Symbol interdependency in conceptual processing
(or: language encodes perceptual relations)

Max Louwerse
Tilburg Center of Cognition and Communication
Tilburg University

We are cognitively lazy, yet we know many concepts...
How do we do it?

Concept/language acquisition device?
Massive computational power?
Incredible memory skills?
Something else? Language perhaps?

There is another possibility that has been almost entirely overlooked, and it is the point of the remainder of this chapter to explore it. I think Chomsky and his followers have articulated a correct view about language learning, but they offer an answer that inverts cause and effect. I hypothesize that the source of prior support for language acquisition must originate from inside the brain, on the uninitiated assumption that there is no other possible source. But there is another alternative: that the extra support for language learning is vested neither in the brain of the child nor in the brains of parents or teachers, but outside brains, in language itself. To explain what I mean, I begin by offering a couple of extended analogies that I think portray a similar problem. I'll start with a computer analogy.

Deacon (1997)

Conclusion

• The support for language comprehension and language production should not only be explained by the brain of the language user, perceptual experiences, or computational processes, but also in language itself.

Embodied relations are encoded in language

Max M. Louwerse
University of Tilburg, Tilburg, Netherlands

Jeuniaux, 2006). That is, pre-linguistic conceptual knowledge (spatial iconicity) used when speakers formulate utterances gets translated into linguistic conceptualizations (word order patterns; Levelt, 1989), so that as a function of language use, embodied relations are encoded in language. Indeed, embodiment studies have shown a recognition of the environment (Pinker & Bloom, 2004). These theories of cognition as guided by the laws of representational systems have been explored. For these systems, the language is the language, the symbols, and the language is an abstraction of the world. According to the theory, the symbols in the mind are used as the abstraction in the brain, and the symbols are used to understand the world. According to the theory, the symbols in the mind are used as the abstraction in the brain, and the symbols are used to understand the world. According to the theory, the symbols in the mind are used as the abstraction in the brain, and the symbols are used to understand the world. According to the theory, the symbols in the mind are used as the abstraction in the brain, and the symbols are used to understand the world.

Symbol Interdependency Hypothesis

Symbolic relations between symbols

Perceptual world

Louwerse (2011). Topics
Symbol Interdependency Hypothesis

- Language encodes the perceptual world
- Language has evolved into an efficient communicative tool
- Limited symbol grounding allows language users to bootstrap meaning through language statistics
- Language users rely on language statistics and perceptual simulation depending on the cognitive task, stimulus, individual differences, etc.
- Humans are great at picking up language statistics, because we excel in pattern matching (and language processing)
- Language statistics provide a short-cut to good-enough (not deep, precise and detailed) representations

- Language statistics explain conceptual representations
  - Louwerse & Jeuniaux, 2010
- Language statistics explain good-enough conceptual representations
  - Louwerse & Connell, 2011
- Language statistics explain numerical representations
  - Hutchinson & Louwerse, 2013
- Language statistics explain geographical representations
  - Louwerse & Zwaan, 2009; Louwerse & Benesh, 2012

Overview

- Experiment 1
- Experiment 2
- Experiment 3
- Experiment 4
• **Linguistic factor:** log frequency of a-b (e.g., monitor-keyboard) and b-a (e.g., keyboard-monitor) order of word pairs → Web 1T 5-gram corpus (Brants & Franz, 2006)

• **Embodiment factor:** Iconicity ratings of the likelihood that concepts appeared above one another in the real world by 24 participants
  — High interrater reliability \( r = .76, p < .001 \)

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**Explanation?**

• **Both** linguistic and embodied factors explain conceptual processing

• The relative effect of linguistic and embodied factors depends on stimulus and cognitive task

• **Why?**
  
  Linguistic factors dominate in shallow cognitive tasks, whereas embodiment factors dominate in deeper cognitive tasks (Louwerse & Jeuniaux, 2008; 2010).

