Beyond physical robots: How to achieve joint spatial reference with a smart environment

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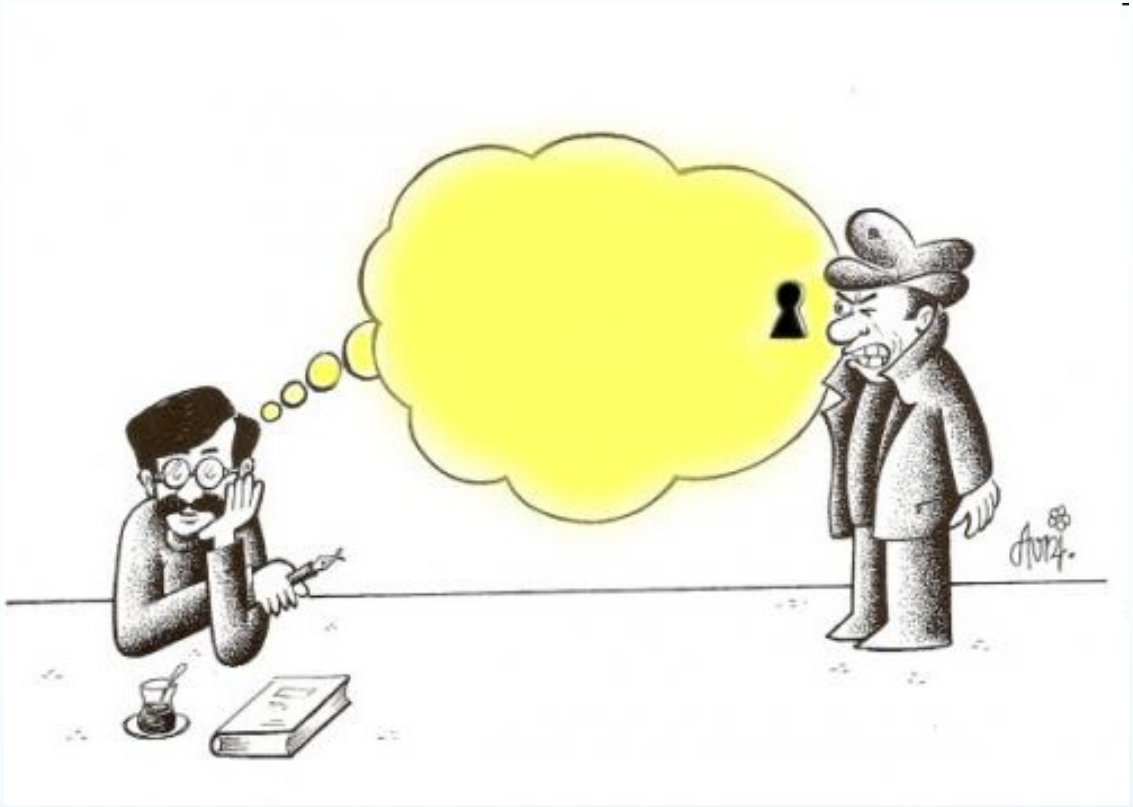
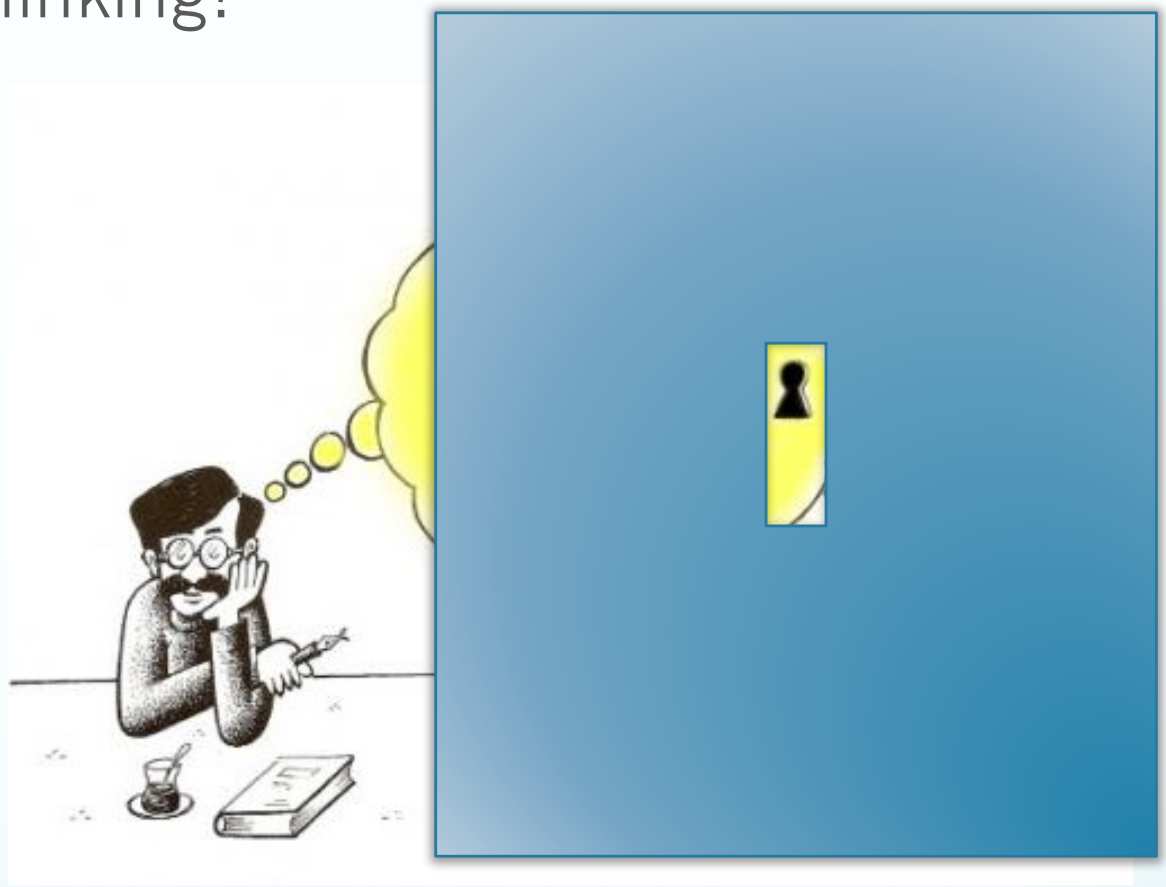
"What are you thinking?"



