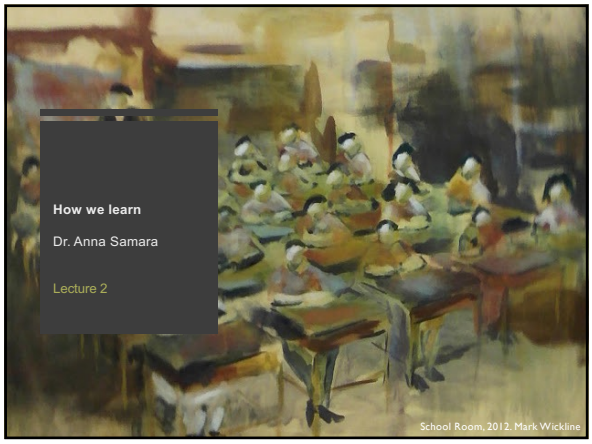

1

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Learning outcomes

- Critically evaluate the Procedural Deficit hypothesis of atypical language development with reference to empirical research
- Define 'memory consolidation' and two of its associated processes (stabilization, enhancement)
- Outline the role of sleep for the consolidation of different types of memories
- Provide research examples that implicate sleep-related memory consolidation processes in language learning

2

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3

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* This is sometimes referred to as SLI in older literature

Procedural Deficit hypothesis (Ullman & Pierpont, 2005)

- Declarative Memory→ vocabulary and semantic knowledge acquisition
- Procedural Memory (PD)→ learning/using rule-governed aspects of language (syntax, morphology and phonology)
- Language difficulties in Developmental Language Disorder* (in particular, grammatical deficits) may be largely explained by Procedural Memory impairments.
  - Severity of PL deficit and whether the declarative system can compensate for learning predicts the extent of difficulties
  - Problems in PL across different modalities affecting both non-verbal/verbal stimuli (Ullman, 2004)

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* This is sometimes referred to as SLI in older literature

Procedural Deficit (PD) hypothesis (Ullman & Pierpont, 2005)

- Conceptually similar framework proposed by Nicolson and Fawcett (2007, 2011) for developmental dyslexia
  - Impaired reading due to a general impairment in the ability to perform skills automatically (thought to be dependent upon the cerebellum)
- At least some research support from case control studies with impaired children and adults (remember, difficulties persist in adulthood)
  - Developmental dyslexia: Howard et al., 2006; Vicari et al., 2005
  - Autism spectrum disorders: e.g., Mostofsky et al., 2000
  - Developmental coordination disorder: e.g., Wilson et al., 2013

5

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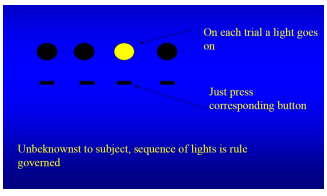
Hsu & Bishop (2014)



Are children with DLD impaired in motor procedural learning task, as predicted by the PD hypothesis?

Serial reaction time task

- Task pioneered by Nissen & Bullemer (1987)
- Pattern phase: repeating sequence of flashing locations
- Random phase: light flashes at random

- In typical populations, decrease in reaction times during pattern phases and a re-bound in RTs when the task proceeds from patterned to random phase

6

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Hsu & Bishop (2014)

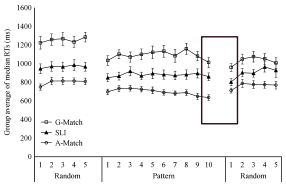

Figure 2 *Group average of median RTs for the three groups in the SRT task. The error bars represent standard errors of the mean.*

- **Participants**
- 7- 11-year- old children with DLD (n = 48)
- Age matched controls (TD group) (n = 20)
- Grammar matched (younger) controls (n= 28)
- Key finding: only the TD group shows the expected rebound in RTs from patterned to random stims
- Impaired procedural learning also reported by Hedenius (2013) and Lum et al. (2010) (see West et al. 2021 for a meta-analysis)

7

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Evaluating the PD hypothesis

- Advantages: **(1)** Draws on evidence from the behavioural, cognitive and brain-based levels of explanation. **(2)** A parsimonious account of multiple developmental disorders?
- Several authors have criticized the theory (e.g., West et al. 2017, 2019; Krishnan & Watkins, 2019) pointing out that the relevant empirical evidence is largely discrepant
  - Methodological issues (typically, learning/memory measured in the lab using few/one task(s)- these often exhibit poor statistical properties such as poor test-retest reliability)
  - Studies with low statistical power are likely to yield false positive results (though note practical difficulties in recruiting large samples)

8

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Sleep maintains memories!

Learning → Consolidation → Recall

process whereby a memory becomes increasingly resistant to interference from competing or disrupting factors through the simple passage of time
(McGaugh, 2000)

9

SLEEP

- A state of reduced consciousness with a lack of response to waking stimuli
- Occurs in mammals, birds, some reptiles and amphibians
- Natural active process that is essential to survival
- Serves a wide range of functions:
  - Biological (e.g. temperature regulation)
  - Emotional regulation

TODAY'S LECTURE: Sleep maintains memory

10

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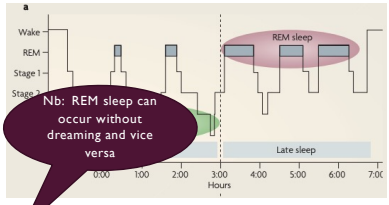
Sleep architecture: The sleep cycle

- Non REM sleep
  - Light sleep stages 1 & 2
  - Slow Wave Sleep (SWS) stages 3 & 4
- REM sleep
  - Dream sleep
  - Muscles paralyzed
  - Light sleep but busy brain: memory consolidation, learning takes place (also, emotion processing, relieving stress)



