Target Users’ Diagrammatic Reasoning of Domain-Specific Terminology

By Louise Pram Nielsen (PhD, MSc)
Outline

1) Introduction
   • Domain-specific terminology and terminological ontologies
   • Research themes (dual visualizations)

2) Method and material
   • Eye tracking, participants and experimental procedure
   • Performance (regression) models

3) Results: Expertise effects
   • Direct and indirect measures of expertise
   • Reduced, absent and reversed expertise effects

4) Results: Trial-number effects and diagrammatic reasoning
   • Performance and question-type interaction
   • Inferring diagrammatic reasoning

5) Conclusion
1) Introduction
Domain-specific terminology

- The study of terms (further specialized discourse, constitute lexical units and express underlying concepts) [Cabré, 2003]
- Belonging uniquely to a particular domain (specialized discourse) e.g. taxation
- Compile terminological resources (terms, relations, definitions) e.g. term banks

Terminological ontologies

- Model concepts by formal feature specifications of attribute-value pairs [Madsen, Thomsen & Vikner, 2004]
- Visualize concepts, relations and characteristics in the graphical format
Research themes

RQ: Whether domain-specific terminology and knowledge can be conveyed to target users by means of diagrams...

Dual-entry mode: From the conventional term-bank format to combining...
  - Concept diagram in the graph format (denoted D)
  - Concept article in the text format (denoted A)

Expertise: From the one-dimensional levels of expertise to suggesting...
  - Background variables (participation, motivation, education, exposure)
  - Self-rating (direct)
  - Representative tasks (indirect)

Experiment: From eye-movements to expertise and trial-number effects...
  - Multiple regression technique
  - Significant predictors of performance (correctness, speed and depth)
2) Method and material
Participants

Sample:

- 40 professional potential target users … to represent the full scale of expertise ranging from low to high.
- 23 females (mean age 41.7) and 17 males (mean age 44.0)
- Danish native speakers

Expertise background variables [Kwak, 1999]

- **Participation/Work place**: 20 inside and 20 outside Tax Administration/SKAT
- **Motivation/Working area**: 18 JUROKPOL vs. 22 OTHER
- **Education/Length**: 29 long (five years or more) vs. 11 short
- **Exposure/Frequency of use of specialized texts**: Seven-point Likert-scale (mean 3.54)
(Remote) Eye tracking

The eye-mind hypothesis:
No appreciable lag between fixation and cognitive processing
[Just & Carpenter, 1980]
Dual-entry mode (Fig. 1)

Hvilken type skat eller afgift er energiskat?

1. Miljøafgift
2. Energieafgift
3. Punktafgift

<table>
<thead>
<tr>
<th>Dansk: Kilde til term:</th>
<th>energiskat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong></td>
<td>punktafgift som pålægges varer og tjenester med det formål at begrænse miljøskadeligt energiforbrug</td>
</tr>
<tr>
<td><strong>Kommentar:</strong></td>
<td>Den største gruppe blandt punktafgifterne er energiskattere, der i 2011 tegnede sig for 44 pct. af samtlige punktafgifter.</td>
</tr>
<tr>
<td><strong>Kilde:</strong></td>
<td>DanTermBank</td>
</tr>
<tr>
<td><strong>English:</strong> Source for term:</td>
<td>energy tax</td>
</tr>
<tr>
<td><strong>Definition:</strong></td>
<td>excise duty imposed on energy consumption to reduce emissions</td>
</tr>
<tr>
<td><strong>Source:</strong></td>
<td>DanTermBank</td>
</tr>
</tbody>
</table>

![Diagram showing the relationship between energy tax and types of taxes](image-url)
8 blocks of 6 questions (Tab. A1)

