Conceptual relations compete during auditory and visual compound word recognition

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Relational interpretations

- Compound words can be paraphrased using conceptual relations
Relational interpretations

- Compound words can be paraphrased using *conceptual relations*.

- **Conceptual relations link the compound’s constituents.**
Relational interpretations

- Compound words can be paraphrased using *conceptual relations*
- Conceptual relations link the compound’s constituents

**Such paraphrases act as an interpretive gist**
snowball
ball made of snow
sweatband
band for sweat
honeybee
bee makes honey
Levi’s 16 relations

Levi (1978)

<table>
<thead>
<tr>
<th>Conceptual relation</th>
<th>Compound</th>
<th>Conceptual relation</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>H ABOUT M</td>
<td>newsflash</td>
<td>M HAS H</td>
<td>doorframe</td>
</tr>
<tr>
<td>H BY M</td>
<td>handclap</td>
<td>H LOCATION IS M</td>
<td>farmyard</td>
</tr>
<tr>
<td>H CAUSES M</td>
<td>joyride</td>
<td>M LOCATION IS H</td>
<td>neckline</td>
</tr>
<tr>
<td>H CAUSED BY M</td>
<td>sunbeam</td>
<td>H MADE OF M</td>
<td>snowman</td>
</tr>
<tr>
<td>H DERIVED FROM M</td>
<td>seafood</td>
<td>H MAKES M</td>
<td>flourmill</td>
</tr>
<tr>
<td>H DURING M</td>
<td>nightlife</td>
<td>H IS M</td>
<td>girlfriend</td>
</tr>
<tr>
<td>H FOR M</td>
<td>mealtime</td>
<td>H USES M</td>
<td>steamboat</td>
</tr>
<tr>
<td>H HAS M</td>
<td>bookshop</td>
<td>H USED BY M</td>
<td>witchcraft</td>
</tr>
</tbody>
</table>
How is this unseen information processed?
Competition between relations (Spalding et al., 2010)

Not always clear what the relational interpretation might be
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- Multiple senses: fire
  firearm discharge from gun
  firewood combustion from burning
Competition between relations (Spalding et al., 2010)

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- Multiple senses: fire
  - firearm discharge from gun
  - firewood combustion from burning

- Ambiguity:
  - “Alaskan beetle can release a deadly bug spray” - spray PRODUCED BY bugs
  - “She wore plenty of bug spray” - spray FOR bugs
Competition between relations (Spalding et al., 2010)

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- Ambiguity:
  “Alaskan beetle can release a deadly bug spray” - spray PRODUCED BY bugs
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- Flexibility of modifier relation:
  plastic - MADE OF
  eye - eye HAS strain, shot FROM eye, bath FOR eye
Multiple relational interpretations are proposed and evaluated
Competition between relations (Spalding et al., 2010)

- Multiple relational interpretations are proposed and evaluated
- This process is competitive
Multiple relational interpretations are proposed and evaluated.

This process is *competitive*.

Greater competition between interpretations makes processing *difficult*.
Evidence from Schmidtke et al., 2016
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- Two visual lexical decision datasets including small set of compound words
Evidence from Schmidtke et al., 2016

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- **Heterogeneous set of relations for compound = slow processing**
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- **A strong dominant relational meaning = fast processing**
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- Two visual lexical decision datasets including small set of compound words
- Heterogeneous set of relations for compound = slow processing
- A strong dominant relational meaning = fast processing
- **Competition quantified: Entropy of conceptual relations**
The current study
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- What about auditory compound word processing?
The current study

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- **Prediction:** same competition effect in auditory and visual lexical processing
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- What about auditory compound word processing?
- Prediction: same competition effect in auditory and visual lexical processing
- Conceptual relations are bridging structures not specified in surface form
- Conceptual combination is a mental operation of concepts
- **Therefore, the linguistic modality of expressed entity should not matter**
The current study

1 Possible relations task; data used to quantify competition
The current study

1. Possible relations task; data used to quantify competition
2. 4 lexical decision datasets (2 visual; 2 auditory)
The current study

1. Possible relations task; data used to quantify competition
2. 4 lexical decision datasets (2 visual; 2 auditory)
3. **Attempt to predict lexical decision latencies from possible relations data**
Possible relations task

Instructions

- “Pretend that you are learning English and know the meaning of the individual words, but have not yet seen the words together.”
- “What is the most likely meaning of this phrase?”

