The Development of Individual Characteristics in Handwriting

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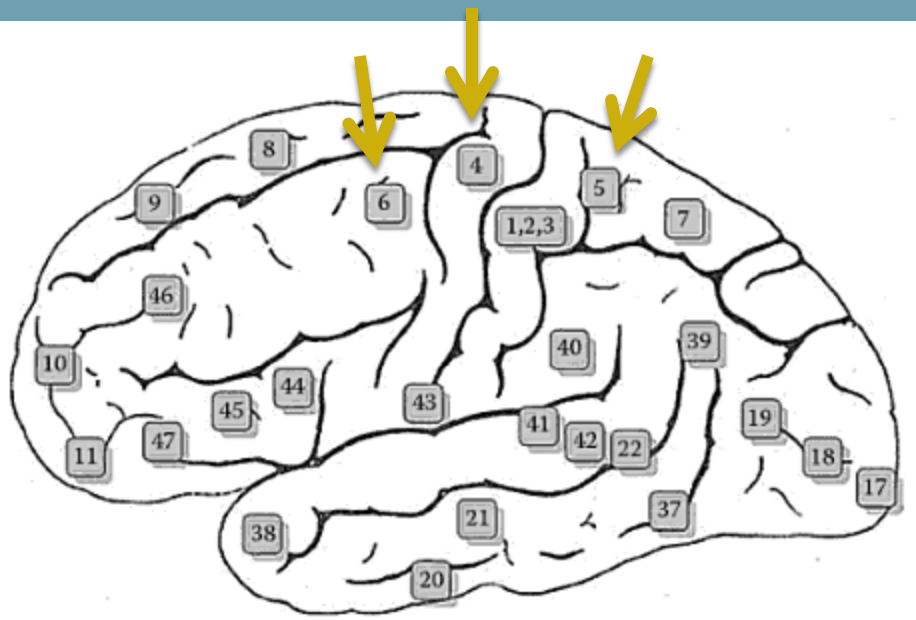
- Does involve ongoing research (preliminary) data.

Handwriting Control

- Three regions play roles in handwriting (Caliguiri, 2012)
  - Primary motor area
    - Control over fine movement
  - Pre-motor area
    - Thought to control visual guidance
  - Supplementary area
    - Regulates muscle firing and the sequences of the firing



There are several stages involved with *Writing Development*

- Pre-conventional – Pretending to write and draw pictures
- Emergent – Beginning to write letter formations
- Developing – Write "sound" words; e.g. MI CT RNS (my cat runs)
- Beginning – The copybook phase; spelling is not important
- Expanding – Students begin to forget about the writing process and instead about the information

(Hill, B.C. & Ruptic , C.A, 1994)

Handwriting at a Young Age

- Brain is developing during preadolescent years (Giedd et al, 1999)

- Young writers begin to think more about the topic, less about how they were taught to write therefore leading to the development of one's own writing style
  - Brain starts visualizing what writing should look like, repeated (Huber, 1999)

- One general statement often made by Handwriting Examiners:
  - As students stray from the copy book style they are taught, individual hand writing habits begin to develop
    - However, this particular statement has not been backed by extensive scientific validation

* Ongoing Study

Development of Individual Handwriting Characteristics in ~ 1800 Students: Statistical Analysis and Likelihood Ratios that Emerge over an Extended Period of Time