Spatial language represents spatial thinking...

"What are you thinking?"



... but what if you're talking to an automatic system?

Outline

- Spatial reference: Ubiquitous – and challenging
  - Agreeing about orientation in dialogue
  - Identifying a perspective in sailing
  - Finding a reference frame when oriented in a different way
  - Agreeing on a reference frame between languages
- Smart environments: Features – and more challenges
- A solution (?) – open for discussion!

Spatial language and cognition

- Fundamental
  - Space is a basic human conceptual domain
  - How we understand space affects / reflects our life and thinking
  - Language reflects human spatial cognition
    - E.g., schematic & functional nature of spatial terms
- Ubiquitous
  - Everyday language contains much information about spatial positions / relative locations etc.
  - Transferred usage in more abstract domains

Challenge 1:

Agreeing about orientation in dialogue

Object Orientation in dialogue

A case study of
spatial inference processes

Schole, Gesa, Tenbrink, Thora, Andonova, Elena, and Coventry, Kenny. 2018. Object orientation in dialogue: A case study of spatial inference processes. *Spatial Cognition 2018*. Berlin: Springer, pp. 92-106.

Moving house...

Spatial reference

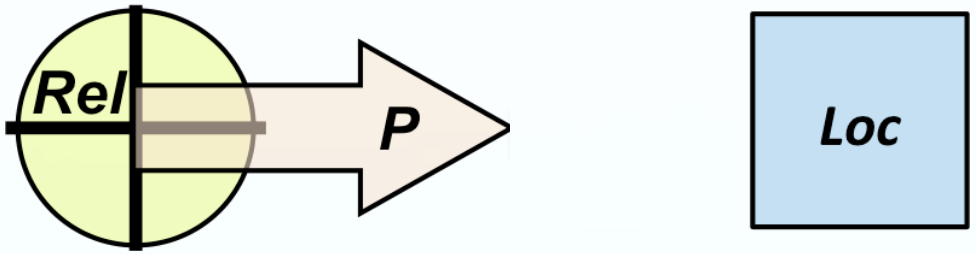
- Many different kinds
- Much evidence for effects of functional relationships

→ Does the man sit under the umbrella?

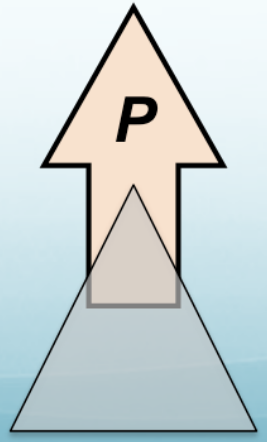
- Projective terms like in front of, to the right of require a perspective

Projective term based basic reference frames

- Intrinsic



- Relative



Tenbrink, Thora. 2011. Reference frames of space and time in language. *Journal of Pragmatics 43*:3, 704-722.

How do we refer to object orientation?

- The sofa's back is along the left wall.
- The chair is oriented towards the table.

→ Establishes orientation information by reference to a relatum

- The chair points to the right.

→ Uses a projective term. Whose perspective is being used?

- The chair's back points north.

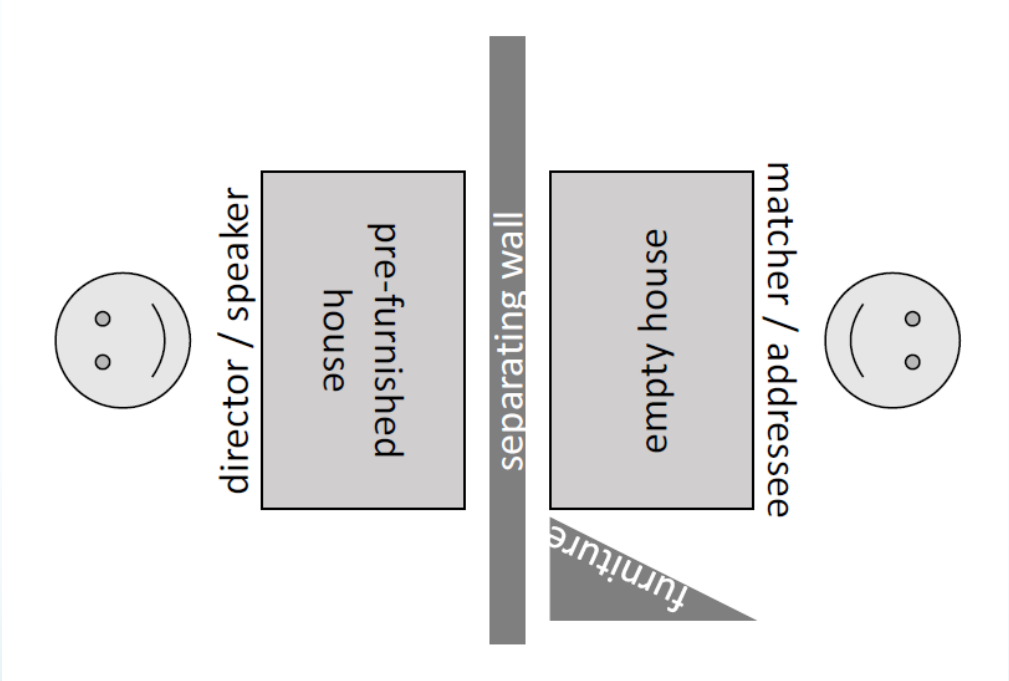
→ Uses an absolute reference frame (compass based), unambiguous

Relevant questions

- How explicit are we in dialogue, and what does this depend on?
- How much information do we need
  – under what circumstances does communication fail?

DollDialogue Corpus

Tenbrink et al. 2008 / 2017



Orientation info: Coding for completeness

- Complete: explicit reference to one of its axes and the axes' directedness if applicable, and a fully specified direction.
- Incomplete: if one of the required parameters was missing, such as the underlying perspective for a projective term.
- The orientation of diagonally placed objects was considered as completely described only when diagonality was made explicit.

