tr>
</tbody>
</table>

\[ M \] \=.208 \=.278 \=.569

(Meltzoff, 1988a)
9 months: 24 hr

TABLE 3
MEANS AND STANDARD DEVIATIONS OF INFANTS' SCORES AS A FUNCTION OF DELAY AND EXPERIMENTAL CONDITION

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>Immediate</th>
<th>Deferred</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Baseline control</td>
<td>1.00</td>
<td>.74</td>
<td>1.17</td>
</tr>
<tr>
<td>Adult-touching control</td>
<td>.75</td>
<td>.45</td>
<td>.58</td>
</tr>
<tr>
<td>Adult-manipulation control</td>
<td>.50</td>
<td>.52</td>
<td>.83</td>
</tr>
<tr>
<td>Imitation</td>
<td>1.54</td>
<td>.93</td>
<td>1.58</td>
</tr>
</tbody>
</table>

NOTE.—Maximum score = 3.

(Meltzoff, 1988b)
6 months: 24 hrs

(Barr, Dowden & Hayne, 1996)
Deferred imitation at 6 months

Target group

(Heimann & Nilheim, 2004)
Deferred imitation at 6 months

Control group

(Heimann & Nilheim, 2004)
DI at 6 months

Mean target actions

Sweden: 6 months

Norway: 6-8 months

N = 45

N = 21

(e.g. Heimann & Nilheim, 2004)
More robust at 9m?

(Heimann & Meltzoff, 1996)
Deferred imitation at 6, 9 and 14 m

Mean target actions

(e.g. Heimann & Meltzoff, 1996; Heimann & Nilheim, 2004)
Conclusion:
Deferred imitation AwO

- Is observable as early as 6m
- Is well established by 9 m
- Reflects early LTM
- Probably an early explicit memory
  - Non-verbal declarative memory
- A base for cultural learning
DI just not just a "simple memory"

- Memory of specific events
  - Hippocampal structures
  - Dentate gyrus
- Infants must encode not just the object properties but also the actual order in which events occur
  - sequencing behavior
  - a function probably subserved by prefrontal cx
- Must also encode motoric actions performed on the objects
  - mapping of motoric responses
  - Could involve a frontobasal ganglia circuit (+ premotor + occipital)

(Nelson & Webb, 2003; Richmond & Nelson, 2007)
DI and declarative memory

• Many have argued that DI provides a measure of declarative memory due to
  – 1. Amnesia test
  – 2. Encoding
  – 3. Retention
  – 4. Storage
  – 5. Retrieval
1. The amnesia test

And, based on work by McDonough, Mandler, McKee, and Squire (1995) in which adults with bilateral lesions of medial temporal lobe structures (including the hippocampus) performed poorly on this task, Nelson (1995) suggested that this paradigm reflects a form of explicit memory.
2. Encoding

- Older infants encode faster than younger
- VPC: Length of familiarization decreases as a function of age
- DI: 6m olds need a longer demonstration period

(Barr, Dowden & Hayne, 1996; Richmond & Nelson, 2007)
2. Encoding

• Age-related changes might depend upon
  – Changes in speed of processing
  – Attentional style (short vs. long lookers)
• ERP changes in latency to peak amplitude
• Changes explained by rapid myelination?
3. Retention

- Older infants remember longer than younger
- VPC: NP after delay only from 9 months
- DI (equivalent levels of immediate im): 6m olds remember after 24hrs, 12m olds up to one week

(Barr, Dowden & Hayne, 1996; Richmond & Nelson, 2007)
3. Retention

- Im and delayed imitation
- ERP to pictures of novel and familiar sequences
- ERP at delayed recognition (after 1 w) predicted behavioral im after 1 months
- VPC: Length of familiarization decreases as a function of age

(e.g. Bauer et al., 2003)
Long term recall

3- or 4-step sequences with or without initial practice [EI procedure]

(Bauer, 2002)
5. Retrieval

• Infant memory = extremely specific
• 6m: Low generalization
  – Room changes at home ok
• 14m: Home to lab
• DI: Memory affected if tested with different but equivalent prop
• VPC also constrained by retrieval cues

(Barr, Dowden & Hayne, 1996; Hanna & Meltzoff, 1994; Hayne et al., 2000; Richmond & Nelson, 2007)
5. Retrieval

- 6m: mat or cue could change
- 9m: both mat and cue could change
- Lack of hierarchical encoding – infants bind focal cue and context together

(Learmonth, Lamberth & Rovee-Collier, 2004)
Early memory as a marker of cognitive development:

- DI a new tool for assessing early cognitive development
Individual differences
Building a model
Predicting gestures produced at 14 months

(Heimann, Strid, Tjus, Smith, Ulvund & Meltzoff, 2006)
Individual differences
DI and JA collapsed: Low vs. high performance

Results (B): Predicting cognition at 4 years

- Low Recall Memory, 9m
- Low Joint Attention, 14m

Low Cognition, 50m

![Graph showing total score on McCauly vs. groups: Low and High.](image)
Conclusion – if any

• Did DI pass the test?
  – Amnesia filter
  – Parameter filter
  – Mental time travel
• DI = continuously developing skill
• “Rudimentary declarative memory abilities develop early in infancy” – but can we call it episodic?
Studies using the deferred imitation paradigm have revealed continuity in the development of declarative memory over the first two years of life.

(Jones & Herbert, 2006)