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Award : #2010-DN-BX-K212

Minnesota BCA Bureau of Criminal Apprehension

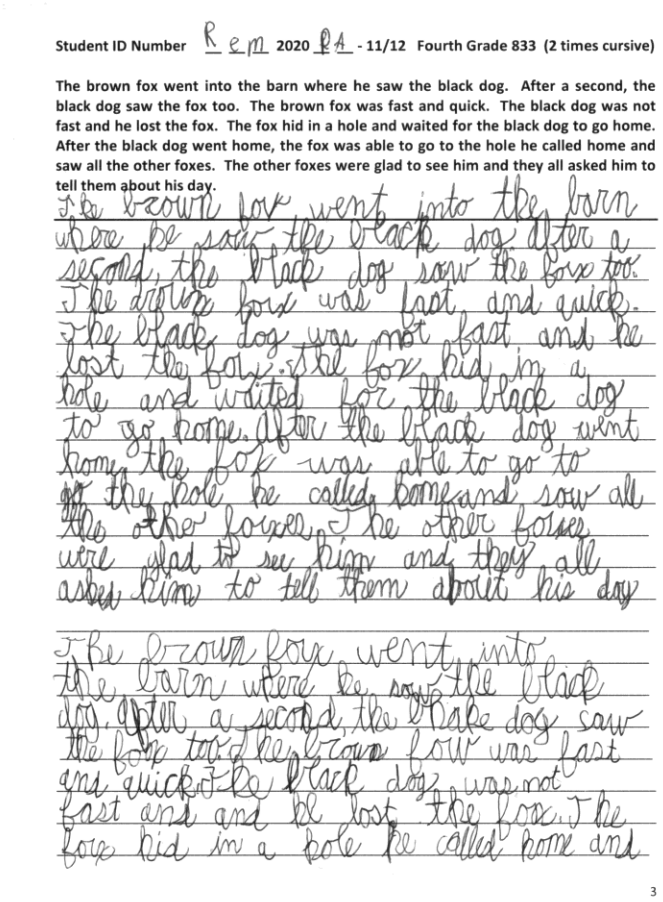
NIJ National Institute of Justice

Introduction

- Purpose of this study: Measure the physical features of individual characteristics as they develop in grade school children's writing
  - Requests have been made for this type of research by National Academy of Sciences
    - Help validate the reliability and accuracy of examinations
    - Gather data to support why handwriting comparisons are possible
- Hypothesis: As a student quits copying the copybook, they begin to develop their own individual handwriting characteristics

Sample Example

- Cursive



Student ID Number R e m 2020 P A - 11/12 Fourth Grade 833 (2 times cursive)

The brown fox went into the barn where he saw the black dog. After a second, the black dog saw the fox too. The brown fox was fast and quick. The black dog was not fast and he lost the fox. The fox hid in a hole and waited for the black dog to go home. After the black dog went home, the fox was able to go to the hole he called home and saw all the other foxes. The other foxes were glad to see him and they all asked him to tell them about his day.

The brown fox went into the barn where he saw the black dog. After a second, the black dog saw the fox too. The brown fox was fast and quick. The black dog was not fast and he lost the fox. The fox hid in a hole and waited for the black dog to go home. After the black dog went home, the fox was able to go to the hole he called home and saw all the other foxes. The other foxes were glad to see him and they all asked him to tell them about his day

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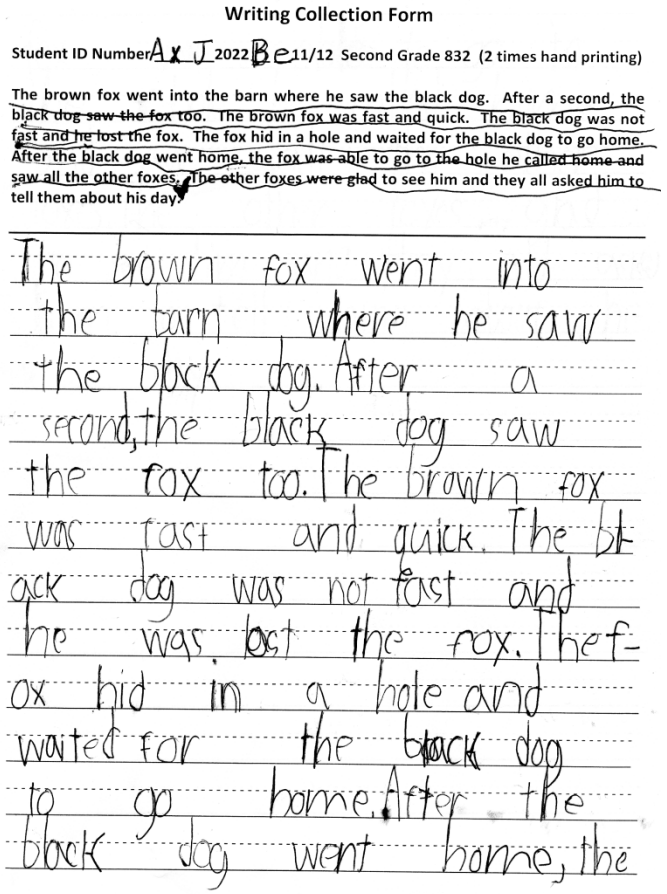
3