Coding for completeness

Cond.	Speaker	Orientation Description	Locatum	Locatum's Axes	Direction	Diagonal	Extent Explicitness
F	Director	uh the toilet is uh parallel to the shower practically placed at the back wall	A02	undirected	yes	n.a.	incomplete
F	Director	and the opening points toward the bed, yes	B08	yes	yes	n.a.	complete
F	Director	yes, well, diagonally opposite the wardrobe so beside the armchair there in the corner	B07	no	yes	yes	incomplete
NF	Director	with the blue thing at the wall, right	B05	yes	yes	n.a.	complete
NF	Matcher	so uhm with the back towards me with the	B01	no	yes	n.a.	incomplete
NF	Director	n+ n+ no with the side towards you, and the side towards you	B01	undirected	yes	n.a.	incomplete

Complete Orientation Information

- reference to one of the object‘s (directed) axes + direction (+ relatum)

---

speakerA jetzt haben wir noch diesen bunten Schrank.
[and now we have this colourful cupboard]

speakerB und wohin zeigt das Bunte?
[and where does the colourful side point?]

speakerA das zeigt ins Schlafzimmer.

[it points into the bedroom.]

Complete Orientation Information

- reference to one of the object‘s (directed) axes + direction (+ relatum)

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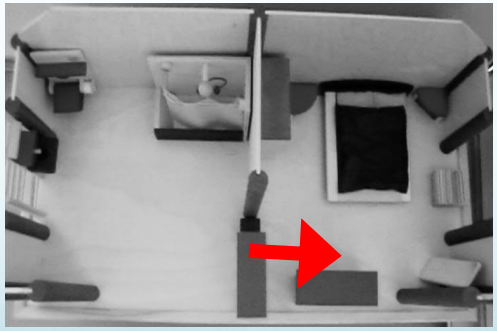
speakerB und wohin zeigt das Bunte?

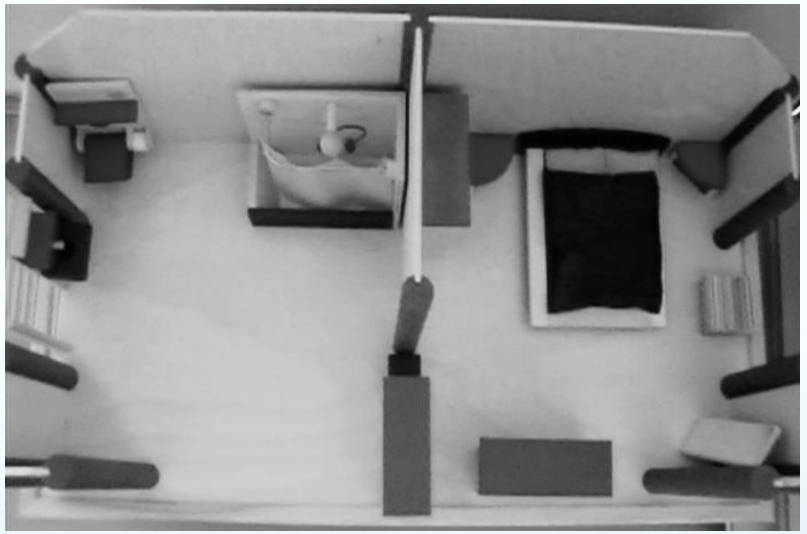
speakerA das zeigt ins Schlafzimmer.



Incomplete orientation information

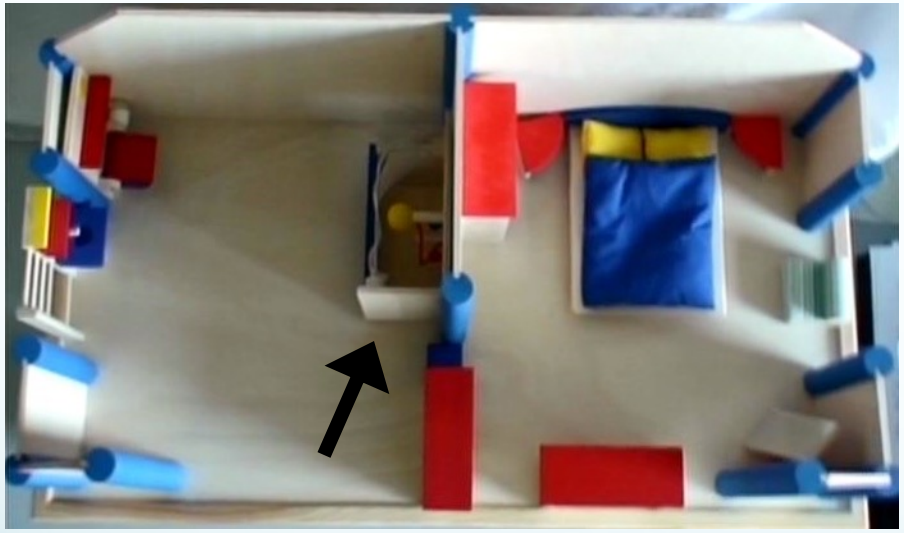
‘put the shower on the middle wall’

speakerA: also erstmal das Obergeschoss in der linken Hälfte steht äh die Dusche. Die Dusche ist an die Mittelwand gestellt.
speakerB: ja Moment ma‘, ähm Mittelwand rechts oder links?
speakerA: äh ja also ah
speakerB: achso an die Mitte
speakerA: die linke Seite an die Mittelwand
speakerB: ah ok ja gut

