Maps for Verbs: The relationship between interaction dynamics and verb use

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Where do word meanings come from?

- Associative learning hypothesis: Children and perhaps robots might learn word meanings by associating words with events and objects in the present scene.

- Examples of associative learning of word meanings by robots or programs: Steels, Oates and Cohen, Steedman, Regier, Roy, Reiter, Siskind.

- Each designs features of the present scene to which word instances may be associated (e.g., one block's center of gravity is in line with another's).

- What is the evidence that kids associate such features with word meanings?
Is there evidence for MFV framework?

Before

- VR = V(A) - V(B)
- VR > 0
- VR = 0
- VR < 0

During

- E(AB) < 0
- E(AB) = 0
- E(AB) > 0

After

- D(AB) > 0
- D(AB) = 0
- D(AB) < 0

Distance of AB unit > 0
Method

• Make movies of two-blob interactions whose dynamics vary according to the MFV model; movies are generated by parameterized behavior models

• Show the movies to young children and collect the stories they tell about them

• Test whether the distributions of words the children use are independent of the parameters of the behaviors that generated the movies
Illustrative Movies
Stimuli and Subjects

• 18 movies:
  – Two versions of chase
  – Hit coast, stat, and wander
  – Push coast, stat, and wander
  – Shove coast, stat, and wander
  – Harass coast, stat, and wander
  – Countershove stat, wander
  – Bounce stat, wander

• 16 children between 26 and 60 months old (mean 50 months)
Typical responses

E: Okay, last one. Can you tell me a good story about this one?
S: Even gooder than all of the other ones?
E: Make it the best story!
S: It’s going umm gooder and it’s playing but the red is letting the blue push him. And the red is letting the blue one push
E: How come he’s letting the blue push?
S: Because he wanted to.
E: Why does he want to?
S: Because he likes to play like that.
Canonicalized words that occurred at least three times

PUSHING, 85; MOVING, 57; BONKING, 54;
AWAY, 46; TRYING, 38; PLAYING, 28; FAST, 27;
RUNNING, 27; AROUND, 25; UP, 25; GETTING, 21;
CHASING, 19; FRIENDS, 18; BUMPING, 17;
SLOW, 16; HITTING, 16; DOWN, 16; CIRCLE, 11;
CATCHING, 10; STANDING, 7; TAG, 7; ZOOMING, 6;
STOPPING, 6; COMING, 4; FLYING, 4; KNOCKING,
4; FOLLOWING, 4; BOUNCING, 4; ABOUT, 4;
TOGETHER, 4.
## Representing the data:
*Word Frequency Vectors*

### Relative Frequency Vector

<table>
<thead>
<tr>
<th>Shove-Stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUSHING, 0.192; MOVING, 0.115; BONKING, 0.0; AWAY, 0.115; TRYING, 0.038; PLAYING, 0.0; FAST, 0.115; RUNNING, 0.077; AROUND, 0.0; UP, 0.0; GETTING, 0.0; CHASING, 0.038; FRIENDS, 0.077; BUMPING, 0.038; SLOW, 0.038; HITTING, 0.0; DOWN, 0.0; CIRCLE, 0.0; CATCHING, 0.038; STANDING, 0.0; TAG, 0.0; ZOOMING, 0.038; STOPPING, 0.0; COMING, 0.0; FLYING, 0.0; KNOCKING, 0.0; FOLLOWING, 0.0; BOUNCING, 0.038; ABOUT, 0.038; TOGETHER, 0.0.</td>
</tr>
</tbody>
</table>

### Word Frequency Vectors Table

<table>
<thead>
<tr>
<th>Movie</th>
<th>Around</th>
<th>Away</th>
<th>Bonking</th>
<th>Stopping</th>
<th>Tag</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movie 0</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>54</td>
<td>61</td>
<td>32</td>
</tr>
<tr>
<td>Movie 1</td>
<td>17</td>
<td>31</td>
<td>30</td>
<td>...</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Movie 17</td>
<td>51</td>
<td>47</td>
<td>37</td>
<td>...</td>
<td>9</td>
<td>21</td>
</tr>
</tbody>
</table>
Representing the data: Movie vectors

Vector of parameters for the shove-stationary movie

::BEFORE-SUBJECT-ACTION = 'agent-coast
::BEFORE-ACTOR-ACTION = 'approach-slow-down
::BEFORE-ACTOR-ORIGINAL-SPEED = 2
::BEFORE-ACTOR-DESIRED-SPEED = .5
::BEFORE-ACTOR-DISTANCE-FOR-SLOW-DOWN = 1.5
::BEFORE-ACTOR-DISTANCE-FOR-STOP = 0

::DURING-ACTOR-ACTION = 'agent-approach-speed-up
::DURING-ACTOR-SPEED-UP-START-TIME = 'self
::DURING-ACTOR-SPEED-UP-END-TIME = .4
::DURING-ACTOR-ORIGINAL-SPEED = 'self
::DURING-ACTOR-DESIRED-SPEED = 6
::DURING-ACTOR-SELF-WAIT = .6
::DURING-2-ACTOR-ACTION = 'agent-halt
::DURING-2-ACTOR-SELF-WAIT = .5

::AFTER-SUBJECT-ACTION = 'agent-coast
::AFTER-ACTOR-ACTION = 'agent-run-away-speed-up
::AFTER-ACTOR-SPEED-UP-START-TIME = 'self
::AFTER-ACTOR-SPEED-UP-END-TIME = 1
::AFTER-ACTOR-ORIGINAL-SPEED = 'self
::AFTER-ACTOR-DESIRED-SPEED = 2
::AFTER-2-SUBJECT-ACTION = 'agent-halt
::AFTER-2-ACTOR-SELF-WAIT = 1
Correlating Word Vectors and Movie Vectors

Calculate similarities of pairs of word vectors and pairs of movie vectors

Rank pairs by similarity according to each

Compare the rankings

AD, BC, AE, BD, ..., BE

AD, CD, AE, BC, ..., AB
Correlating Word Vectors and Movie Vectors

Each pair of movies i,j gets two similarity scores

\[ \text{Sim}_{\text{Movies}}(i,j) \] based on movie parameter vectors

\[ \text{Sim}_{\text{Words}}(i,j) \] based on word probability vectors

The correlation of these scores is 0.949
Conclusions

• The distributions of words used by children (mean age 50 months) to describe movies are not independent of the parameters of the behaviors in the movies
• Aspects of behaviors seen in movies give rise to different word distributions
• Weak evidence that Maps for Verbs framework describes behaviors that give rise to different word distributions

• Associative learning hypothesis: Children and perhaps robots might learn word meanings by associating words with events and objects in the present scene
• What about hidden aspects of word meaning, e.g., antonymy?
Related work – Cannon, Cohen, Morrison

• Each of 44 adult subjects saw 18 movies
• Each was asked to write about
  – 1. What are the balls doing in this movie? (Give your overall impression of what was happening between them, the ‘gist’)
  – 2. What is the red ball doing?
  – 3. What is the blue ball doing?
  – 4. Can you think of any words to describe the tone or the mood of the movie? (e.g., the balls are friendly/ not friendly)
• We canonicalized all words – pushed, push, pushing -> pushing
• We selected 65 verbs, those used by at least 10 subjects