Multiple choice examinations: similarity of answers and cheating in candidate networks

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Peter Richmond, Roadmap

- Theoretical Physics, Queen Mary College, University of London.
- **Academic:**
  - Physics, University of Kent, UK. University of NSW, Sydney, Australia
  - Maths, Institute of Advanced Studies, ANU Canberra,
  - Physics, Trinity College Dublin.
- **Industrial and public sector management**
- Research manager, Unilever
- Director, Institute of Food Research Norwich UK
- Technical Director, Food manufacturing and retail Industry
- **EC consultancy**
- EC Project TA (project officer)
- **Publications and research interests**
  - econophysics, sociophysics, statistical physics

- Presently: Member Examinations committee Radio Communications Foundation that sets examinations for amateur radio in UK
Background

- On most US university campuses, 70% of students admitted to cheating.
- From 10,000 faculty, 44% who were aware of student cheating in past 3 years never reported the fact
  - US study McCabe June 2005
- Duke University: 70%;
- Rutgers Management Education Centre, 75%;
- Miami University 91%
- Josephson Institute of Ethics in USA surveyed 43000 high school students in October 2010
  - More than ½ admitted cheating on test during past 12 months; 1/3 more than twice.
    - Report updated in USA today Feb 14 2011
- UK: concern with medical examinations
  - IC McManus et al BMJ 330 7 May 2005, 1064
Amateur radio

- Global hobby licensed by government
- In UK three graduated levels awarded after theoretical and practical examinations:
  - Foundation (26), Intermediate (45), Advanced (62)
- Each multiple choice question has 4 options
- Advanced examination
  - Examination spans, license conditions, principles of electronics, receivers, transmitters, antennae, propagation, electrical interference, measurement methods
  - 4 times each year with ~ 100 students
  - Exam offered across ~20 centres in UK (England, Scotland, N Ireland)
  - Number of candidates at any one centre varies from 1 to 20
  - Usually candidates taught in local club by tutors who also act as volunteer invigilators
Potential consequences of cheating

• Medicine
  o People more likely to die when treated by unqualified personnel

• Amateur radio
  o Operating equipment at high voltage (>2KV possible in some systems)
  o High RF: UK 400W; Other countries 1KW!
    • Danger of serious burns to people from RF voltages and currents
    • Trees supporting antennae may catch fire
    • Interference
      o Across neighborhood into mains, audio and TV
      o Medical devices (eg, pacemakers)
      o Satellite, emergency, military communications
Data

- Three data sets from Advanced examinations
- Questions/ syllabus: Administration:

- Data sets from years: 2012, 2011 & 2008
Candidate network

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Typical Data

- 2012
- 63 candidates
- 1953 candidate pairs across 25 centres
- Number per centre ~ 1 to 6
- Centres inspected
- Desk layout and seating plans approved beforehand
- Named and registered volunteer invigilators
Results ranking

Pass is >36 (~60%)
Similarity and overlap

- Candidate I answers $A_i$ questions correctly
- Candidate J answers $A_j$ questions correctly
- $A_{ij}$ is the number of correct answers shared by the two candidates

![Graph showing similarity and overlap](image)
Select exponent such that $\Sigma \delta y = 0$.

$$y = 62\left(\frac{x}{62}\right)^{1.8}$$
Output 2012 (63)

$y = 62 \left( \frac{x}{62} \right)^{\alpha}$

\(\alpha = 1.5\)
\(\alpha = 1.8\)
\(\alpha = 2.0\)

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Ranking
2008

110 candidates 5995 pairs
Three data points!
12431, 18039
18042, 18039
18042, 12431
All from same centre!
Apply Bonniferi correction to eliminate false positives

- \( p_c = p_r \times \frac{2}{N(N-1)} = \frac{p_r}{5995} \approx p_r \times 10^{-4} \)

Log scale!

Bonferroni correction is 4 orders of magnitude

Outlier displaced 8 orders of magnitude

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2011

116 candidates 6670 pairs

\[ \alpha = 1.82 \]
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- CDF tail

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Bonniferi correction

- \( p_c = p_r \times \frac{2}{N(N-1)} = \frac{p_r}{6670} \sim p_r \times 1.5 \times 10^{-4} \)
But we studied together....

- From ~6000 candidate pairs, the ones which appear as extreme and unusual outliers are always from same centre.

- Most other same centre pairs embedded in ‘normal’ region

- Suggests studying together may not be credible excuse
  - NB The candidates identified by algorithm used here are identical to those identified by Wesolowsky’s (McMaster Uni) proprietary algorithm
  - Further study: Explore overlaps with wrong answer?
Summary

• Outliers plus knowledge of seating plan suggests irregular returns
• Plan to implement outcome into UK amateur radio exam results processing and build algorithm into OM marking software
• Further reduce opportunity to cheat during exam by randomizing sequence of individual answer options for different candidates. Each candidate then has different paper
  o Does not work if invigilator and candidates collude either during or ‘afterwards’
• Further study:
  o Explore overlaps with wrong answers?
Econophysics and Physical Economics

Trinity College
University of Dublin

• Networks:
  o Bubbles and foam
  o People

• Interaction is the key
Trinity College Long Room
Book of Kells
Chester Beatty’s Library

- ‘Not just the best museum in Ireland, but one of the best in Europe’
  - Lonely Planet
- Has been described at the finest collection of manuscripts and books made by a private collector in 20th century.
- Includes representative samples of the world’s heritage (artistic, religious, and secular) from about 2700 BC to the present century.
NUI Galway

One of only two Irish universities to be rated 5 stars for excellence

Ranked 3rd of the Irish Universities in international rankings

In the top 2% of universities in the world

World Class Facilities

- Ireland’s largest School of Engineering (picture)
- Newly opened Arts, Humanities and Social Sciences Research Building
- Ireland’s largest Biosciences Research Building
- Dedicated Arts and Culture wing in the Bailey Allen Hall
- State-of-the-art Sports Centre and swimming pool
  Opening soon
- A Translational Research Facility
- A Clinical Research Facility

Established in 1845, NUI Galway has a distinguished reputation for teaching and research excellence.
NUI Galway

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- Celtic culture

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Working Group 2

- ‘Ways of seeing’
- The way different disciplines exploit data
- Physics and natural science, economics, social sciences & humanities
  - Prof Sorin Solomon Hebrew University of Jerusalem: Complex systems
  - Prof Bertrand Roehner, Paris: Simulation of complex social systems…but using insects! (bonding and suicide)
  - Prof Judit Bar-Ilan: Altmetrics
- University of Galway, Ireland
- April 23–25, 2014