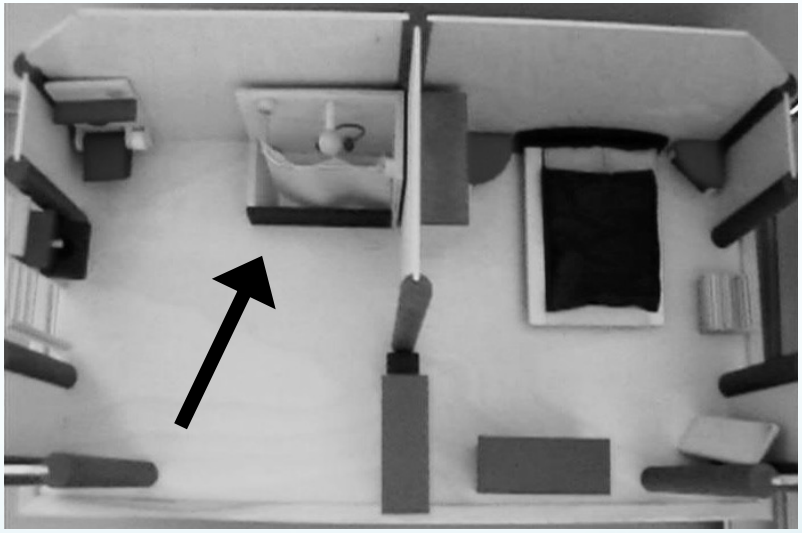


Incomplete orientation information

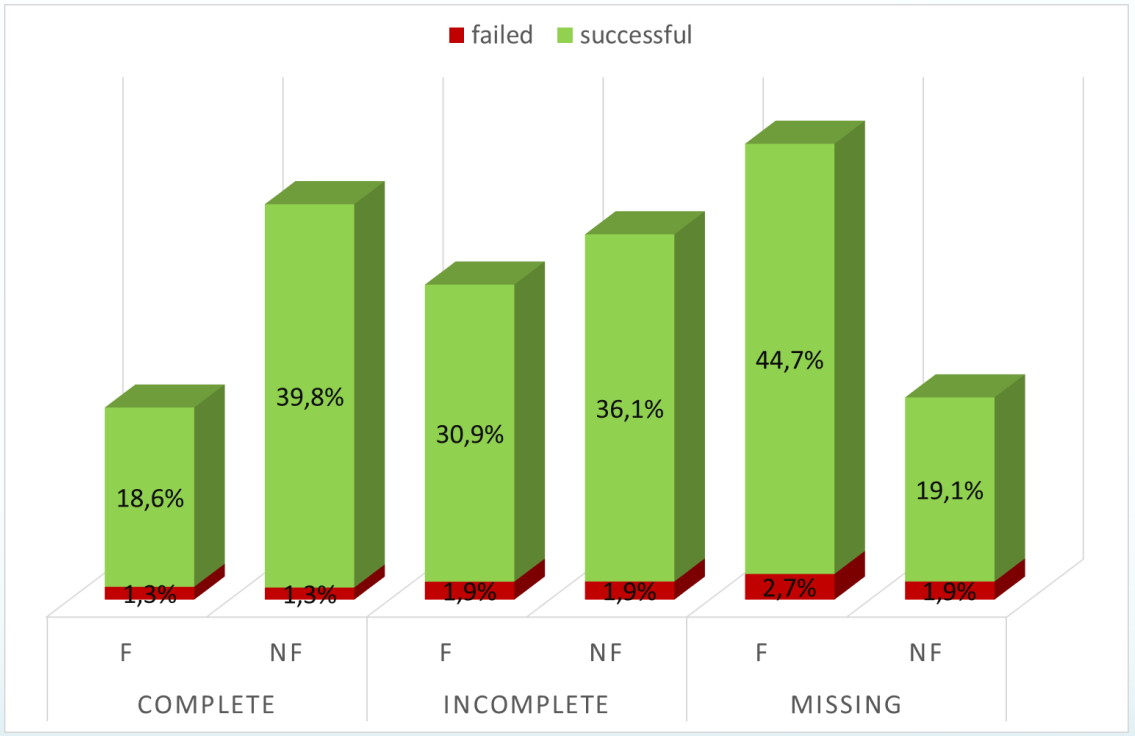
- Participant‘s result



- Model position



Extent of orientation information



Relevant answers

- How explicit are we in dialogue, and what does this depend on?
  - Speakers are only explicit when they feel they need to be. They often assume their interaction partner will know
- How much information do we need
  – under what circumstances does communication fail?
  - Listeners are often able to infer the intended meaning, drawing on background knowledge and shared situational input – common ground.
  - Communication fails when the common ground is not sufficient to interpret the given input

But do we always share common ground?

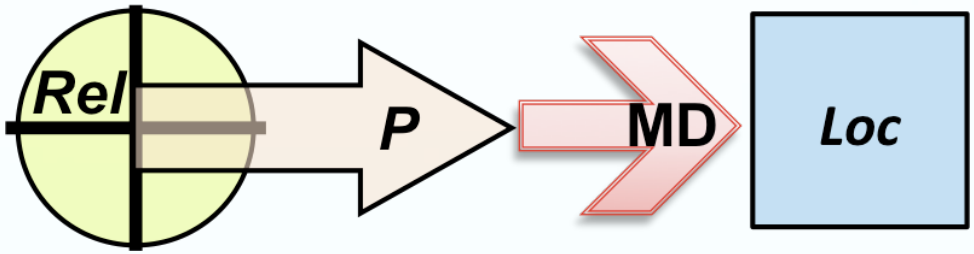
Some examples (of spatial reference) where this may be a bit difficult

Challenge 2:

Identifying a perspective in sailing

Projective term based basic reference frames

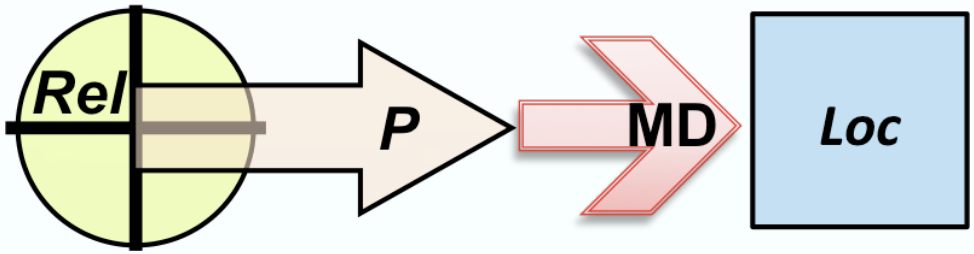
- Intrinsic



Tenbrink, Thora. 2011. Reference frames of space and time in language. *Journal of Pragmatics 43*:3, 704-722.

