Understanding the Cognitive Processes in Note-taking and the Relationships between Idea Units in Written Notes or Summaries and Brain Connectivity during Reading Comprehension

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Introduction

I will cover 2 lines of research

- First, I will present research my students and I have conducted on the cognitive processes associated with note-taking

- Then, I will present results of a research collaboration with Virginia Berninger and her team at University of Washington (Seattle) on the relationships between idea units in notes or summaries and brain connectivity during Reading comprehension

Why Study the cognitive processes related to note-taking?

1. Perceptions of the Importance of note-taking
2. Frequency of Use
3. Evidence on the relationship of notes to test performance
4. Very limited evidence on the cognitive processes related to skill in note-taking

What Principles Guided our Work?

There are two constants on the development of skill in the execution of basic academic tasks:

1. The simultaneous and effective execution of higher and lower level processes
2. A limited capacity working memory

How did we determine which cognitive processes to study?

Based in research on writing with children especially, we identified the following:

1. Handwriting Speed (Berninger's "alphabet task"; WJ Writing Fluency)
2. Language Ability (Nelson Denny; Main Idea Identification task; listening comprehension measure from the WIAT)
3. Working Memory (Daneman & Carpenter's listening or reading span task; Engle's OSP)

Cognitive processes associated w/ note-taking? (cont.)

4. <u>Attention (Posner)</u>
   a. Executive (Stroop)
   b. Sustained (Lottery subtest of the Test of Everyday Attention)
5. <u>Background Knowledge</u> (history--experimenter constructed measure)
6. Other Processes (SAVC, fine motor fluency, spelling)

Outcome Measures

- Test Outcomes
  - Written Recall
  - Multiple Choice
    - Text Explicit
    - Text Implicit

Typical Method

1. S’s are asked to take notes while watching a pre-record lecture (15-20 20 minutes in length). Notes scored for quantity; quality)
2. Experimental tasks
3. Review of notes
4. Experimental tasks
5. Test(s)

<u>Results</u> from non-intervention studies on College students w/o disabilities)

1. Handwriting only: *Lecture (4 studies) & Text (1) note-taking* w/college students

<u>DV=Notes</u>

- handwriting speed
- Language ability
- Sustained attention
- (How these compare to the survey results)

Results (College students w/o disabilities), Cont.

<u>DV=Written Recall</u>

- Notes

<u>DV=Multiple Choice</u>

- Memory Items
  - Notes
  - language ability
  - background knowledge
- Inference Items
  - background knowledge
  - Language Ability

Results (College students w/o disabilities), Cont.

2. Lecture note-taking w/college students (handwriting vs laptop)

Method

- Essentially the same (with one exception; rewriting their notes during review)

Results (College students w/o disabilities), Cont.

Results

- Comparison of Groups: <u>Note-taking & Note-Review</u>:
  - # of Propositions: laptop > handwriting
  - # of Connections: laptop > handwriting
  - # of Themes: handwriting > laptop

- (Differences significant @.05 but not .006)

Results (College students w/o disabilities), Cont.

- Cognitive Processes Related to Note-taking
  - Letter speed
  - Language comprehension
  - Letter speed X Metacognition (faster letter speed + higher self-reported metacognition = higher note-taking scores)

Results (College students w/o disabilities), Cont.

- Cognitive Processes Related to Review
  - Letter speed X writing medium: (i) faster handwriting was related to <u>higher</u> note-review scores & (ii) Faster typing was related to <u>lower</u> notes review scores

- Cognitive Processes Related to <u>Test Performance</u>: Total Score on Multiple Choice Test
  - Main Effect for Writing Medium: Handwriting > laptop
  - Main Effect of Notes-Review: Higher notes review scores = better performance

Results (College students w/o disabilities), Cont.

- Variables Related to Performance on Memory Items
  - Writing > typing
  - Language comp x writing medium:
    - + relationship between language competence & performance for the handwriting group;
    - - relationship between language competence and performance for typing group

Results (College students w/o disabilities), Cont.