Nb: REM sleep can occur without dreaming and vice versa

11

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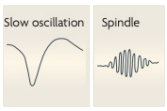
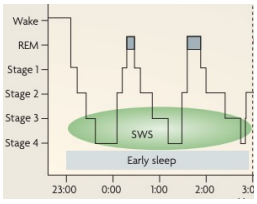
Neurophysiological characteristics of sleep stages

- Specific patterns of oscillatory activity in each sleep stage





Neocortical slow oscillations and thalamic spindles are hallmarks of the EEG during slow-wave sleep

12

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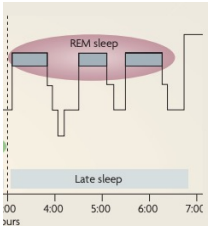
Neurophysiological characteristics of sleep stages

- Specific patterns of oscillatory activity in each sleep stage



- Ponto-geniculo-occipital (PGO) waves:
- propagating activity between three key brain regions, being the Pons, Lateral Geniculate Nucleus and Occipital Cortex.
- Seen in a range of mammalian species during sleep but can also be identified in waking perception and eye movement

13

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How does sleep change memories ?

1. Qualitative changes in memory representations (e.g. higher-order learning, being able to solve a logical problem that one could not solve before sleep)
2. Quantitative changes ('strengthening')
   - Memories may be strengthened through **stabilization** (resistance to interference from a similar task) or **enhancement** (e.g., restoring previously lost memories; producing additional learning without practice)
   - These post-encoding processes seem to be mechanistically distinct (Walker, 2004)
   - Enhancement appears to occur primarily during sleep

14

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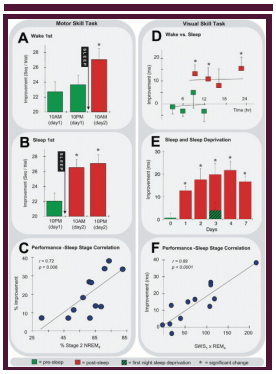
Sleep and declarative memory

- Methods: (1) Different post-training sleep architecture (e.g., amount of REM sleep) following intensive learning practice within a verbal memory task? (2) Learning impairment following sleep deprivation?
- Conflicting evidence regarding sleep's role in declarative memory consolidation, at least in early work (e.g., Meienberg, 1977; De Koninck et al. (1989)
  - Materials: Learning novel word associations between unrelated items (e.g., dog-leaf) or related items (e.g., dog-bone)
  - Task difficulty and emotional salience of material may explain discrepant results (e.g., Wagner et al., 2001; Tilley & Empson 1978)

15



Walker et al. (2003a)

Sleep and procedural memory

- Robust and consistent evidence supporting the link between sleep and procedural memory across domains (visual, auditory, motor)
- No significant learning improvement following 12 hr of wake (green bars), only after a night of sleep (day 2, red bar)
  - NB: Sleep/wake order counterbalanced
- Overnight learning gains correlate with the amount of stage 2 NREM sleep

16

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For a review, see Rasch (2017). Sleep and language learning

Sleep consolidation in language learning?

- The relationship between sleep and memory extends to **language learning**
  - Henderson et al. (2012). 7- 12-year-olds only integrate newly taught nonwords (e.g., biscal) into verbal long-term memory following one night's sleep (rather than exposure after similar time awake) (see also Dumay & Gaskell, 2007 for evidence in adults)
  - Mirković & Gaskell (2016). Sleep implicated in the formation of new arbitrary mappings between forms and meaning (e.g., *mofeem* = ballerina) (declarative learning). No (evidence of) advantagein terms of procedural learning performance
  - Nieuwenhuis et al. (2013). In a two-phase (learning, test) artificial grammar learning task, post-training sleep improves rule-based classification performance in adults

17

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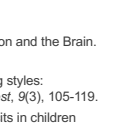
Summing it up and open questions

- Without consolidation, knowledge is bound to be forgotten
- New skill learning/declarative information continues to develop post-training
- Offline processing (i.e., while the learner is not longer directly engaged in the task) may occur both during time spent awake and during sleep
  - Increasing evidence implicated the latter in memory across a range of cognitive domains
  - Finding bear important practical implications though many open questions await investigation
    - Children vs. adults; optimal amount of sleep for improvements etc.

18

Q & A ON PRE-RECODED LECTURE & SEMINAR

- Please go to Menti.com
- The digit code **6626 6325**



19

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Core & recommended reading

- **Core reading**
- Blakemore, S.-J., & Frith, U. (2005). The learning brain: Lessons for education. Blackwell Publishing [chapters 10&11]
- Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron*, *44*(1), 121-133.
- Ullman, M. T., Earle, F. S., Walenski, M., & Janacsek, K. (2020). The neurocognition of developmental disorders of language. *Annual review of psychology*, *71*, 389-417.

20

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Core & recommended reading

- **Additional reading**
- Fletcher, F. E., Knowland, V., Walker, S., Gaskell, M. G., Norbury, C., & Henderson, L. M. (2020). Atypicalities in sleep and semantic consolidation in autism. Developmental science, 23(3), e12906.
- Dehaene, S. (2020). How We Learn: The New Science of Education and the Brain. Penguin Books Ltd. [chapters 1&2]
- Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological science in the public interest*, 9(3), 105-119.
- Hsu & Bishop (2014). Sequence-specific procedural learning deficits in children with specific language impairment. Developmental Science, 17, 352-365.
- West, G., Vadillo, M. A., Shanks, D. R., & Hulme, C. (2017). The procedural learning deficit hypothesis of language learning disorders: We see some problems. Developmental Science, e12552

21