‘Forward’ in an intrinsic reference frame

- Intrinsic

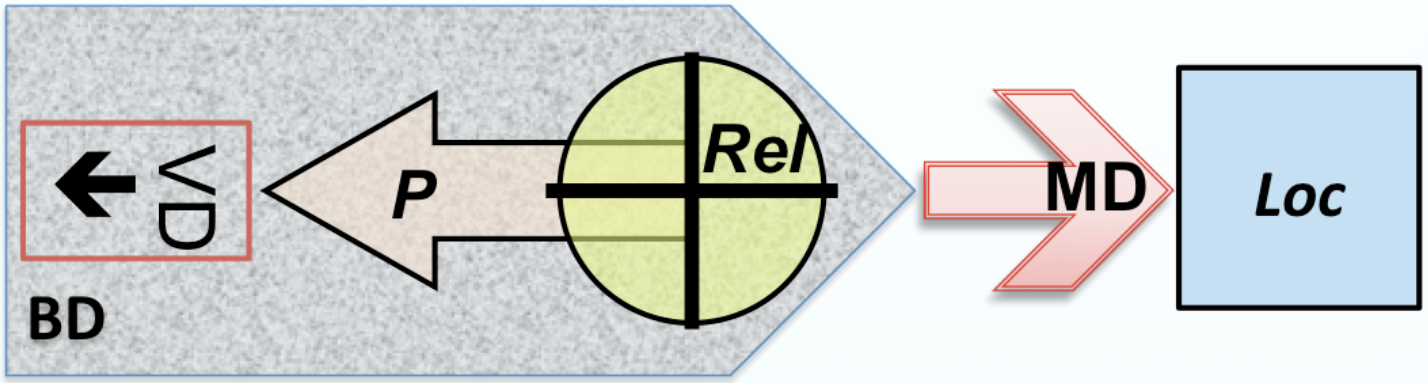


- The movement direction is determined in relation to the **Rel**atum.
  - ‘I am moving to a position (**Loc**atum) that is in front of my previous location, where ‘in front of’ is defined by my view direction.’
- In this case, the speaker is the Relatum in an intrinsic reference system.


facebook.com/leocoastalrowing

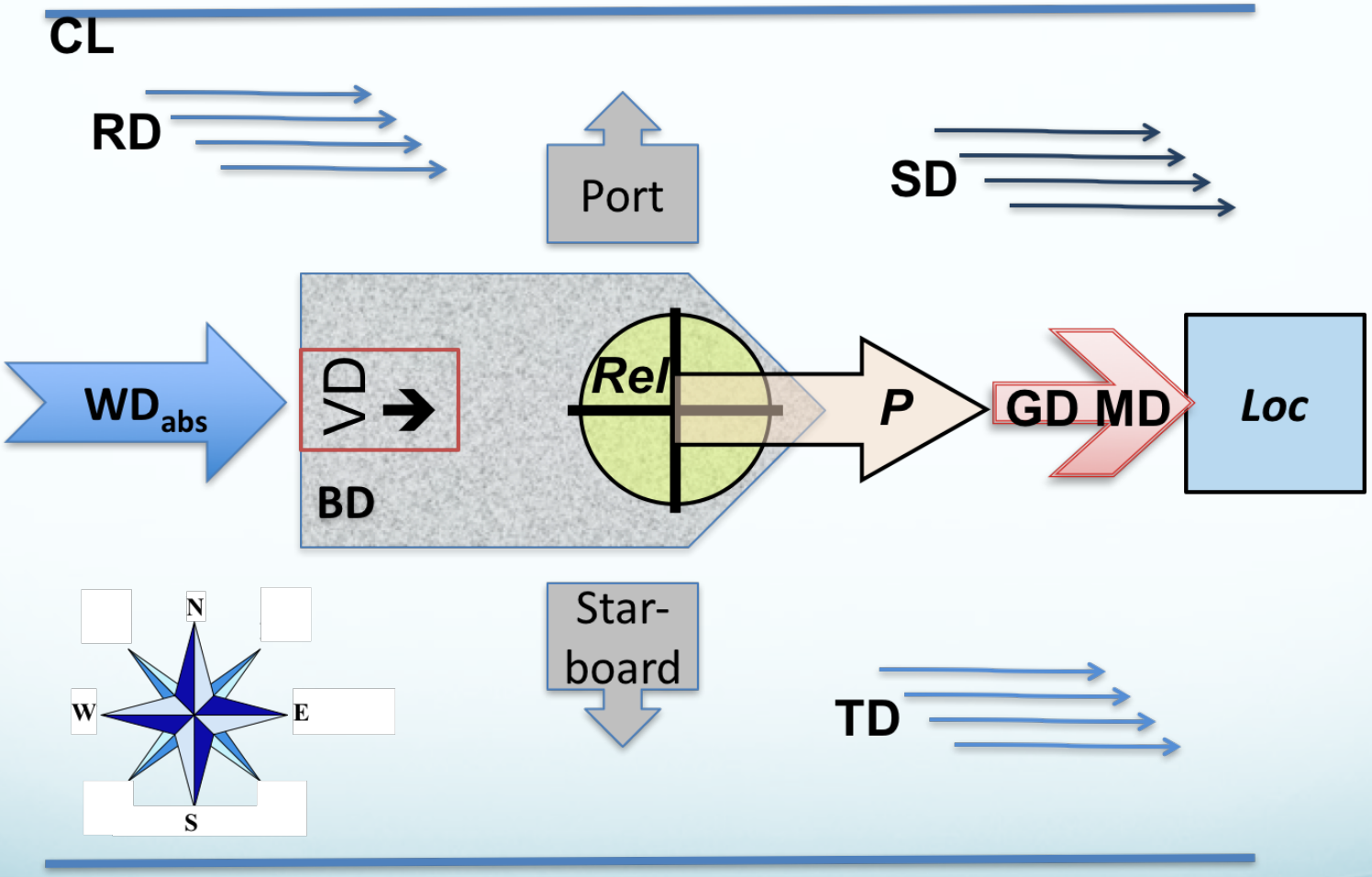
Reference frame for rowing

- Am I rowing forwards or backwards?