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**A Taste of Words: Linguistic Context and Perceptual Simulation Predict the Modality of Words**

Max Louwerse, Louise Connell

Department of Psychology, University of Montana

Abstract

Previous studies have shown that object properties are processed faster when they follow properties from the same perceptual modality than properties from different modalities. These findings suggest that language activates ideomotor processes, which, according to these studies, can only be explained by a mental model of cognition. The current paper shows how a statistical linguistic approach of word co-occurrence can also reliably predict the category of perceptual modality a word belongs to (auditory, efficacy-perceptual, visual-kinetic). Even though the statistical linguistic approach is less precise than the mental approach (auditory, efficacy, perceptual, visual), it shows how the statistical linguistic approach is comparable with the mental embodied approach in an experiment in which participants verify properties that short or slow modifications. Response times suggest that fast responses can best be explained by the linguistic account, whereas slow responses can explain their slower responses.

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**Neurological evidence linguistic processes precede perceptual simulation in conceptual processing**

Max Louwerse and Sterling Hartshorne

Department of Psychology, University of Montana, Missoula, MT, USA

INTRODUCTION

Conventional processing the perceptual simulations. For instance, people easily read the words in the left panel. The general trend observed above the floor processing relation when the experimenter often than when the words are presented in the internal order. (Louwerse & Connell, 2011. Cogn. Sci.)

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Previous studies have shown that object properties are processed faster when they follow properties from the same perceptual modality than properties from different modalities. These findings suggest that language activates ideomotor processes, which, according to these studies, can only be explained by a mental model of cognition. The current paper shows how a statistical linguistic approach of word co-occurrence can also reliably predict the category of perceptual modality a word belongs to (auditory, efficacy-perceptual, visual-kinetic). Even though the statistical linguistic approach is less precise than the mental approach (auditory, efficacy, perceptual, visual), it shows how the statistical linguistic approach is comparable with the mental embodied approach in an experiment in which participants verify properties that short or slow modifications. Response times suggest that fast responses can best be explained by the linguistic account, whereas slow responses can explain their slower responses.
SNARC has been attributed to perceptual simulation

Strong negative correlation between magnitude and frequency

Could frequency of the number explain SNARC?
Experiment 1

Bigrams also explained RTs, $F(1, 3072.72) = 4.12, p = .04$, $R^2 = .14$
• Bigrams also explained RTs, F(1, 2098) = 42.22, p < .001, R^2 = .53

• But if frequency can explain RTs, how can frequency explain handedness in SNARC?

<table>
<thead>
<tr>
<th>Instrument Words</th>
<th>Log Frequency</th>
<th>Action Words</th>
<th>Log Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>book</td>
<td>16.26</td>
<td>eat</td>
<td>15.77</td>
</tr>
<tr>
<td>big</td>
<td>16.75</td>
<td>hear</td>
<td>15.97</td>
</tr>
<tr>
<td>empty</td>
<td>16.63</td>
<td>hear</td>
<td>15.36</td>
</tr>
<tr>
<td>angry</td>
<td>16.70</td>
<td>here</td>
<td>15.36</td>
</tr>
<tr>
<td>sad</td>
<td>16.78</td>
<td>hurry</td>
<td>15.45</td>
</tr>
<tr>
<td>way</td>
<td>16.69</td>
<td>how</td>
<td>15.95</td>
</tr>
<tr>
<td>sell</td>
<td>16.19</td>
<td>child</td>
<td>15.18</td>
</tr>
<tr>
<td>give</td>
<td>15.94</td>
<td>deal</td>
<td>15.53</td>
</tr>
<tr>
<td>get</td>
<td>17.20</td>
<td>dog</td>
<td>16.71</td>
</tr>
<tr>
<td>happy</td>
<td>16.45</td>
<td>from</td>
<td>16.06</td>
</tr>
<tr>
<td>angry</td>
<td>16.21</td>
<td>fish</td>
<td>15.80</td>
</tr>
<tr>
<td>leer</td>
<td>16.40</td>
<td>famous</td>
<td>17.84</td>
</tr>
<tr>
<td>worry</td>
<td>16.35</td>
<td>girl</td>
<td>16.99</td>
</tr>
<tr>
<td>riot</td>
<td>16.19</td>
<td>hot</td>
<td>15.88</td>
</tr>
<tr>
<td>mark</td>
<td>19.06</td>
<td>house</td>
<td>16.37</td>
</tr>
<tr>
<td>number</td>
<td>20.37</td>
<td>human</td>
<td>16.71</td>
</tr>
<tr>
<td>possess</td>
<td>17.30</td>
<td>hand</td>
<td>15.77</td>
</tr>
<tr>
<td>plan</td>
<td>17.45</td>
<td>him</td>
<td>15.60</td>
</tr>
<tr>
<td>gym</td>
<td>17.17</td>
<td>inc</td>
<td>16.62</td>
</tr>
<tr>
<td>ask</td>
<td>18.86</td>
<td>her</td>
<td>15.65</td>
</tr>
<tr>
<td>use</td>
<td>17.83</td>
<td>percent</td>
<td>16.09</td>
</tr>
<tr>
<td>ring</td>
<td>18.15</td>
<td>percent</td>
<td>16.09</td>
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<tr>
<td>close</td>
<td>16.87</td>
<td>plant</td>
<td>15.30</td>
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<tr>
<td>camp</td>
<td>17.82</td>
<td>prog</td>
<td>16.07</td>
</tr>
<tr>
<td>create</td>
<td>15.70</td>
<td>rue</td>
<td>17.41</td>
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<tr>
<td>summarise</td>
<td>16.24</td>
<td>real</td>
<td>16.65</td>
</tr>
<tr>
<td>two</td>
<td>16.70</td>
<td>sleep</td>
<td>16.35</td>
</tr>
<tr>
<td>make</td>
<td>20.65</td>
<td>true</td>
<td>16.35</td>
</tr>
<tr>
<td>right</td>
<td>16.20</td>
<td>woman</td>
<td>16.75</td>
</tr>
<tr>
<td>ice</td>
<td>16.40</td>
<td>women</td>
<td>16.75</td>
</tr>
</tbody>
</table>

