Size Matters: Effects of Relative Distance on the Acceptability of Spatial Prepositions

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Introduction // Spatial Preposition Processing

1. **world-knowledge**
   (e.g., Carlson-Radvansky, Covey, & Lattanzi, 1999; Coventry & Garrod, 2004; Coventry, Prat Sala, & Richards, 2001; Hörberg, 2008)

(image source: Coventry et al., 2001, p. 381)
1. **world-knowledge**  
(e.g., Carlson-Radvansky, Covey, & Lattanzi, 1999; Coventry & Garrod, 2004; Coventry, Prat Sala, & Richards, 2001; Hörberg, 2008)

2. **geometric properties**  
(e.g., Gapp, 1995; Hayward & Tarr, 1995; Kelleher, Ross, Sloan, & Namee, 2011; Logan & Sadler, 1996; Regier & Carlson, 2001; Schultheis & Carlson, 2017)
Introduction // Spatial Preposition Processing

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- **debate about interaction**
  (e.g., Carlson, Regier, Lopez, & Corrigan, 2006; Coventry et al., 2010; Landau, 2016)

(image sources: Coventry et al., 2001, p. 381; Regier & Carlson, 2001, p. 288)
Introduction // Spatial Preposition Processing

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(image sources: Coventry et al., 2001, p. 381; Regier & Carlson, 2001, p. 288)
"The X is above the O."

(Logan & Sadler, 1996)

(image source: Carlson & Logan, 2005, p. 332; data from Logan & Sadler, 1996)
Attentional Vector Sum (AVS) model (Regier & Carlson, 2001)

- input: LO, RO, & preposition
- output: acceptability rating

AVS:
Introduction // Attention and Computational Models

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- **central mechanism**: attention (e.g., Carlson & Logan, 2005; Logan, 1994, 1995; Logan & Sadler, 1996)
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“Die Box ist über der Wurst”
‘The box is above the sausage’

(image source: Burigo & Knoeferle, 2015, p. 6)
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**AVS:**

- LO
- vector sum
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- **Reversed AVS (rAVS) model** (Kluth, Burigo, & Knoeferle, 2017)
Geometric Properties

LO

\( \delta_c = \Rightarrow \) larger rating

rAVS: relative distance

\( \times \) reference direction

(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

- center-of-mass orientation

\[ \delta_c = \Rightarrow \text{larger rating} \]

\[ r_{AVS}: \text{relative distance} \]

(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

- center-of-mass orientation
- proximal orientation

(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

- center-of-mass orientation
- proximal orientation

smaller $\delta \implies$ larger rating

\[ r_{AVS} = \text{relative distance} \]

Regier, 1996; Regier & Carlson, 2001

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(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

- center-of-mass orientation
- proximal orientation
- smaller $\delta \implies$ larger rating
- rAVS: relative distance

(Regier, 1996; Regier & Carlson, 2001)
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(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

- center-of-mass orientation
- proximal orientation
- smaller $\delta \Rightarrow$ larger rating
- rAVS: relative distance

1. [Diagram of geometric properties with labels LO, CoM, RO, $\delta_p$, $\delta_c$, and reference direction]

2. (Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

1. center-of-mass orientation
2. proximal orientation
3. rAVS: relative distance

smaller $\delta \implies$ larger rating

(Regier, 1996; Regier & Carlson, 2001)
Geometric Properties

1. center-of-mass orientation
2. proximal orientation
3. rAVS: relative distance

smaller $\delta \implies$ larger rating

1. not today
2. empirical data

(Regier, 1996; Regier & Carlson, 2001)
Stimuli // Effect of Center-of-Mass Orientation

The dot is above the object.

→ difference in acceptability?
Stimuli // Effect of Center-of-Mass Orientation

center-of-mass orientation: known effect on acceptability
(Regier, 1996; Regier & Carlson, 2001)
lower $\delta \Rightarrow$ higher acceptability
$\Rightarrow$ higher ratings for taller rectangles

The dot is above the object.
rAVS model // Role of Relative Distance

modulated by relative distance

(Kluth, Burigo, & Knoeferle, 2017)
rAVS model // Role of Relative Distance

example
relative distance := 1.0

(Lkuth, Burigo, & Knoeferle, 2017)
rAVS model  // Role of Relative Distance

example
relative distance := 1.0

example
relative distance := 0.3

(Kluth, Burigo, & Knoeferle, 2017)
rAVS model // Role of Relative Distance

example
relative distance := 1.0

example
relative distance := 0.3

lower relative distance
⇒ lower δ
⇒ higher rating

(Kluth, Burigo, & Knoeferle, 2017)
relative distance $= \frac{d_y}{h} + \frac{d_x}{w}$

taller rectangle $\implies$ lower relative distance $\implies$ lower $\delta$ $\implies$ higher acceptability
Relative distance \( \frac{d_y}{h} + \frac{d_x}{w} \)

Relative distance \( \Rightarrow \)

Higher ratings for taller rectangles
center-of-mass orientation & relative distance $\implies$ higher ratings for taller rectangles
The dot is above the object. / The dot is below the object.