- Cognitive Processes Related to Inference Items
  - Handwriting > typing
  - Significant + main effect for notes review

Results (Students w/ & w/o Disabilities): ADHD

1. Lecture note-taking w/ post-secondary students w/ & w/o ADHD

- IVs: Disability status, handwriting speed (HS), sustained attention (SA), language comprehension (LC)
- DVs: Notes; written recall (WR)

Students with/without ADHD: Results cont.

Group Differences

- S's with ADHD had significantly lower scores on HS and WR

Significant Predictors

- Notes: SA; LC
- WR: Disability status, LC, and Notes

Students with/without ADHD: Results cont.

2. High School S's w/ & w/out ADHD

- IV's; Disability Status, Handwriting speed (HW), Sustained attention (SA), & Listening Comprehension
- DV's: Notes, Performance on Multiple Choice Test (Memory & Inference Questions)

Students with/without ADHD: Results cont.

<u>DV=Notes</u>

- Language ability
- Sustained attention
- Handwriting speed

<u>DV=MC</u>

- Memory Items
  - Notes
  - language ability
- Inference Items:
  - language ability

Students with/without ADHD: Results cont.

3. Lecture note-taking w/high school students w/without LD (1 study).

<u>Differences between Non LD vs. LD on:</u>

- handwriting speed
- background knowledge
- language ability,
- sustained attention
- notes
- MC exam

Results (Cont.)