Nijmegen – Toronto (Canada)
• Geographical knowledge can come from pictorial representations and language (Montello & Freundschuh, 1995)
• Implausible that people process descriptions of the relation of each individual city to every other city
• If they did, that mapping process would become a combinatorial explosion
• Unless language has intrinsically encoded geographical information
• Language users are continuously exposed to geographical information in both production and comprehension

Geographical information
• To what extent can geographical (=world) information be extracted from linguistic information, even though the linguistic information does not necessarily consist of spatial descriptions
• Hypothesis: Cities that are located together are debated together

Method
• Geographical locations
• LSA cosine values between cities (50 x 50 matrix)
• Matrix submitted to MDS ALSCAL algorithm
Latent Semantic Analysis

• Latent semantic analysis (LSA) is a statistical, corpus based, technique for representing world knowledge that estimates semantic similarities on a scale of -1 to 1 between the latent semantic structure of terms, paragraphs, or texts

(Landauer, et al. 2007)

Method

• New York Times, Wall Street Journal, Los Angeles Times

• Newspapers did not describe geographical information *per se*

• New York – New Orleans – new song – new movie

(Louwerse & Zwaan, 2009)

Bidimensional regressions for the newspaper estimates and the actual coordinates

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Street Journal</td>
<td>.529**</td>
</tr>
<tr>
<td>New York Times</td>
<td>.277*</td>
</tr>
<tr>
<td>Los Angeles Times</td>
<td>.427**</td>
</tr>
</tbody>
</table>

Note. "" p < .01, "" p < .05.

Correlations between human and LSA

<table>
<thead>
<tr>
<th></th>
<th>Human longitude estimates – Newspaper estimates</th>
<th>Human latitude estimates – Newspaper estimates</th>
<th>Bidimensional regressions</th>
<th>Human – LSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Street Journal</td>
<td>.588**</td>
<td>.400**</td>
<td>.497**</td>
<td></td>
</tr>
<tr>
<td>New York Times</td>
<td>.415**</td>
<td>.590**</td>
<td>.337**</td>
<td></td>
</tr>
<tr>
<td>Los Angeles Times</td>
<td>.411**</td>
<td>.456**</td>
<td>.427**</td>
<td></td>
</tr>
</tbody>
</table>

Note. "" p < .01, "" p < .05.

(Louwerse & Zwaan, 2009)

But...