- Printed



Writing Collection Form

Student ID Number A x J 2022 B e 11/12 Second Grade 832 (2 times hand printing)

The brown fox went into the barn where he saw the black dog. After a second, the black dog saw the fox too. The brown fox was fast and quick. The black dog was not fast and he lost the fox. The fox hid in a hole and waited for the black dog to go home. After the black dog went home, the fox was able to go to the hole he called home and saw all the other foxes. The other foxes were glad to see him and they all asked him to tell them about his day.

The brown fox went into the barn where he saw the black dog. After a second, the black dog saw the fox too. The brown fox was fast and quick. The black dog was not fast and he lost the fox. The fox hid in a hole and waited for the black dog to go home. After the black dog went home, the

Method

- Subject size actually 2200+ students from 2 suburban MN school districts (Suburban schools were chosen to keep the "move in/move out" ratio low and data numbers high from year to year)
  - Started with 2nd, 3rd and 4th grade students
  - Second year includes 3rd, 4th and 5th grade students and so on …
  - Collection of samples every spring for 3 years (to begin with)
  - Each student is assigned an ID number so student's are protected (as per IRB requirements)

- Students are asked to produce 4 writing samples each
  - 2 request cursive paragraphs
  - 2 request printed paragraphs

The samples collected last year are from the last 2nd graders who will be taught cursive writing!

Method

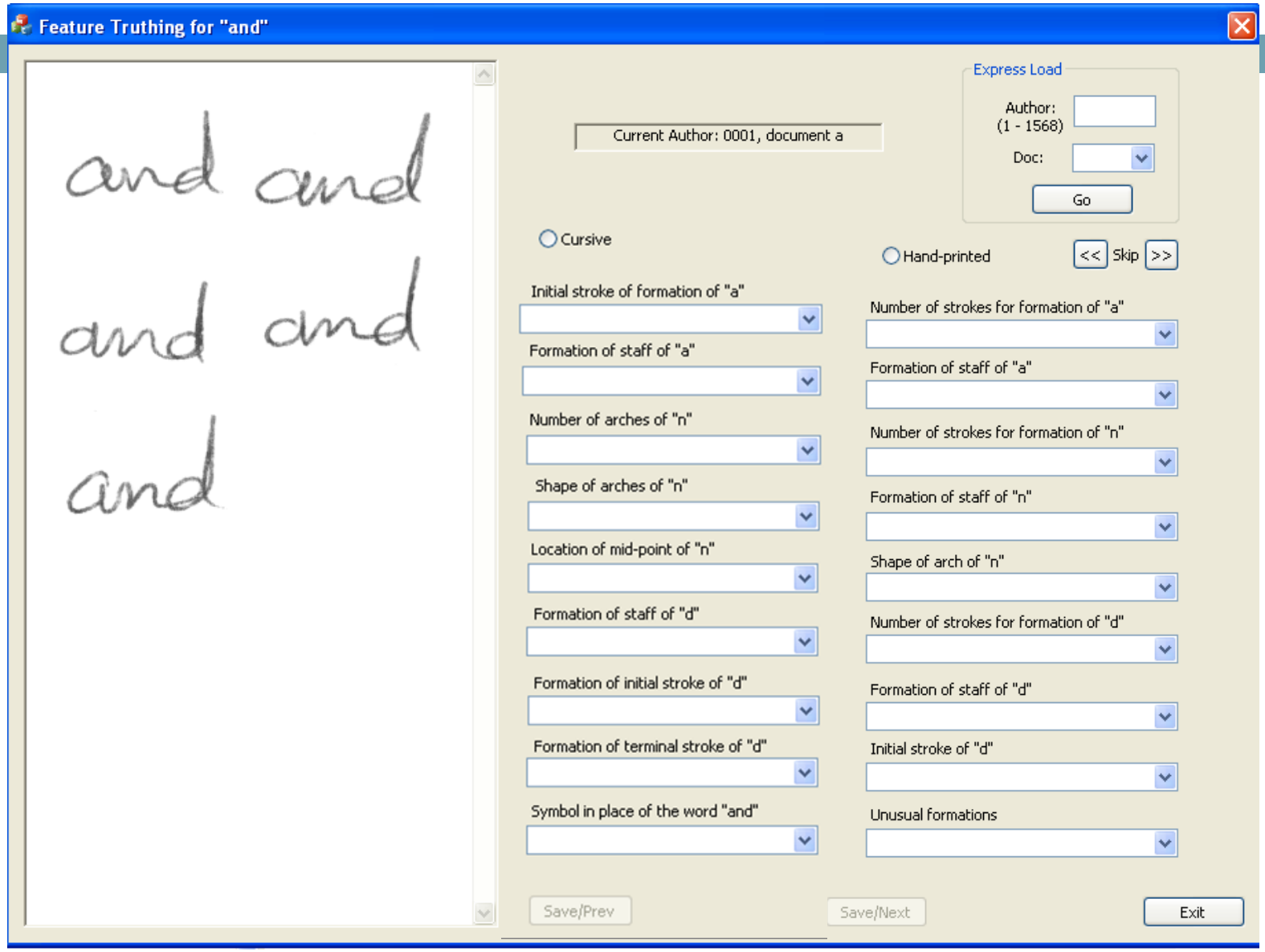
- The same requested paragraph will be collected each year from the same 2200+ students
  - Samples will be compared to other writers in the same grade, as well as to their own writing from the previous year(s)
- Every digitized sample will be examined using i-FOX software
- Additional data mining will be continued into the future of the many words that were intentionally repeated within the *Request Paragraph*

