leveraging writing analytics for a more personalized view of student performance
a few acknowledgments

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The focus of this webinar is on writing analytics, which involves measurement and analysis of written texts for the purpose of understanding writing processes and products in their educational contexts. This approach is used to gain insights into the writing processes and products in educational contexts. 

Buckingham Shum, Knight, McNamara, Allen, Bektik, & Crossley, 2016
focus of this webinar

Measurement and analysis of written texts

Written texts?
focus of this webinar

Understanding writing **processes** and **products**

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**Your Total Score**

1010 | 400–1600

50th Nationally Representative Sample Percentile

36th SAT User Percentile

**Section Scores**

490 | 200–800

44th Nationally Representative Sample Percentile

31st SAT User Percentile
focus of this webinar

In their **educational contexts**
assumption: the language of others (and our own!) can provide important data about individual differences, performance, learning processes, and other factors important for learning
focus of this webinar

how can writing analytics be used to provide better training and feedback in educational contexts?

Allen, Likens, & McNamara, 2019; McNamara et al., 2018
focus of this webinar

what might the properties of our written discourse reveal about us & our students?

(how can we tap into and leverage these differences to improve educational outcomes?)
outline

- perspectives
  - important properties of writing
- analytics methodologies
  - stealth assessment
  - writing behaviors
- analytics applications
  - writing pal
- future research
  - next steps
  - long-term goals
perspectives
important features of writing that should dictate theory, analytics & practice:

1. Writing is multi-dimensional

2. Writing is dynamic
writing is **multi-dimensional**, constrained by surface and deep levels

(Graesser et al., 2011; Sardinia & Pinto, 2014)

linguistic analyses tend to focus on a single dimension of writing (e.g., words)

attending to the dimensions of writing (and their interactions) can help model its complexities
writing is **dynamic, recursive, self-organizing, and non-linear**
(Beckner et al., 2009; De Bot, 2008; Ellis, 2011; Van Geert, 2008)

traditional models of statistics treat increased variability as source of noise

*structure* of variability can reveal important information about complex processes
analytic methodologies
Writing is **multi-dimensional**

use of Natural Language Processing (NLP) techniques to understand (model) and ultimately improve writing **processes** and **performance**

Bird, Klein, & Loper, 2009;
Crossley, Allen, Kyle, & McNamara, 2014
NLP can help analyze language along a number of linguistic dimensions:

- **Descriptive**
- **Lexical**
- **Cohesion**
- **Semantics**

In fifth grade Officer Brown, my D.A.R.E. instructor, asked any class to draw a picture representing the physical characteristics of a typical drug dealer. I drew an evil looking man with snaky like eyes. He was wearing dark black clothing, and he was standing on a grungy street corner in front of an abandoned warehouse. The purpose of this exercise was to demonstrate that anyone could be a drug dealer. A drug dealer could be a sweet suburban soccer mom who bakes homemade cookies for her children, or a drug dealer could be a drug dealer looking gay wearing a black coat on the street corner. Officer Brown explained that as a society, we tend to associate negative characteristics with drug dealers because the media depicts drug dealers in this manner. As a result, this negative image of drug dealers has been imbedded into our minds at a very young age.

Disney movies have been instrumental in influencing children's views of good versus evil. The movies place great emphasis on the characters' physical appearance. For example, in *The Little Mermaid*, Ariel lives in a well-maintained golden castle. The water is crystal clear. On the floors of the sea, there is green seaweed and bright colored fish. The water surrounding the castle is black, and at other times, the water is dark blue. Arial's cave is dark, and it is full of doing sounds and skeletons. The only form of life near the cave is Arial's assistants, eels. Arial is black with slim like eyes that glow a yellowish-green color. The floor of Arial's cave is not made of grass. Instead the floor is made of dirt and rocks. The entire atmosphere surrounding the castle represents darkness.

In the previous paragraph it was alluded that the use of color also helps distinguish between "good" and "evil" characters involving the "good" characters combined an abundant amount of color. There are mostly bright vibrant colors. Arial is black with slim like eyes that glow a yellowish-green color. The floor of Arial's cave is not made of grass. Instead the floor is made of dirt and rocks. Arial herself is a dark purple, and there are some dark blues and greens. There is also the yellowish-green glow that comes out of the eels' eyes.