Example trial

jaw bone

- bone USED BY jaw
- bone USES jaw
- jaw LOCATED bone
- bone LOCATED jaw
- bone FOR jaw
- bone ABOUT jaw
- bone DURING jaw
- bone BY jaw
- bone CAUSES jaw
- bone CAUSED BY jaw
- bone HAS jaw
- jaw HAS bone
- bone MAKES jaw
- bone FROM jaw
- bone MADE OF jaw
- jaw IS bone
Stimuli, participants and platform

- Possible relations task administered on Amazon Mechanical Turk
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- 600 existing unspaced English compounds
Stimuli, participants and platform

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- 47-48 participant ratings per compound
Stimuli, participants and platform

- Possible relations task administered on Amazon Mechanical Turk
- 600 existing unspaced English compounds
- 47-48 participant ratings per compound
- all participants US English monolingual speakers
Raw results: distribution of possible relations

- M location is H
- M has H
- H used by M
- H makes M
- H made of M
- H location is M
- H is M
- H has M
- H from M
- H for M
- H causes M
- H by M

homeland

0 2 4 6 8

39 / 65
Entropy of conceptual relations

- **High Entropy** indicates greater uncertainty and high competition
Entropy of conceptual relations

- **High Entropy** indicates greater uncertainty and high competition
- **Low Entropy** indicates more structuredness and low competition
Examples

**Processing benefit**
- Bathrobe $H = 0.85$
  - h location is m
  - h is m
  - h during m

**Processing cost**
- Speedboat $H = 1.83$
  - h uses m
  - h makes m
  - h has m
  - h for m

Probability of selection
Lexical decision datasets: visual

- **English Lexicon Project (ELP; Balota et al., 2007)**
  - 497 compounds
  - 816 US participants
  - 15,145 trials

- **British Lexicon Project (BLP; Keuleers et al., 2012)**
  - 417 compounds
  - 78 UK participants
  - 13,354 trials
Analysis

- Linear mixed effects models
- Predicting response time latencies
- Lexical predictors
  - Entropy of conceptual relations
  - Semantic similarity
    - Left-whole: *car-carwash*
    - Right-whole: *wash-carwash*
  - Compound frequency
  - Left and right constituent frequencies
  - Left and right family sizes
  - Compound length
  - Duration (auditory)
  - Uniqueness point and complex uniqueness point (auditory)

- Other controls
  - Trial number
  - Random effects for participant and item
Results

Visual lexical decision

Entropy of conceptual relations, scaled

Response time, ms

ELP
BLP
Results

Visual lexical decision

Response time, ms vs Entropy of conceptual relations, scaled

- Low competition
- High competition

ELP
BLP
Lexical decision datasets: auditory

- **Auditory exp 1**
  - Massive Auditory Lexical Decision (MALD; Tucker & Brenner, submitted)
  - 416 compounds
  - 230 Canadian monolingual participants
  - 1,693 trials

- **Auditory exp 2**
  - 426 compounds
  - 55 Canadian monolingual participants
  - 21,236 trials
Results

**Auditory lexical decision**

![Graph showing response time (ms) vs. entropy of conceptual relations (scaled)](image)

- **Y-axis:** Response time (ms)
- **X-axis:** Entropy of conceptual relations (scaled)
- **Graphs:**
  - **Black line:** Exp 2
  - **Dashed line:** Exp 1

The graph illustrates the relationship between response time and entropy of conceptual relations, with separate lines for Exp 2 and Exp 1.
Results

Auditory lexical decision

Response time, ms

Entropy of conceptual relations, scaled

Exp 2
Exp 1

high competition
low competition
825
850
875
900
925
950
975
1000
1025
−2 −1 0 1 2

Entropy of conceptual relations, scaled
Response time, ms

Exp 2
Exp 1
Other effects in auditory lexical decision

- **Auditory exp 1**
  - Effect of right-whole semantic similarity
    - **Boost** for greater similarity: *wash-carwash*
  - No constituent frequency effects (consistent with prior studies)
  - No family size effects

- **Auditory exp 2**
  - Effect of left-whole semantic similarity
    - **Boost** for greater similarity: *car-carwash*
  - No constituent frequency effects
  - No family size effects
Results: summary of competition effects

**Visual word recognition**

- Response time, ms
- Entropy of conceptual relations, scaled

**Auditory word recognition**

- Response time, ms
- Entropy of conceptual relations, scaled
Results summarized

- Compositional information important for visual and auditory processing
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  - Conceptual combination operates over conceptual structure
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- **Conceptual combination in acoustic processing is:**
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- Conceptual combination in acoustic processing is:
  1. present without role of constituent frequency
Results summarized

- Compositional information important for visual \textit{and} auditory processing
  - Conceptual combination operates over conceptual structure

- Conceptual combination in acoustic processing is:
  1. present without role of constituent frequency
  2. \textit{complementary to semantic transparency effects}
Conclusions

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  - **Competition between relational meanings** complements co-activation of semantic representations of constituents and whole words

We provide a new measure that taps into access of nuanced compositional meanings.

Future work:
- What about novel compounds?
- When does this high-level information come into play?
- Reading in context. A role of individual differences?
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Thanks!

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