Process

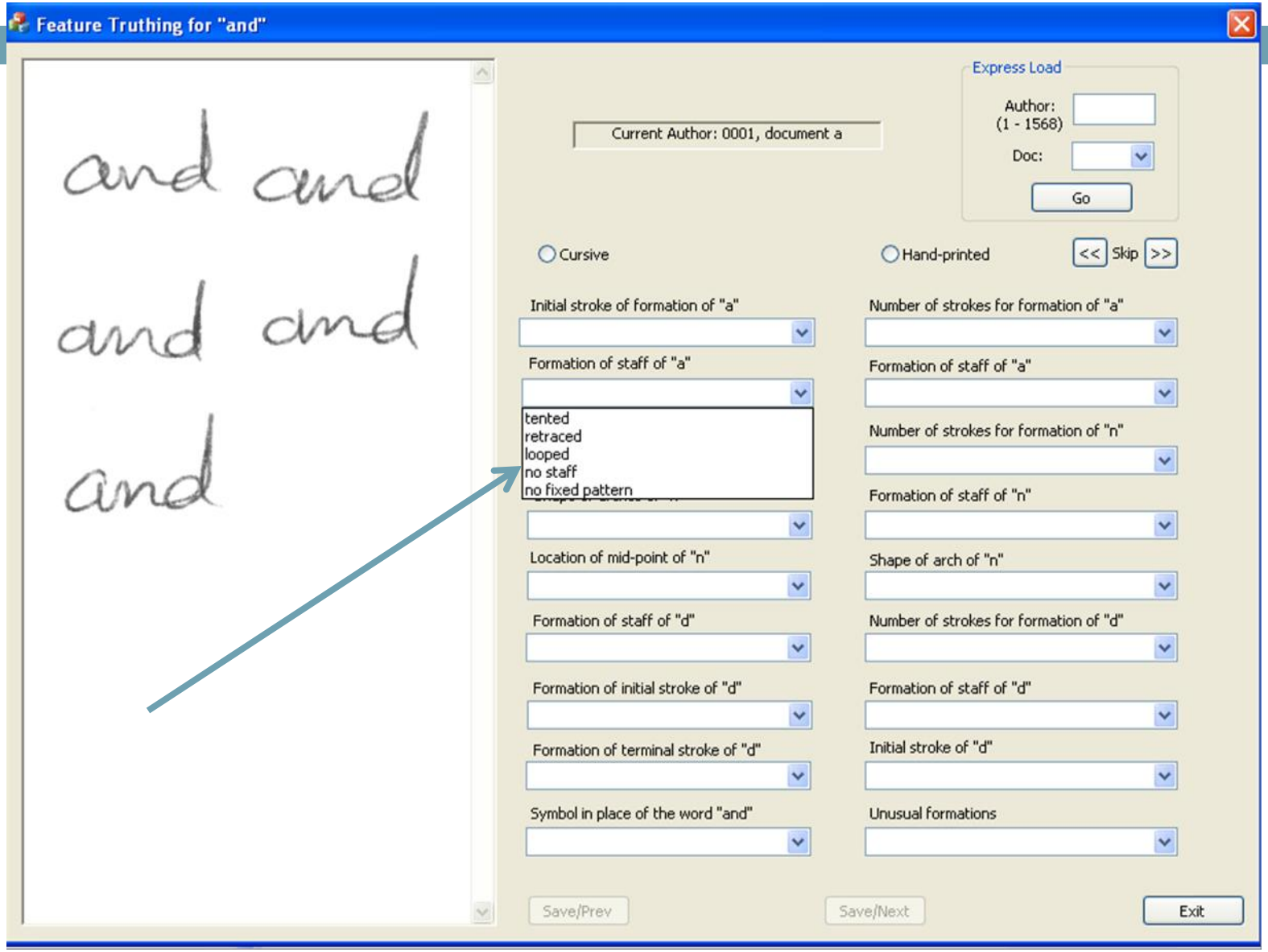
- Process:
  - Digitize the samples and prepare them for the analysis program
  - Analyze the samples from students from 6 schools;