Officer Brown was to something when he stated that the media influences our opinion. It may not be obvious to children as they watch *The Little Mermaid* or another Disney movie but that the movie is influencing their opinion. The movie gives children a template to how "good" individuals should look, how they should act, and even what they should possess. Of course, the movies also give children a template on what "good" individuals. The template teaches children that "evil" individuals should look, act, and even what they should possess. For example, in *The Lord of the Rings* the goblins are in a castle, but Arial was not even good enough to have a house. Instead she lived in a castle that was a mixture of dark and light blue stones. Most of the fish in the sea are a mixture of colors. Some are red with yellow fins, purple with yellow fins, blue with red fins, and blue with green fins. Other animals are red and orange. There is also some pink mixed among the animals. The scene involving the "evil" characters lack color almost entirely. The little color that is used is cold and black. The most abundant color representing Arial is black. Arial herself is a dark purple, and there are some dark blues and greens. There is also the yellowish-green glow that comes out of the eels' eyes.

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Louis Althusser coined the term interpellation, the idea that is individuals we tend to accept society's norms as our own. Therefore in the beginning of the paper when I described my picture of a drug dealer in the fifth grade, it could be conjectured that I obtain those images from society, and not from reality. In reality there is no such concept as a "typical" drug dealer. As officer Brown stated, anyone could be a drug dealer.
what can **multi-dimensional**
writing analytics tell us that we
don’t already know?

Some examples...
substantial research in the learning sciences has been devoted to understanding the role of individual differences in performance on discourse comprehension and production tasks. We know that working memory, vocabulary knowledge, domain knowledge are all linked to performance on these tasks (Attali & Powers, 2008; Hoskyn & Swanson, 2003). But how do they influence these processes?
higher vocabulary scores related to generation of text with more complex sentence structures, less familiar words, and greater incidence of words that signal logical connections

Allen, Perret, & McNamara, 2016
These multidimensional analytics provide insights into the processes underlying writing and can be used to inform **stealth assessments** & deliver **personalized feedback**.
students use a variety of strategies to develop coherent representations while learning from text

self-explanation fosters activation of prior knowledge, prompts inference generation, and promotes increased processing of causally relevant information (particularly for expository texts)

How do the properties of students’ constructed responses to text relate to their understanding?
Q: Will self-explanation promote deeper understanding of a complex topic (i.e., natural selection) compared to thinking-aloud or re-reading?

Participants in the self-explanation condition outperformed both the think-aloud and rereading conditions.

F = 43.17, p < .001
To understand whether self-explanation instructions prompted participants to generate different forms of connections, we can analyze the linguistic features of the responses.

The way individuals are making connections across a text can provide important information about successful discourse processing strategies.

Allen, McNamara, & McCrudden, 2015; McCrudden, Allen, & McNamara, 2018
we can examine these different connection types through **cohesion** analyses

**referential cohesion**

explicit overlap at the noun level across sentences
e.g., *Jane* went to the store to buy a *sandwich*. The *sandwich* tasted very good to *Jane*.

**semantic cohesion**

semantic overlap of concepts across sentences
e.g., *The dog* caught the frisbee. *The animals* enjoyed playing at the park.

Allen et al., 2016; Creer et al., 2019
Do these beneficial self-explanation processes manifest in the cohesion of students’ responses to the text they are given to read?

Allen, McNamara, & McCrudden, 2015; McCrudden, Allen, & McNamara, 2018
Q: Do these beneficial self-explanation processes manifest in the cohesion of individuals’ responses to the text they read?

- Cohesion was predictive of condition (p < .001)
- Classified 69.1% of individuals’ experimental conditions based on the cohesion of text responses

Allen, McNamara, & McCrudden, 2015; McCrudden, Allen, & McNamara, in prep
Cohesion indices significantly correlated with scores on the natural selection knowledge test \((r = .36, p < .01)\)
Self-explanation led to increased knowledge of natural selection compared to thinking-aloud or re-reading.

**writing analytics** can be used to model comprehension processes and can be leveraged to provide automated feedback to students on their reading behaviors.