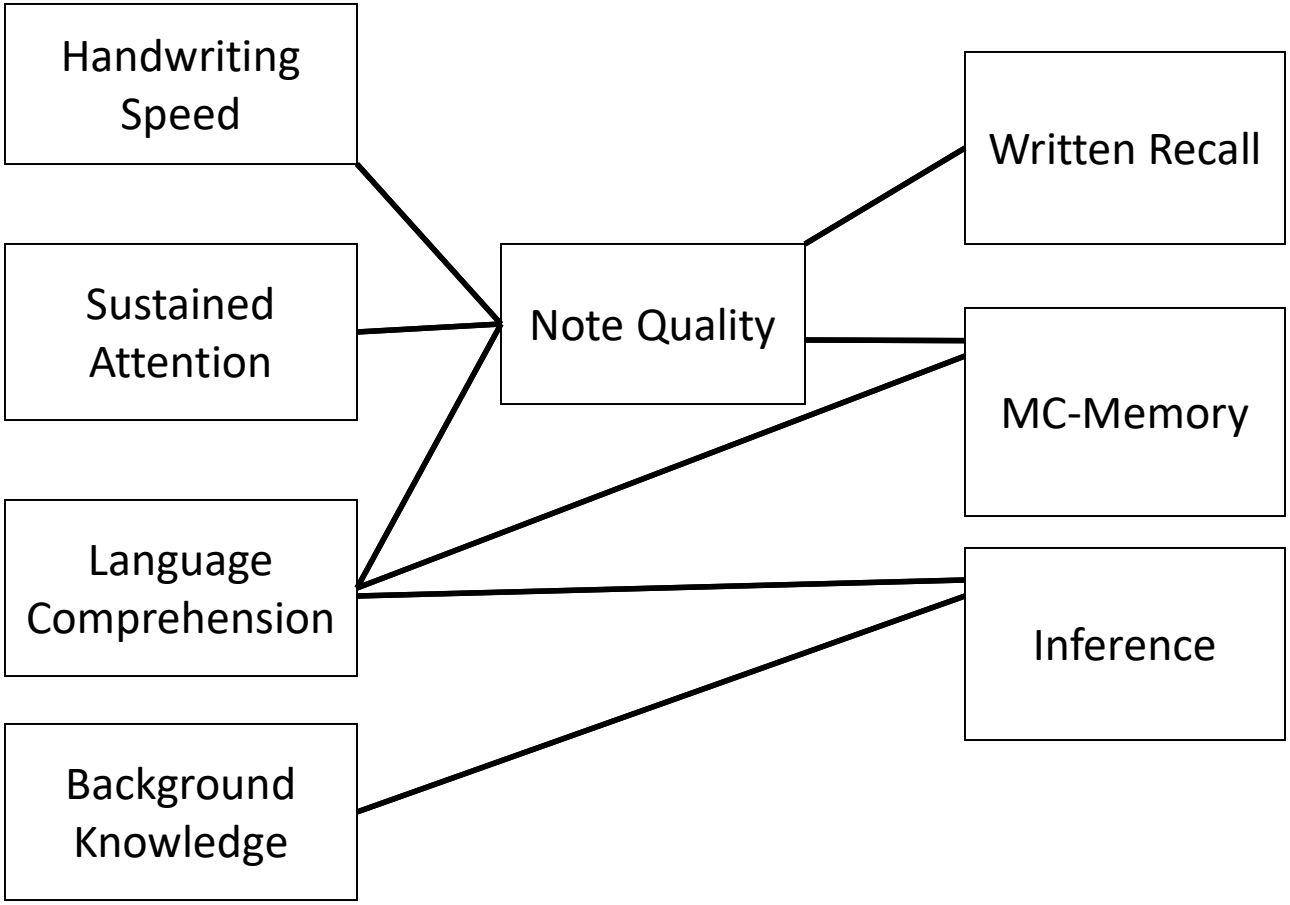
<u>DV=Notes</u>

- LD status

<u>DV=MC</u>

- Memory Items:
  - Notes
  - language ability
- Inference Items:
  - language ability

Summary


Handwriting Speed
Sustained Attention
Language Comprehension
Background Knowledge
Note Quality
Written Recall
MC-Memory
Inference

Other Outcomes in Lecture Note-taking?

1. Gender
2. Handwriting speed
3. Working memory
4. Memory vs inference items

Collaborative Studies with the University of Washington

Study 1 Thompson et al. (2016)

27 students diagnosed with persisting writing disabilities in grades 4 to 9 were randomly assigned to one of two groups for computerized instruction (12 lessons once a week): (a) alternating between using a stylus on iPad screen and hunting and pecking while looking at keys on keyboard, or (b) using a groovy pencil (with grooves providing somatosensory feedback to help with pencil grip) and taught touch typing (looking at screen not keyboard).

Both groups improved on normed measures of handwriting and composing: Writing *PAL Alphabet* from Memory (number of legible letters in first 15 seconds), *DASH Copy Sentence in Best Handwriting*, *PAL Paragraph Copying* (sustained over 30-second, 60-second, and 90-second intervals), and *WJ 3 Writing Fluency* (composing sentences based on 3 provided words for 7 minutes).

For reading source material, both groups wrote more decipherable words in summaries than notes; but for listening to source materials, the group that alternated between groovy pencil and touch typing produced the most decipherable words in written notes.

Thus, for Study 2 groovy pencil was alternated with touch typing.

Collaborative Studies with the University of Washington

Study 1 Thompson et al. (2016)

- Aim—to investigate the relationship between mode of language input (reading; listening) to mode of language output

- Participants: 27 students diagnosed with writing disabilities in grades 4 to 9.

- They were randomly assigned to one of two groups for computerized instruction (12 lessons once a week):
  - Group A alternated between using a stylus on iPad screen and hunting and pecking while looking at keys on keyboard, or

  - Group B used a groovy pencil (with grooves providing somatosensory feedback to help with pencil grip) and taught touch typing (looking at screen not keyboard).