- Start out by analyzing 2nd, 3rd and 4th grader's writing using the word "and" and then add the letter combination "th"

Process


Feature Truthing for "and"
and and
and and
and
Current Author: 0001, document a
Express Load
Author:
(1 - 1568)
Doc:
Go
Cursive
Hand-printed
<< Skip >>
Initial stroke of formation of "a"
Formation of staff of "a"
Number of arches of "n"
Shape of arches of "n"
Location of mid-point of "n"
Formation of staff of "d"
Formation of initial stroke of "d"
Formation of terminal stroke of "d"
Symbol in place of the word "and"
Number of strokes for formation of "a"
Formation of staff of "a"
Number of strokes for formation of "n"
Formation of staff of "n"
Shape of arch of "n"
Number of strokes for formation of "d"
Formation of staff of "d"
Initial stroke of "d"
Unusual formations
Save/Prev
Save/Next
Exit

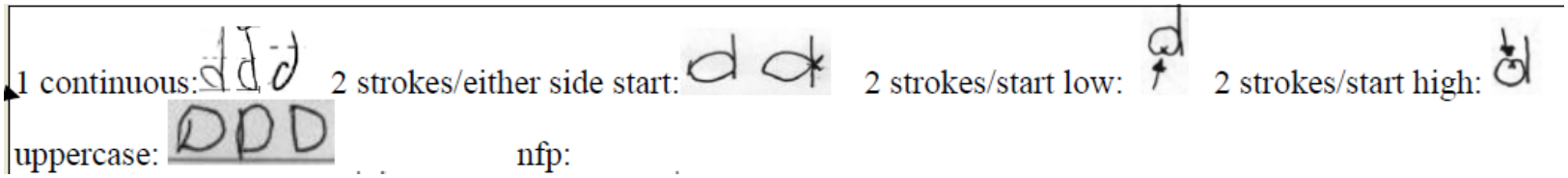
Process


Feature Truthing for "and"
and and
and and
and
Express Load
Author:
(1 - 1568)
Doc:
Go
Current Author: 0001, document a
Cursive
Hand-printed
<< Skip >>
Initial stroke of formation of "a"
Number of strokes for formation of "a"
Formation of staff of "a"
Formation of staff of "a"
tented
retraced
looped
no staff
no fixed pattern
Number of strokes for formation of "n"
Formation of staff of "n"
Location of mid-point of "n"
Shape of arch of "n"
Formation of staff of "d"
Number of strokes for formation of "d"
Formation of initial stroke of "d"
Formation of staff of "d"
Formation of terminal stroke of "d"
Initial stroke of "d"
Symbol in place of the word "and"
Unusual formations
Save/Prev
Save/Next
Exit