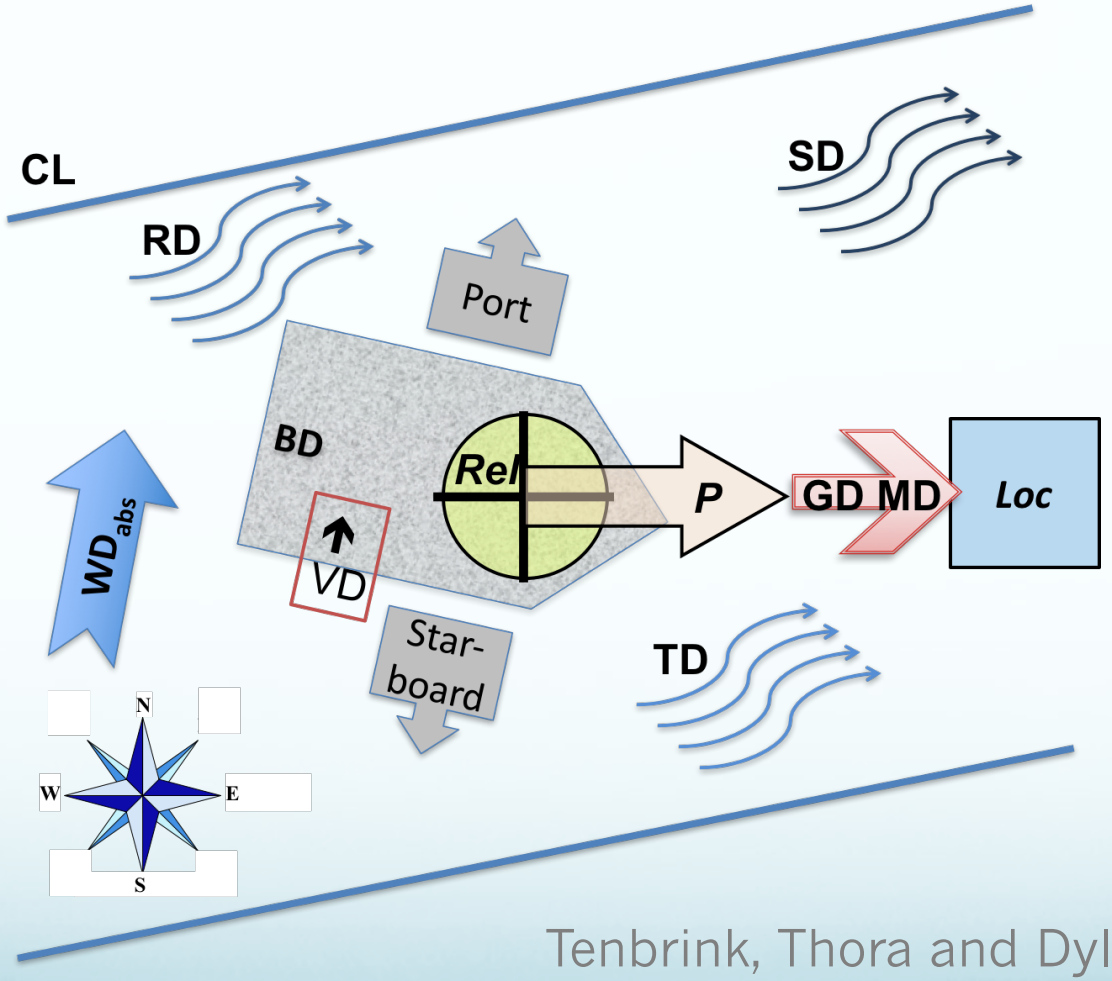



SAPHIRE
SUNRA

Reference frames for sailing



Reference frames for sailing



Tenbrink, Thora and Dylla, Frank. 2017. Sailing: Cognition, action, communication. Journal of Spatial Information Science 15:3-33.

Spatial references in sailing?

- Sailors typically avoid saying ‘forward’ – at all!
- They say ‘course made good’
- Intuitive knowledge that ‘forward’ could be based on many things (perspectives)

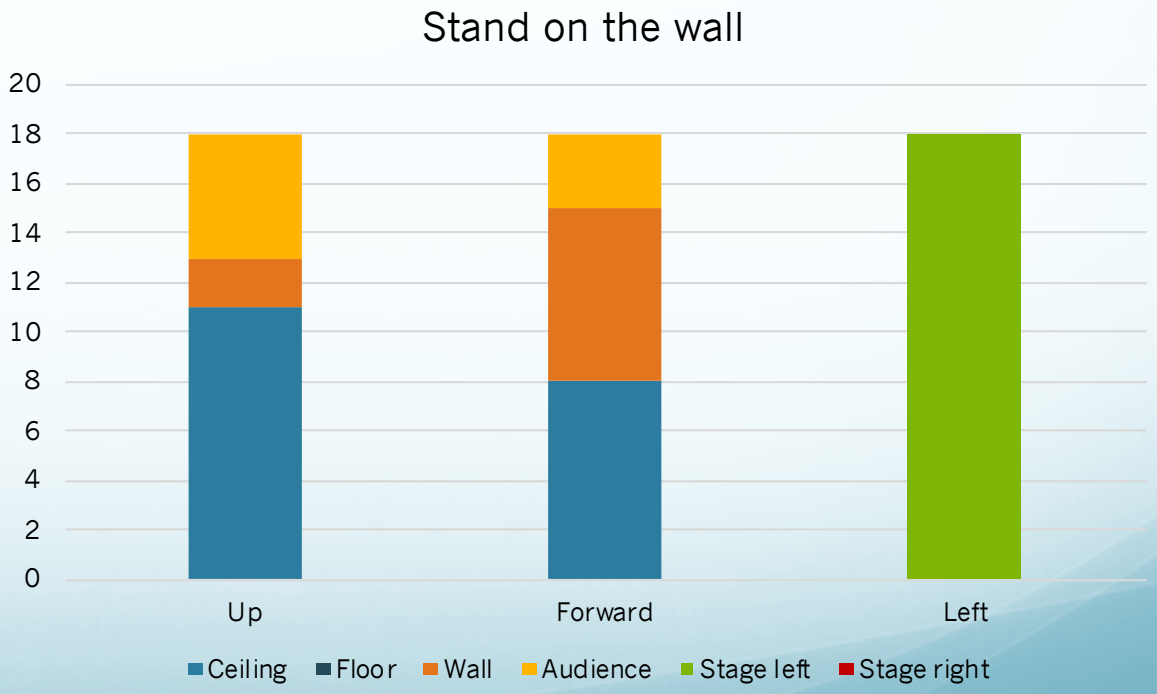
Challenge 3:

Finding a reference frame when oriented in a different way

Vertical Dance
Kate Lawrence

Which way is up?
Which way is forward?