- Outcome measures for all 12 lessons: (a) writing notes from what they read and hear; (b) writing summaries from what they read and heard

Collaborative Studies with the University of Washington

Results

- **Both groups improved on normed measures of handwriting and composing:**
  - Writing *PAL Alphabet* from Memory (number of legible letters in first 15 seconds),
  - *DASH Copy Sentence in Best Handwriting*,
  - *PAL Paragraph Copying* (sustained over 30-second, 60-second, and 90-second intervals),
  - *WJ 3 Writing Fluency* (composing sentences based on 3 provided words for 7 minutes).

- **Reading source material--both groups wrote more decipherable words in summaries than notes;**
- **Listening to source materials, the group that alternated between groovy pencil and touch typing produced the most decipherable words in written notes.**

- **Thus, for Study 2 groovy pencil was alternated with touch typing**

Collaborative Studies with the University of Washington

Study 2 Richards, Peverly et al. (2016)

Aims:

- Continue to explore the effect of strategy instruction of notetaking and summarizing
- To explore changes in brain functioning due to instruction

Participants:

- 7 children (average age 11) diagnosed with writing disabilities (dyslexia—impaired word spelling—or dysgraphia—impaired handwriting), who were right handed, who completed brain imaging before and after participating in computerized writing instruction and had usable brain imaging data for all tasks during scanning.

Collaborative Studies with the University of Washington

Study 2 Richards, Peverly et al. (2016)

Method:

Brain imaging before and after intervention.

Students were taught: (1) touch typing by keyboard on an ipad, & (2) writing on paper with groovy pencil

Students were also taught 12 weekly lessons on : (1): Strategies for Reading Source Material, (2) Strategies for Taking Notes, & (3) Strategies for Writing Summaries

The efficacy of the interventions was tested on: (1) Reading Source Material and Taking Written Notes* & (2) Writing Summaries Based on Notes*

*Alternated across sessions between Writing by Groovy Pencils and by Touch Typing

Collaborative Studies with the University of Washington

Study 2 Richards, Peverly et al. (2016)

Tasks Performed during Brain Imaging:

<u>Single Sentence Comprehension</u>
Press yes if sentence is meaningful. Press no if sentence is not meaningful.

The bee, which buzzes, can sting you. The bee, witch buzzes, can sting you.

<u>Multi-Sentence Comprehension</u>
Press yes if last sentence is true. Press no if last sentence is not true.

1. Tomorrow is the day of the picnic.
2. If it rains, the picnic will be canceled.
3. Amy listens for the weather report.
4. She hopes it will rain.
5. Amy wants to go to the picnic.

Collaborative Studies with the University of Washington

Study 2 Richards, Peverly et al. (2016)

Results for Effects of Instruction: Correlations not significant at time 1 (before instruction) but significant at time 2 (after instruction)

- Between proportion of ideas during note taking by pencil and fMRI brain connectivity for left superior temporal gyrus with left Broca's area, for right tempoparietal region with left Broca's area, and for right precentral gyrus with right Broca's area during single-sentence reading comprehension.

- Between proportion of ideas during note taking by pencil and fMRI brain connectivity for angular gyrus with cingulate gyrus during multi-sentence reading comprehension.

- Between proportion of ideas for summaries by pencil and fMRI brain connectivity for right temporooccipital with left inferior occipital cortex during multi-sentence reading comprehension.

- Between proportion of ideas for touch typing notes and fMRI brain connectivity for left inferior occipital cortex with left fusiform during multi-sentence reading comprehension.

- Between proportion of ideas for touch typing written summaries and fMRI brain connectivity for left inferior occipital cortex with left fusiform during multi-sentence reading comprehension.

Collaborative Studies with the University of Washington

Study 2 Richards, Peverly et al. (2016)

Results for Effects of Instruction: Significant Changes in fMRI brain connectivity from time 1 before instruction to time 2 after instruction

- between right angular gyrus (related to reading) and right Broca's area (related to executive functions for orthographic coding) **during single-sentence reading comprehension**.
- between right angular gyrus (related to reading) and cingulate (related to executive functions for written language) **during multi-sentence reading comprehension**.

Conclusion: Writing instruction and written learning activities can change neural networks in the brain related to reading comprehension.