Further research has replicated these findings and extended it to other contexts, including **multiple document comprehension** and **peer** explanation.

Creer & Allen, in prep; Allen, McCarthy, & McNamara, in prep
We have identified a number of linguistic features that model students’ comprehension processes through their verbal protocols as well as the ways in which the verbal protocols change over time. These features include cohesion, syntax, lexical sophistication, and semantics.
dynamics

writing is dynamic

Can use dynamic modeling techniques to analyze the time-varying properties of discourse processes

Orsucci et al., 2000; Simon, 1990
Recurrence Quantification Analysis
Maps time series against itself on x- and y-axes to uncover states and sequences that recur over time

Provides means to **visualize** and **quantify** recurrent patterns in continuous or categorical time series

So how does it work?

Offers potential to develop deeper understanding of the ways in which comprehension processes unfold over time

Allen et al., 2017; Likens, Allen, & McNamara, 2018
dynamics

Conversion

Convert transcripts or texts to sequence of numeric identifiers

“The ice cream man brought ice cream on Friday.”

The = 1; ice = 2; cream = 3…

1, 2, 3, 4, 5, 2, 3, 6, 7

Level of analysis here: words
“The ice cream man brought ice cream on Friday.”
“The ice cream man brought ice cream on Friday.”
“The ice cream man brought ice cream on Friday.”
“The ice cream man brought ice cream on Friday.”
“The ice cream man brought ice cream on Friday.”
dynamics

Recurrence Quantification Analysis

- Entropy
- Determinism
- Maximum Line Length
- Average Line Length
- Recurrence Rate
RQA metrics account for 38% of variance in individuals’ deep comprehension of text material

Allen et al., 2017; Allen, Likens, McCarthy, & McNamara, under review
Dynamical methodologies such as recurrence quantification analysis allow us to model the time-sensitive properties of writing.

**Categorical Data**
- e.g., words, topics

**Continuous Data**
- e.g., keystrokes, dyads, physiological data

Allen, Likens, & McNamara, 2017; Likens, Allen, & McNamara, 2018; Wallot, 2017
individuals engage in complex behaviors while producing writing (e.g., editing behaviors, production, etc).

Keystroke analyses can provide important information about how writing is produced over time — rather than solely focusing on the final product.

How do individuals’ typing behaviors relate to the quality of their writing?
Keystroke Dynamics

Patterns of keystroke behaviors account for 43% of variance in essay scores.

Allen, Likens, & McNamara, in prep; Likens, Allen, & McNamara, 2017
More Keystroke Dynamics

Recent research has used keystroke behaviors to predict **clusters** of writers based on linguistic properties of essays.

Identified **four clusters** of source-based writers:

- Academic/Argumentative
- Descriptive
- Story Tellers
- Summarizers

**Basic Keystroke behaviors** classify participants into clusters with 78% accuracy.
analytics applications
Multi-dimensional and dynamic writing analytics can provide new insights into the psychological processes involved in discourse processing.

Research on discourse processes can be leveraged to develop educational interventions and technologies.
Expert Human Tutors

Provide interactive and adaptive scaffolding to support effective learning

Intelligent Tutoring Systems

Mimic (or improve upon) human tutoring tactics to support learning

Can be as effective as human tutors

VanLehn, 2006; 2011
Immediate, corrective feedback, scaffolding, and strategies

Adaptive and Individualized
• inner and outer loops
• knowledge tracing, student tracing
• respond to student responses

Well-defined Learning Domains
• grounded in clear procedures
• rely on simple, repeated assessments

Nkambou, Bourdeau, & Mizoguchi, 2010; VanLehn, 2006; 2011
Writing ITS

Language Factors
- Subjectivity
- Humor
- Dialect

System Adaptivity
- Individual differences
- Performance
- Affective States
- Metacognitive Accuracy

Feedback
- Summative assessment
- Formative feedback
- Suggested activities

Roscoe et al., 2013
Writing Pal: Intelligent Tutoring System designed to support adolescent writing proficiency via strategy instruction, educational games, and automated summative and formative feedback.
Psychology encompasses many specializations and these areas that have been extensively studied by today’s clinical practitioners are called clinical psychology. Although these practices used together they stress different ways of looking at the psychology of a person. Behaviorism was the dominant movement in the United States during the first half of the 20th century. Behaviorism psychologists primarily emphasized the study of observable behavior and stimuli. Psychologists prior to behaviorism stressed more internal processes that were subjective and therefore the data analysis to resolve bias and validity issues. Behaviorists argued their way was superior to the methodological approach, unlike previous studies behavioral psychologists used operational definitions in order to more objectively test the results of behavior.