• Results come from LSA...

algorithm to derive a Multidimensional Scaling (MDS) representation of the stimuli. Values were standardized on a ±1 to 1 scale before the computation of proximities. The fitting of the data was poor (Stress = .402, R² = .232). Nevertheless, stimulus coordinates across cities were compared with the actual longitude and latitude, as in Study 1a. Dimension 1 correlated with actual longitude (r = .36, p = .01, n = 50), and Dimension 2 correlated with actual latitude (r = .32, p = .02, n = 50). Bidimensional regressions showed similar results (r = .32, p < .01, n = 50). Those results are comparable to those obtained using LSA (longitude: r = .32 vs .29–.61 vs. 32; latitude: .32–.44 vs .32; bidimensional regression: .28–.52 vs. .32), with one important difference, which is the strength of higher-order co-occurrence algorithms over a first-order co-occurrence algorithm: the corpus used in the current analysis was 250,000 times larger than the corpora used in the LSA analyses.
But…

- Results come from English…
- LSA Space of the Chinese Wikipedia
  - MDS: Stress value = .33 and an $R^2 = .59$
  - Latitude – dimension 1; $r = .64, p < .001, n = 50$
  - Longitude – dimension 2; $r = .33, p = .02, n = 50$
- Bidimensional regression analysis
  - $r = .57, p < .001, n = 50$
  - Frequency and population size: $r = .47, p < .001, n = 50$

- LSA Space using Arabic Wikipedia
  - Stress = .35, $R^2 = .69$
  - Latitude – dimension 1; $r = .41, p < .001, n = 50$
  - Longitude – dimension 2; $r = .57, p < .001, n = 50$
- Bidimensional regression analysis
  - $r = .57, p < .001, n = 50$
  - Frequency and population size: $r = .61, p < .001, n = 50$
Question

• Where do people get geographical knowledge from?

– Can they get geographical information from language?

– Do they get geographical information from language?

How to distinguish geographical knowledge from text vs. maps?

• Not a ‘real’ world to avoid information came from maps, static and dynamic pictures, transportation

• Text that has already been read to avoid undesirable experimental conditions

Geographical estimates

• Study 1
  – Human estimates based on map

• Study 2
  – Computer estimates based on text

• Study 3
  – Human estimates based on text

Louwerse & Benesh (2012)
<table>
<thead>
<tr>
<th>Study 1</th>
<th>Bidimensional regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human estimates based on map</td>
<td>$r = .82^{**}$ (SD = .20)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study 2</th>
<th>Bidimensional regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational estimates based on text</td>
<td>$r = .46^{**}$</td>
</tr>
<tr>
<td>Random -- Monte Carlo simulations</td>
<td>$r = .16$ (SD = .08)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study 3</th>
<th>Bidimensional regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human estimates based on text</td>
<td>$r = .78^{**}$ (SD = .12)</td>
</tr>
</tbody>
</table>

- Across 11 LOTR editions we looked at, less than a third of the cities were displayed on maps, $M = 10$ (SD = 7.51).
- No difference in performance between those who frequently consulted the maps and those who didn’t.

- In the Lord of the Rings movies only 8 out of the 32 cities were mentioned in dialogue.
- A map of Middle Earth with city names was presented a total of three times, each for less than 30 seconds.
- When a map was shown, only nine cities could be distinguished.
Conclusion I

• Language encodes geographical information
  – Longitude and latitude can be estimated from language
  – Population size can be estimates from language

• These findings cannot be explained by
  – Techniques such as LSA (also 1st order co-occurrences)
  – Language (English, Chinese, Arabic)
  – Genre (newspapers, Wikipedia, novels)
  – Geography (US, China, Middle East, Middle Earth)

Conclusion II

• Language statistics explain conceptual processing because language encodes perceptual information (e.g., spatial relations, modalities, numerical, geography)

• Shallow, good-enough processes are best explained by language statistics and deeper, detailed processes best explained by perceptual simulation

• This is modulated by cognitive task and stimulus

Conclusion

• The support for language comprehension and language production should not only be explained by the brain of the language user, perceptual experiences, or computational processes, but also in language itself

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