References for Cognitive Processes in Note-Taking

- Peverly, S. T., Ramaswamy, V., Brown, C., Sumowski, J., Alidoost, M., & Garner, J. (2007). Skill in lecture note-taking: What predicts? *Journal of Educational Psychology*, *99*, 167-180.

- Peverly, S. T., & Sumowski, J. F. (2012). What variables predict quality of text notes and are text notes related to performance on different types of tests? *Applied Cognitive Psychology*, 26: 104–117. DOI: 10.1002/acp.1802.

- Peverly, S. T., Vekaria, P. C., Reddington, L. A. Sumowski, J. F. Johnson, K. R. & Ramsay, C. M. (2013). The Relationship of Handwriting Speed, Working Memory, Language Comprehension and Outlines to Lecture Note-taking and Test-taking among College Students. *Applied Cognitive Psychology, 27,* 115-126. DOI: 10.1002/acp.2881

- Peverly, S. T., Garner, J. K., & Vekaria, P. C. (2014). Both handwriting speed and selective attention are important to lecture note-taking. *Reading and Writing: An Interdisciplinary Journal*, *27*, 1-30. DOI: 10.1007/s11145-013-9431-x

- Reddington, L. A., Peverly, S. T., & Block, C. J. (2015). An examination of some of the cognitive and motivation variables related to gender differences in lecture note-taking. *Reading and Writing: An Interdisciplinary Journal, 28,* 1155-1185. DOI 10.1007/s11145-015-9566-z

- Vekaria, P. C., & Peverly, S. T. (2018). Lecture note-taking in post-secondary students with attention-deficit/ hyperactivity disorder. *Reading and Writing: An Interdisciplinary Journal. 31*, 1551-1573, doi *10.1007/s11145-018-9849-2*

- Oefinger, L. M., & Peverly, S. T. (2020). The lecture note-taking skills of adolescents with and without learning disabilities. *Journal of Learning Disabilities, 53,* 176-188. (Title of Special Issue: The interaction of reading, spelling and handwriting difficulties with writing development). https://doi.org/10.1177%2F0022219419897268

- Kodaira, Y. & Peverly, S. T. (in preparation)

References for UW Collaboration Studies

- Kintsch, W. (1998). Comprehension: A paradigm for cognition. New York: Cambridge University Press.

- Richards, T., Peverly, S., Wolf, A., Abbott, R., Tanimoto, S., Thompson, R., Nagy, W. and Berninger, V. (2016 Sept, October 1; July 22 on line). Idea units in notes and summaries for read texts by keyboard and pencil in middle childhood students with specific learning disabilities: Cognitive and brain findings. *Trends in Neuroscience and Education*., 5, 146-155. doi: 10.1016/j.tine.2016.07.005 Epub 2016 July 21 Pub ID TINE73 http://www.journals.elsevier.com/trends-in-neuroscience-and-education/ Public Access:: PMCID: PMC5261361

- Tanimoto, S., Thompson, R., Berninger, V., Nagy W., & Abbott, R. (2015). Computerized writing and reading instruction for students in grades 4 to 9 with specific learning disabilities affecting written language. *Journal of Computer Assisted Learning, 31,* 671-689. doi: 10.1111/jcal.12110
  Public Access: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4743045

- Thompson, R. , Tanimoto, S, Abbott, R., Nielsen, K., Geselowitz, K., Lyman, R., Habermann, K., Mickail, T., Raskind, M., Peverly, S. Nagy, W., & Berninger, V. (2016, July 19, on line). Relationships between language input and letter output modes in writing notes and summaries for students in grades 4 to 9 with persisting writing disabilities. *Assistive Technology Journal.* DOI: 10.1080/10400435.2016.1199066 Link for on line published paper: http://www.tandfonline.com/doi/full/10.1080/10400435.2016.1199066 NIHMS 846387 Public Access: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5291827

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