**Essay Writing Feedback Report**

- **LENGTH**: Acceptable
- **RELEVANCE**: Acceptable
- **STRUCTURE**: Acceptable

**CONCLUSION BUILDING**

Persuasive essays contain conclusion paragraphs that summarize the main points in the essay. Providing a concluding phrase in the conclusion paragraph signals your reader that your essay is coming to an end.

- Concluding phrases are a great way to begin your conclusion paragraph and to introduce your restate thesis.
- Concluding sentences should clearly tell your reader that your essay is coming to a close.
- Some examples of concluding phrases are: "In conclusion," "In summary," or "As we have seen.

**INTRODUCTION BUILDING**

High scoring essays contain both thesis statements and argument previews in their introduction paragraphs. These components introduce the reader to the main idea and help them understand the "big picture" of the essay.

- A clear thesis statement combined with an argument preview will help guide the structure and coherence of an essay.
- Example: I think that writing a thesis statement along with an argument preview is useful to readers.
- The combination of these two strategies is important, because it shows your reader where you are going, relates your ideas directly to the prompt, and gives an outline of the structure for your essay.

**CONCLUSION BUILDING**

An effective conclusion ties together all of the ideas presented in the body paragraphs of the essay. One way to improve your essay is to make sure that
Goal: Examine efficacy of W-Pal to improve the writing skills and monitoring accuracy of its users

High school students (n = 86) participated in summer workshop program

Writing Pal essay practice with automated feedback
- write and revise 16 essays
- typical of current writing tools (e.g., Criterion)

Learning with complete Writing Pal system
- write and revise fewer (8) essays
- strategy instruction and game-based practice
Students tended to overestimate their essay ratings (M = 3.75; SD = 0.89) relative to W-Pal (M = 2.36; SD = 0.91); t (84) = 11.36, p < .001.

Essay scores increased (p = .01), whereas self-assessment (p<.001) and misalignment scores (p =.01 decreased).

No significant effect nor interaction.

Allen, Crossley, Snow, Jacovina, & McNamara, 2015
findings

students able to learn from W-Pal
  writing performance
  monitoring accuracy

strategy instruction and practice led to equivalent gains compared to heavier doses of deliberate writing practice with feedback

computer-based writing instruction can promote better monitoring accuracy— an important element of transfer

Allen et al., 2014; Crossley, Allen, Roscoe, & McNamara, 2013; Roscoe, Allen, et al., 2013
future
How can computational linguistic analyses be used to provide better training and feedback in the classroom?

Allen, under review; Creer, Oncel, & Allen, in prep
future

how can you apply writing analytics to your own research?

do you have data that is linguistic in nature?

how might this data provide new information about the students?

could you use what you learn to drive feedback or adaptivity in a system?
Consider your data sources
(short statements, essays, etc.)
(individual differences, performance metrics)

Formulate your research question
what do you want to learn about the learning process from this data?

Develop an analysis plan based on your data type and research question
what techniques or tools do you want to use to analyze the language in your data?

There are a variety of tools and packages available to help you answer your questions
There are a variety of tools and packages available to help you answer your questions.
The Development of the Writing Assessment Tool

Provides **students**, **teachers**, and **researchers** access to automated writing analytics for summarization, persuasive essays, and source-based writing assignments

with Danielle McNamara and Scott Crossley
development of writing analytics points to potential areas for **improving** processing and production of discourse
thank you

Danielle McNamara
Katie McCarthy
Aaron Likens
Simon Buckingham Shum
Simon Knight
Puren Oncel
Sarah Creer
Caitlin Mills
Scott Crossley
questions?

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p.s. I am currently recruiting graduate students for Fall 2020
additional information

- Link to Linguistic Analysis Tools
- To sign up to test WAT
  Email me @ Laura.Allen@unh.edu