Process

- Various characteristics of the word “and” are identified
  - Ex. Number of strokes for a letter and height of one letter to the next

- Each characteristic is assigned a specific number

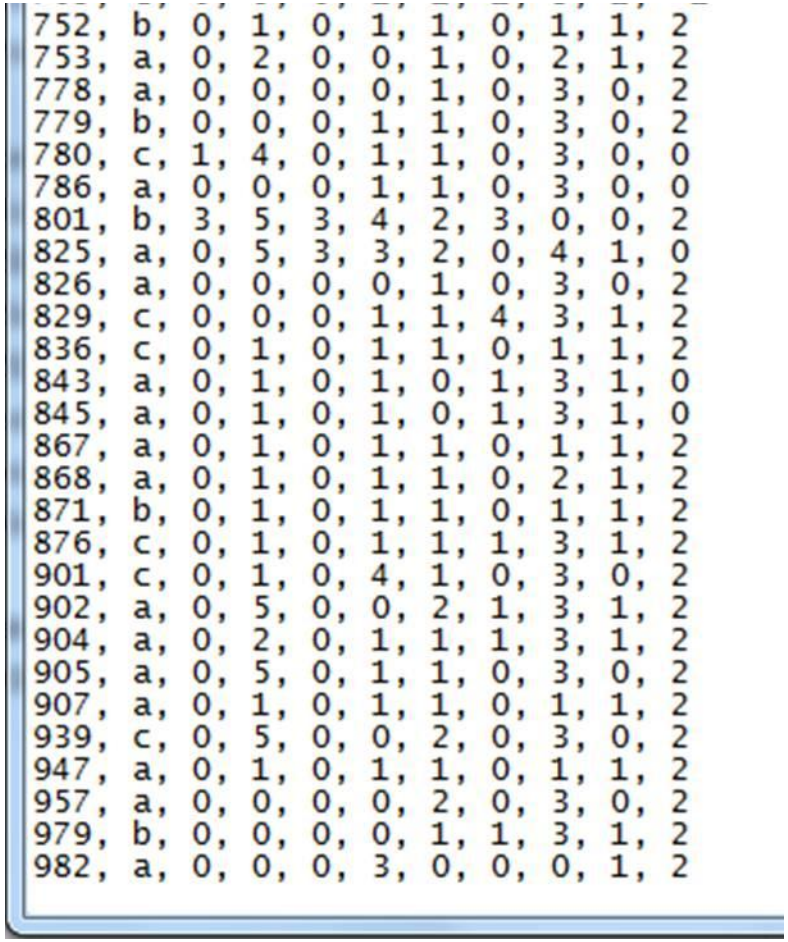


i-Fox Truthing Tool

Writer ID # 1, 2, 1, 0, 2, 2, 1, 1, 2

- 1: Initial Stroke left of staff
- 2: Looped staff
- 1: 2 Arches for "n"
- 0: Pointed arches
- 2: Arch midpoint at baseline
- 2: Looped staff of "d"
- 1: Underhand initial stroke of "d"
- 1: Terminal stroke straight
- 2: No symbol for "and"