- Canonical orientation is distorted



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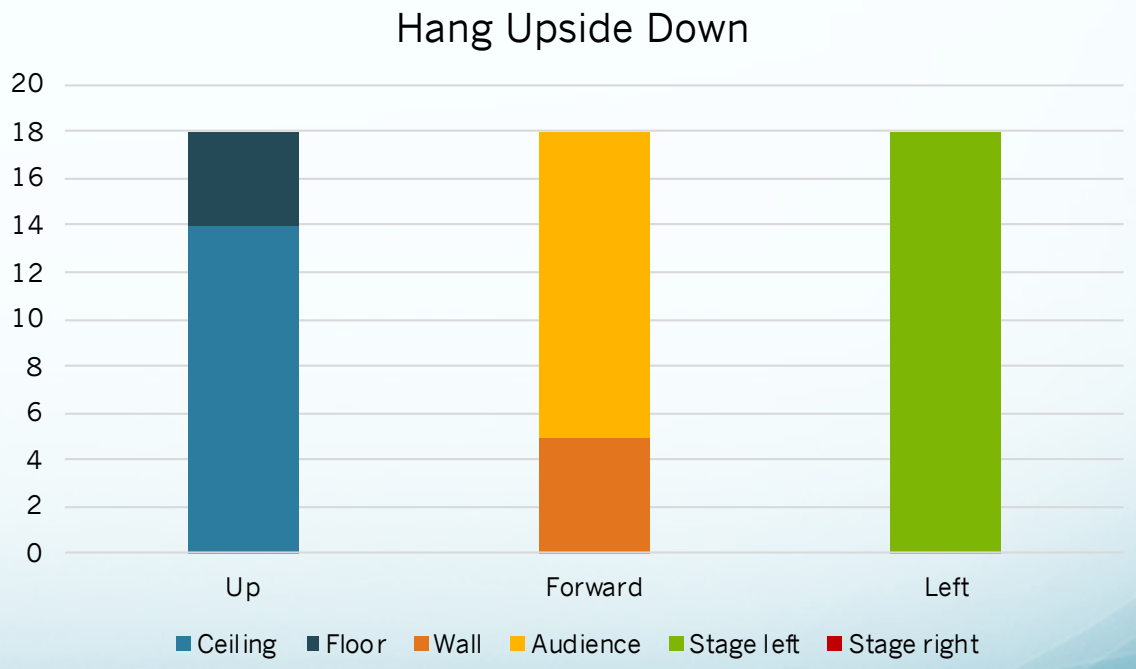
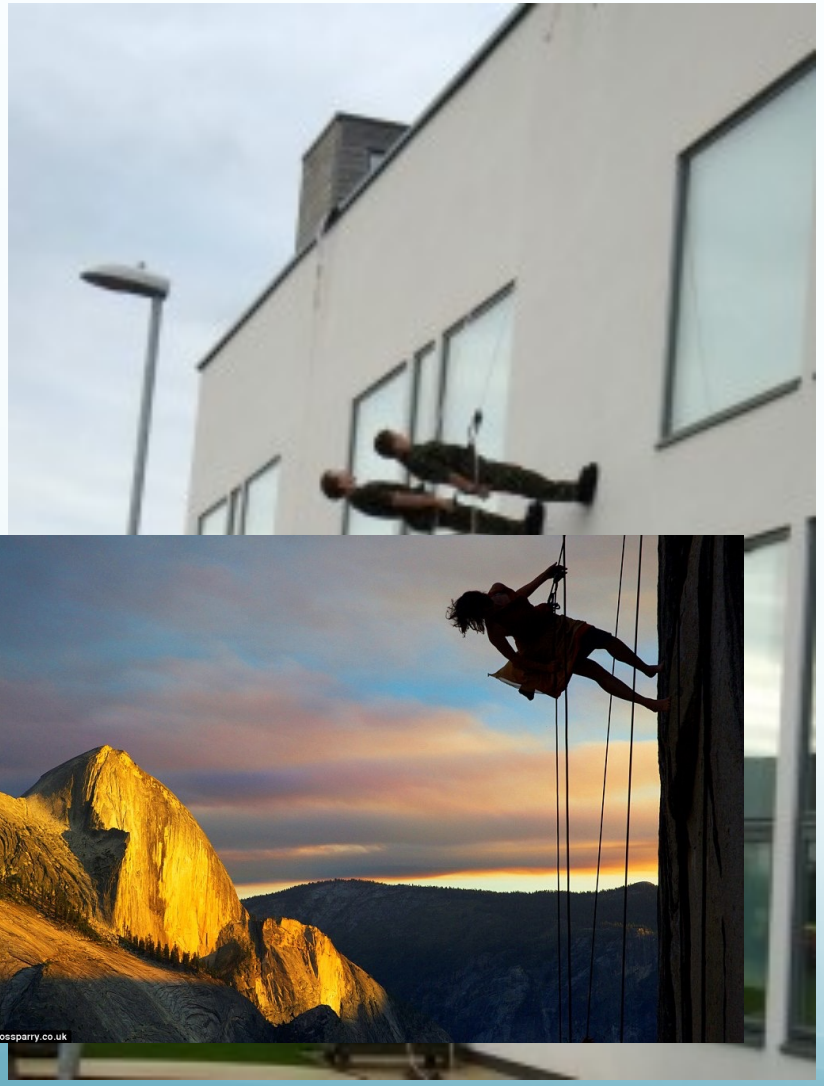
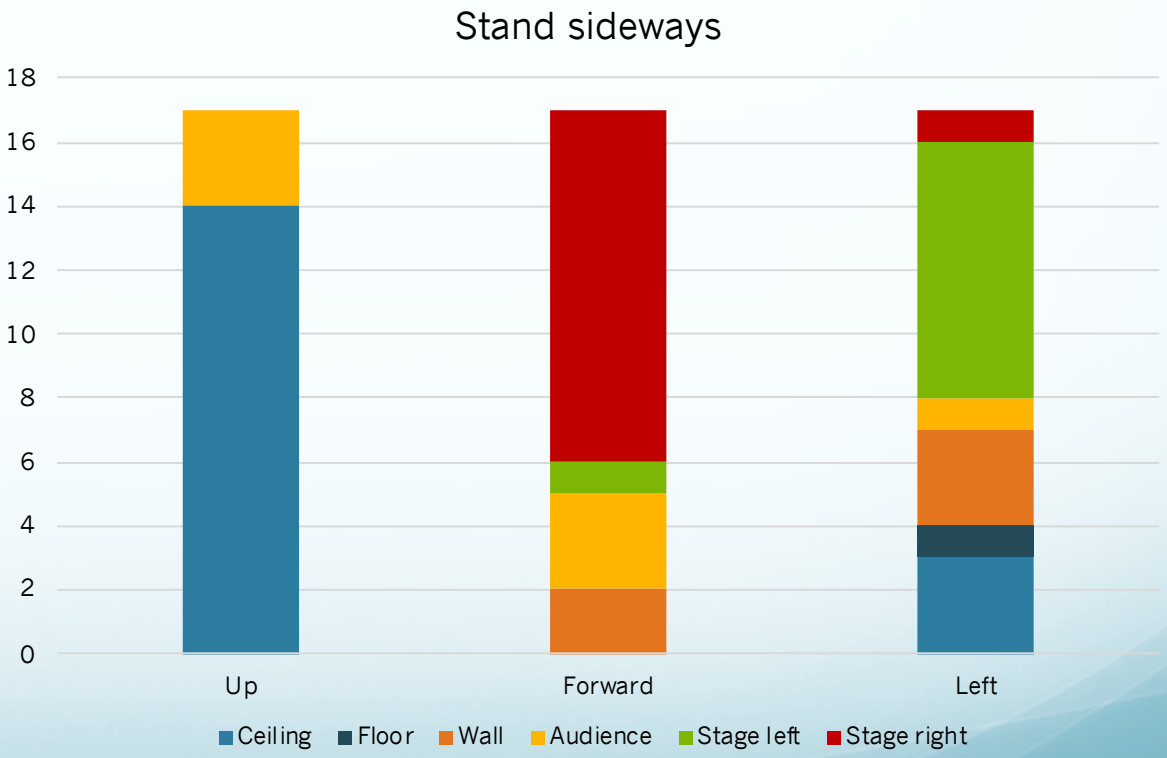