<table>
<thead>
<tr>
<th>Question type</th>
<th>Term-bank content</th>
<th>Question</th>
<th>Available answer</th>
<th>Correct answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram (D1)</td>
<td>Sub-ordinates</td>
<td>How many types of energy taxes exist?</td>
<td>1: Four</td>
<td>No. 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Six</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Eight</td>
<td></td>
</tr>
<tr>
<td>Diagram (D2)</td>
<td>Sub-division criteria</td>
<td>What separates carbon dioxide tax from duty on nitrogen oxides?</td>
<td>1: Purpose</td>
<td>No. 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Content</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Taxpayer</td>
<td></td>
</tr>
<tr>
<td>Article (A1)</td>
<td>Equivalents</td>
<td>What can 'energy tax' be translated into in Danish?</td>
<td>1: <em>energiavgift</em></td>
<td>No. 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: <em>energiskat</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: <em>energitakst</em></td>
<td></td>
</tr>
<tr>
<td>Article (A2)</td>
<td>Comments</td>
<td>Energy taxes constituted 44 per cent of excise duties in 2011 according to whom?</td>
<td>1: OECD</td>
<td>No. 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Eurostat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Statistics Denmark</td>
<td></td>
</tr>
<tr>
<td>Diagram-Article (DA1)</td>
<td>Super-ordinate (Definition)</td>
<td>What type of tax or duty is energy tax?</td>
<td>1: Environmental duty</td>
<td>No. 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Energy duty</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Excise duty</td>
<td></td>
</tr>
<tr>
<td>Diagram-Article (DA2)</td>
<td>Attributes (Definition)</td>
<td>What is the purpose of energy tax?</td>
<td>1: Limiting environmentally damaging energy consumption</td>
<td>No. 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Limiting environmentally damaging consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Limiting environmental Damage</td>
<td></td>
</tr>
</tbody>
</table>
Heat maps and scan paths
Experimental procedure

Background questionnaire
- Self-rating task
- Terminology crash course
- Recalling task (List)
- Categorizing task (Define)

Eye-tracking experiment
- Reading task
- Dual-entry mode (visualization)

Retrospection (after-the-event interview)
- User situation, preference, performance, difficulty, exposure, user needs
Performance models (Tab. A2)

Expert performance guided the choice of dependent variables:

- Representative tasks to demonstrate superior performance of experts [Charness & Tuffiash, 2008]
- Expert performance characteristics: deep, error-free and fast [Rikers & Paas, 2005]
- DVs: correctness, response time (defined as the sum of processing and answering time on each question.) and diagram-fixation time (defined as the sum of all fixations over 200 ms on the screen in the relevant AOI).

Multiple regression techniques (linear mixed-effects modelling) [Balling, 2008]:

- To model dependencies in the observations as the answers of each participant are not considered independent
- To assess multiple correlations of explanatory (independent) variables with a specific (dependent) performance variable
3) Results: Expertise effects
(No) Expertise effects

Expectation: Expertise effects from the subset of explanatory variables measuring expertise levels (directly or indirectly)

Result: No explanatory variables reflecting expertise are significant predictors of performance

Interpretation

- Reduced: Overload of limited processing capacity [Mayer & Moreno, 2003]
- Absent: Expertise measures do not fully capture complexities [Alexander, 1992]
- Reversed: Information redundancy [Kalyuga & Sweller, 2004]
4) Results: Trial-number effects and diagrammatic reasoning
Trial-number effects (Fig. 2)

- D-questions require significantly longer response time compared to A- and DA-questions.
- D-questions require significantly longer diagram-fixation time compared to A- and DA-questions.
- DA-questions require significantly longer diagram-fixation time compared to A-questions.

Significant interaction between performance and question type.
Diagrammatic reasoning

Interpret the trial-number effects of the performance models to infer the underlying diagrammatic reasoning…

Correctness:
• D-questions are not resulting in lower correctness
• Diagrammatic reasoning of diagrams as effective as “non-diagrammatic reasoning” of articles

Response time (on correct answers)
• D-questions are more (response) time consuming
• Diagrammatic reasoning of the D-questions is the least efficient compared to A- and DA-questions

Diagram-fixation time (on correct answers)
• DA-questions: Diagrams are fixated but without longer total response time… therefore, answers are probably not retrieved from D!
• Diagrammatic reasoning is most likely inefficient
5) Conclusion
Conclusion

Access to dual visualizations of domain-specific terminology:

Conclusion based specifically on the diagrammatic reasoning:
It depends on the information need (question type) of target users:
  • D-questions: Evidence for effective and improving diagramatic reasoning
  • DA-questions: Evidence for inefficient diagrammatic reasoning

Conclusion based on general knowledge acquisition:
Terminological ontologies should be an integral feature of in the interface of terminological resources
  • Target users are able to reason about diagrams despite relatively long reasoning and response times.
Thank you!