Overview

Motivation

Why Study Similarity?
Modeling of Similarity

Direct Assessment

Different Views of Concept Structures
A Concrete Example

Latent Variable Models
Outline

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Why Study Similarity?
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Latent Variable Models
Basic Psychological Research

- categorization
- memory
- learning
  - especially imitation learning
- decision theory
Applications

- internet search
- recommendation algorithms
Similarity Models and their Experimental Validation

Motivation

Why Study Similarity?

Applications

1. including picture search
2. recommendation: especially interesting, because suggestion should be similar, but not too similar
3. if in line with human cognition, probably more successful
Outline

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Latent Variable Models
The Need for Representations

- models need input
  - for similarity models: object representations
- 2 questions:
  1. How are objects represented in the mind?
  2. How do we access these representations?
Two Approaches

- direct assessment
  - simply ask the subject
1. in theory, one could do both in order to increase reliability
2. \( \Leftarrow \) multi modal assessment
Two Approaches

- direct assessment
  - simply ask the subject
- latent variable analysis
  - object representation as a latent construct
  - observable variables: similarity ratings
1. in theory, one could do both in order to increase reliability
2. ⇐ multi modal assessment
A Short Excursion Into Psychology

Questionnaires vs. "objective" methods

- “objective”: indirect assessment
  - avoids Rosenthal effect

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1Lieberman et al., “A Hot New Way to Measure Aggression”.
A Short Excursion Into Psychology

Questionnaires vs. "objective" methods

- “objective”: indirect assessment
  - avoids Rosenthal effect
- Example 1: racial views
  - direct assessment problematic
  - indirect method: IAT
- Example 2: self-worth

\(^1\)Lieberman et al., “A Hot New Way to Measure Aggression”.
A Short Excursion Into Psychology

Questionnaires vs. "objective" methods

- "objective": indirect assessment
  - avoids Rosenthal effect
- Example 1: racial views
  - direct assessment problematic
  - indirect method: IAT
- Example 2: self-worth
- other indirect methods
  - proxemics
  - hot sauce allocation

\[1\]

\[1\] Lieberman et al., “A Hot New Way to Measure Aggression”.
Outline

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Different Views of Concept Structures

• 2 questions:
  1. How are objects represented in the mind?
     • geometric
     • featural
     • structural
  2. How do we access these representations?
Geometric Description

- objects as points in an n-dimensional space\(^2\)
- object attributes: values on dimensions
- similarity as distances

Geometric
Pros and Cons

- **Pros**
  - easy to conceptualize in 2-dimensional space
  - many stimuli can be accurately represented on dimensions

- **Cons**
  - hard to conceptualize in more than two dimensions
  - metric axioms do not apply to similarities in many cases\(^3\)

\(^3\)Tversky, “Features of Similarity”. 
Featural Description

- objects as feature sets\(^4\)
- object attributes: elements in the feature sets
- similarity as evaluation of feature sets
  - intersection: commonalities between the objects
  - symmetric difference: differences between the objects

\(^4\)Tversky, “Features of Similarity”. 
Featural
Pros and Cons

- **Pros**
  - very versatile
  - objects are easy to conceptualize

- **Cons**
  - comparisons between objects are hard to conceptualize
  - no relations between the features
Structural Description

- objects as nodes in a network\(^5\)
- object attributes as descendants of the object node
- similarity as the degree of alignment between two structures

\(^5\)Gentner and Markman, “Structure Mapping in Analogy and Similarity.”
Structural Description

1. that's my guess; haven't seen a description of structural object representation
2. original paper was interested in relation of objects to each other
Structural

Pros and Cons

- **Pros**
  - can explain the most phenomena
  - network structure resembles the brain’s architecture

- **Cons**
  - very complex
  - concepts are hard to construct
What we Chose

Feature models, because...

- set membership is relatively easy to access
- sweet spot between explanatory power and complexity
Outline

**Motivation**
- Why Study Similarity?
- Modeling of Similarity

**Direct Assessment**
- Different Views of Concept Structures
- A Concrete Example

**Latent Variable Models**
A Concrete Example

- 2 questions:
  1. How are objects represented in the mind?
  2. How do we access these representations?
- examplified by my bachelor thesis\(^6\)

The GLW Model

- $M$ is the superset of the attribute sets $A, B, C, D, \ldots$

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7 Geist, Lengnink, and Wille, “An Order-Theoretic Foundation for Similarity Measures”.
The GLW Model\textsuperscript{7}

- $M$ is the superset of the attribute sets $A, B, C, D, \ldots$
- $\mathcal{P}(M)$ is the power set of $M$

\textsuperscript{7}Geist, Lengnink, and Wille, “An Order-Theoretic Foundation for Similarity Measures”.