4 rectangles × 2 prepositions (über, unter)
4 rectangles $\times$ 2 prepositions ($\text{"uber}$, $\text{"unter}$) $\times$ 18 locations

- 34 subjects, 1–9 rating scale
Predictions

- taller rectangle $\implies$ higher rating
- rAVS: relative distance modulates effect of center-of-mass orientation
Results: Rating patterns by type of RO

- Thin
- Thick
- Square
- Tall

Acceptability rating vs. proportion

Regression model pred. w/ 95% prob. mass
Emp. data
Results // Effect of Relative Distance

![Graph showing the effect of relative distance on acceptability rating. The x-axis represents center-of-mass orientation (in radian, centered), and the y-axis represents acceptability rating. The graph shows a trend where the acceptability rating decreases as the center-of-mass orientation increases.](image-url)
Results // Effect of Relative Distance

![Graph showing the effect of relative distance on acceptability rating](image)

- **mean rel. dist., thin rect.**
- **mean rel. dist., thick rect.**

Center-of-mass orientation (in radian, centered) vs. acceptability rating.
Results // Effect of Relative Distance

- mean rel. dist., thin rect.
- mean rel. dist., thick rect.
- mean rel. dist., square
- mean rel. dist., tall rect.

Acceptability rating:

- Center-of-mass orientation (in radian, centered)

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Conclusions

question

1. higher ratings for taller rectangles?

outcome

1. no
Conclusions

question

1. higher ratings for taller rectangles?
2. effect of relative distance?

outcome

1. no
2. yes, larger relative distance $\implies$ larger effect of CoM-orientation

smaller rectangles
Conclusions

question

1. higher ratings for taller rectangles?
2. effect of relative distance?
3. ... as described by rAVS?

outcome

1. no
2. yes, larger relative distance $\Rightarrow$ larger effect of CoM-orientation
3. partially; contrasting evidence for effect of proximal orientation; read Kluth, Burigo, Schultheis, and Knoeferle (submitted) for details
Thank you!

References


rAVS model // Role of Relative Distance

larger relative distance
⇒ higher importance of CoM orientation
lower relative distance
⇒ higher importance of proximal orientation

(Kluth, Burigo, & Knoeferle, 2017)
More LOs // Adding Proximal Orientation
Results: Rating patterns by type of RO, all LOs

- Thin
- Thick
- Square
- Tall

Rating vs. Proportion

- Model pred. w/ 95% prob. mass
- Emp. data
Results // Interactions I

![Graph showing the mean relative distance of thin and tall rectangles as a function of proximal orientation. The x-axis represents proximal orientation in radians, centered. The y-axis represents acceptability rating. The graph compares CoM orientation mean thin rect. and mean tall rect.]

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Results // Interactions I

![Graph showing mean relative distance for thin and thick rectangles with CoM orientation contrast]

- **mean relative distance, thin rect.**
- **mean relative distance, thick rect.**

**Acceptability rating** vs **proximal orientation (radian, centered)**

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Results // Interactions I

CoM orientation
- mean thin rect.
- mean tall rect.

mean relative distance, thin rect.
mean relative distance, thick rect.
mean relative distance, square
mean relative distance, tall rect.

acceptability rating

proximal orientation (radian, centered)
Results // Interactions II

- **Higher center-of-mass orientation** → **Higher rating**
- Reversing the effect of the center-of-mass orientation!

**Graph Details:**
- **Mean prox. orient., col. C2-C7**
- **Acceptability rating**
- **Relative distance**
  - Mean tall rect.
  - Mean square
  - Mean thick rect.
  - Mean thin rect.
- **Center-of-mass orientation (radian, centered)**
Results // Interactions II

Higher center-of-mass orientation ⇒ higher rating

reversing the effect of the center-of-mass orientation!
## Conclusions II

### Question

<table>
<thead>
<tr>
<th>1. higher ratings for taller rectangles?</th>
<th>2. effect of relative distance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. no</td>
<td>2. yes, larger relative distance $\implies$ ...</td>
</tr>
</tbody>
</table>

### Outcome

<table>
<thead>
<tr>
<th>w/o prox. orient</th>
<th>w/ prox. orient</th>
</tr>
</thead>
<tbody>
<tr>
<td>larger effect of CoM-orientation</td>
<td>1. larger effect of prox. orientation</td>
</tr>
<tr>
<td></td>
<td>2. larger reversed effect of CoM-orientation</td>
</tr>
</tbody>
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3. ... as described by rAVS?

3. no, read Kluth, Burigo, Schultheis, and Knoeferle (submitted) for details
Asymmetrical ROs

(a) Mean ratings for LOs above the L RO

(b) Mean ratings for LOs above the nL RO

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