Big Data



```
752, b, 0, 1, 0, 1, 1, 0, 1, 1, 2
753, a, 0, 2, 0, 0, 1, 0, 2, 1, 2
778, a, 0, 0, 0, 0, 1, 0, 3, 0, 2
779, b, 0, 0, 0, 1, 1, 0, 3, 0, 2
780, c, 1, 4, 0, 1, 1, 0, 3, 0, 0
786, a, 0, 0, 0, 1, 1, 0, 3, 0, 0
801, b, 3, 5, 3, 4, 2, 3, 0, 0, 2
825, a, 0, 5, 3, 3, 2, 0, 4, 1, 0
826, a, 0, 0, 0, 0, 1, 0, 3, 0, 2
829, c, 0, 0, 0, 1, 1, 4, 3, 1, 2
836, c, 0, 1, 0, 1, 1, 0, 1, 1, 2
843, a, 0, 1, 0, 1, 0, 1, 3, 1, 0
845, a, 0, 1, 0, 1, 0, 1, 3, 1, 0
867, a, 0, 1, 0, 1, 1, 0, 1, 1, 2
868, a, 0, 1, 0, 1, 1, 0, 2, 1, 2
871, b, 0, 1, 0, 1, 1, 0, 1, 1, 2
876, c, 0, 1, 0, 1, 1, 1, 3, 1, 2
901, c, 0, 1, 0, 4, 1, 0, 3, 0, 2
902, a, 0, 5, 0, 0, 2, 1, 3, 1, 2
904, a, 0, 2, 0, 1, 1, 1, 3, 1, 2
905, a, 0, 5, 0, 1, 1, 0, 3, 0, 2
907, a, 0, 1, 0, 1, 1, 0, 1, 1, 2
939, c, 0, 5, 0, 0, 2, 0, 3, 0, 2
947, a, 0, 1, 0, 1, 1, 0, 1, 1, 2
957, a, 0, 0, 0, 0, 2, 0, 3, 0, 2
979, b, 0, 0, 0, 0, 1, 1, 3, 1, 2
982, a, 0, 0, 0, 3, 0, 0, 0, 1, 2
```

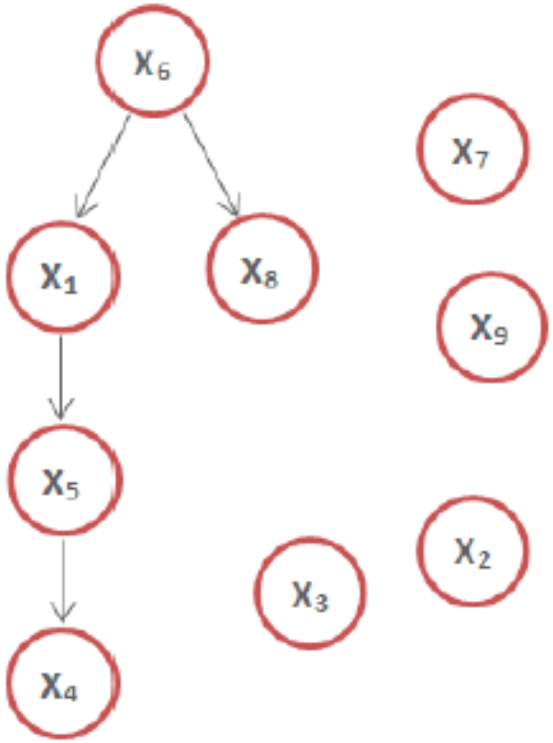
Likelihood Ratios

- Data collected by the software is sent to a statistician to be analyzed
  - Develop likelihood ratios

- Likelihood ratios show how often one expects to find individual characteristics
  - Numbers that represent the probability of letters occurring together
  - We can use this data to find what we may expect to see within similar groups of individuals in the population

Bayesian Network

- Uses Joint Probability
  - One characteristic of a letter influences the formation of the next letter
- Direct Dependencies among variables
  - Formation of the staff of the "*a*" influences staff of the "*n*", etc.
- Results show the differences between letters formed independent of an adjacent letter formation and letters formed when they are dependent on adjacent letter formation



Findings ……

- A set of defined characteristics for the word "*and*" is allowing for easy data collection
- Developed learning algorithms are being used to create statistical models
- Models used to infer probability of characteristics
- Study still ongoing

Future Research

- Continue and complete this research project
- Continue to mine existing data being collected during this three year span for information, add more individualizing characteristics
- Continue to mine new data, collected every year, for information and add more individualizing characteristics
- Continue to research “th” combination (Muehlberger et al. 1976)

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QUESTIONS?