The GLW Model\textsuperscript{7}

- $M$ is the superset of the attribute sets $A$, $B$, $C$, $D$, . . .
- $\mathcal{P}(M)$ is the power set of $M$
- $\mathcal{P}(M)$ is ordered in the following way:

\[(A, B) \geq (C, D) \iff A \cap B \supseteq C \cap D \land A \cap \overline{B} \subseteq C \cap \overline{D} \land \overline{A} \cap B \subseteq \overline{C} \cap D \land \overline{A} \cap \overline{B} \supseteq \overline{C} \cap \overline{D} \]

\textsuperscript{7}Geist, Lengnink, and Wille, “An Order-Theoretic Foundation for Similarity Measures”.
Design of Experiment
Object Selection
Considerations

• ???
1. we are limiting ourselves to 2D images
2. pro abstract: we can construct the stimuli to be suitable to the model
3. pro real life: better generalizable
4. advantage to one category: they should be all comparable
Object Selection
Considerations

- abstract or real life stimuli?
- How much variance should there be?
  - all items from one category?
  - ...or from different categories?
- How many?
1. we are limiting ourselves to 2D images
2. pro abstract: we can construct the stimuli to be suitable to the model
3. pro real life: better generalizable
4. advantage to one category: they should be all comparable
Object Selection
What I Did

- pictures of fruits
- limited to selection from Rosch and Mervis
- inclusion criteria:
  - easily recognizable
  - selection of small, medium and large fruits
- advantages:
  - very familiar stimuli
  - easy to find Creative Commons pictures

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8Rosch and Mervis, “Family Resemblances: Studies in the Internal Structure of Categories”.
Object Selection
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Rosch and Mervis, “Family Resemblances: Studies in the Internal Structure of Categories”

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1. less variety between different “instances” of the object
2. increases generalizability
3. reasoning: ensure that some stimuli are similar and some are rather unsimilar
4. same category ensured that comparisons make sense
Object Selection

Unexpected Problems

- some subjects did not recognize certain images
- pictures needed to be swapped
1. descriptions for grape: lime, star fruit
2. descriptions for blueberry: fig, planet, chocolate fondue
3. descriptions for 2nd grape: kiwi, cactus, light bulb
4. shows importance of pretests
5. somewhat less explosive for pairs instead of quartets
Interactive Part

Write down as many features as come to mind for this object.
Interactive Part

Write down as many features as come to mind for this object.
Motivation

Direct Assessment

Feature Assessment

Brainstorming

Was this a good way to assess features?
How could it be improved?
Feature Assessment

Considerations

• How many features to collect?
• collect both commonalities and distinctions
• ensure that same features are referred to by the same word
Feature Assessment Considerations

- How many features to collect?
- Collect both commonalities and distinctions
- Ensure that same features are referred to by the same word

1. delicious and yummy
One Size Fits All?

- two studies: feature collection and comparison
  - shortens comparison part
  - simplifies AI driven pair selection
  - feature list can be curated
- one study
  - individual assessment of object concepts
e.g. time for more pair ratings
Feature Assessment

Part I: Feature Collection

- features should be general
- solution: ESP game

\[^{9}\text{Von Ahn and Dabbish, “Labeling Images with a Computer Game”}\]
1. advantage: encourages general features
2. discourages more complex descriptions (e.g. “grows on trees”)
Feature Collection

Participant's GUI

223.0 Sekunden von 300.0 Sekunden verblieben.

Sie haben bereits die folgenden Worte eingept:
- Frucht
- Kerne
- orange
- rund
- saftig
- Stücke

Tippen Sie hier bitte ein passendes Merkmal ein: 

Bestätigen

0.0%
1. instructions: nouns and adjectives, features *not* name itself
Feature Collection

Experimenter’s GUI
Creation of Feature List

- most frequent features across all stimuli
- features unique to a certain stimuli
Feature Selection
**Pair Selection**

The Need for Selection

- number: 10
- combinations:
  - asymmetric similarity
    - $10^2 \times 10^2 = 10000$
  - symmetric similarity
    - $\left( \frac{(2+10-1)!}{2!(10-1)!} \right)^2 = 3025$
1. assuming 2 sec/item: 5 hours 30 minutes
2. assuming 2 sec/item: 1 hours 40 minutes
Pair Selection
Considerations

- manageable number for subjects
- representative sample of all possible combinations
Pair Selection

Brainstorming

How would you go about selecting pairs?
Trivial Cases

- trivial:
  - $(A, B), (A, B)$
  - $(A, A), (A, B)$

- curiously not trivial:
  - $(A, A), (B, C)$
Pair Selection

How I Did It

1. Add trivial, comparable combinations
2. Add trivial combinations
3. Add incomparable combinations
4. End of selection process
General Idea

- treat representations as a latent variables
- observable variables: similarity ratings
Latent Variable Models

• **Pros**
  - more objective
  - disciplined way to derive more complicated representations

• **Cons**
  - interpretation of output
Interpretation of LVM output

An Example

• example from Galbraith et al.¹⁰
• data from Kruskal¹¹

¹⁰Galbraith et al., *The Analysis and Interpretation of Multivariate Data for Social Scientists.*
Interpretation of LVM output

Raw Output
Interpretation of LVM output

Raw Output
Who Does the Labeling?

- participant
  - individual labeling
  - LVM output might be unintuitive
- experimenter
Conclusion

- direct assessment: measuring of representation is hard, interpretation is easy
- latent variable models: measuring of representation is easy, interpretation is hard
- If a model is to describe human cognition/behaviour, we have to fill the model components with psychological meaning.
References I


References II


Motivation

References IV


Shepard, Roger N. “The Analysis of Proximities: Multidimensional Scaling with an Unknown Distance Function. II”. In: Psychometrika 27.3 (1962), DOI: 10.1007/BF02289621.


References V