Which way is up?
Which way is forward?





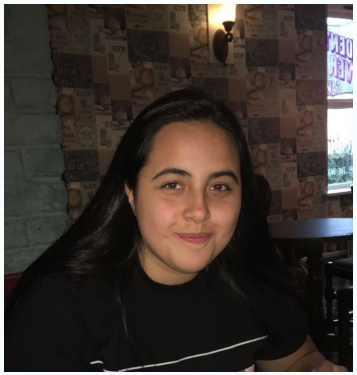
Challenge 4:

Agreeing on a reference frame between languages

Olloqui Redondo, Javier, Tenbrink, Thora, and Foltz, Anouschka. 2019. Effects of animacy and linguistic construction on the interpretation of spatial descriptions in English and Spanish. Language and Cognition 11:2, 256-284.

Foltz, Anouschka, Beatriz Martín-Gascón, Florencia Paz Silva Marytsch, Javier Olloqui-Redondo, and Thora Tenbrink (subm). Syntax and object types contribute in different ways to bilinguals' comprehension of spatial descriptions.

Beatriz Martín Gascón
Universidad de Córdoba



Florencia Silva Marytsch
Bangor University

Javier Olloqui-Redondo
Universidad Complutense de Madrid

Anouschka Foltz
University of Graz

Talking about space

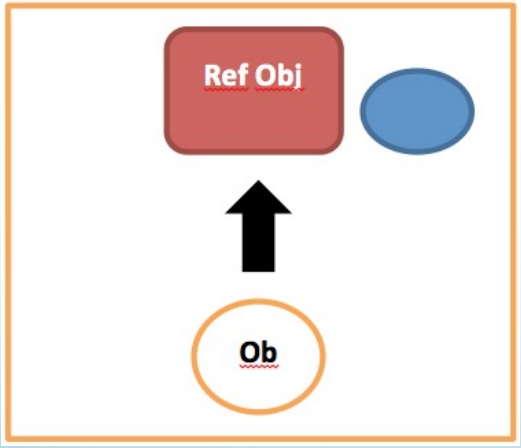
- Speakers of different languages do this in surprisingly different ways:

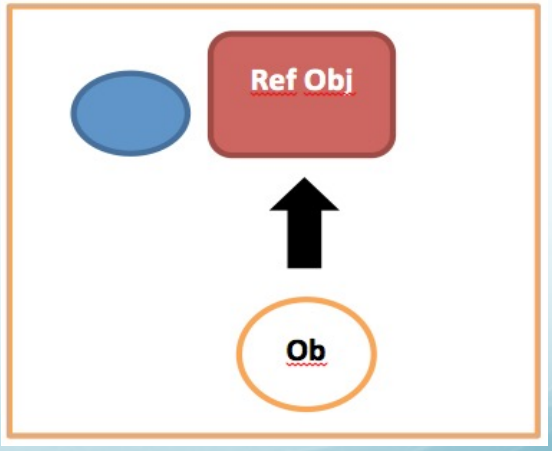
https://www.outsidethebeltway.com/language_shapes_thought/

Pormpuraaw community:
Kuuk Thaayorre

To the left or to the right?

- The ball is to the right of the table
- The ball is to the right of David
- La pelota está a la derecha de la mesa
- La pelota está a la derecha de David





Linguistic differences in the repertory

- English → 2 constructions available ("to the left of David", "on David's left")
  - 'on David's left': intrinsic only?
- Spanish → 1 construction ("a la izquierda de David")
  - Plus a marked construction:
  - *Veo Y. X está a su izquierda/derecha*
  - *I see Y. X is on its left/right*

- If the (possible intrinsic-only) version 'on David's left' doesn't exist as such in Spanish, what does that mean for the choice of reference systems?

rences in usage?

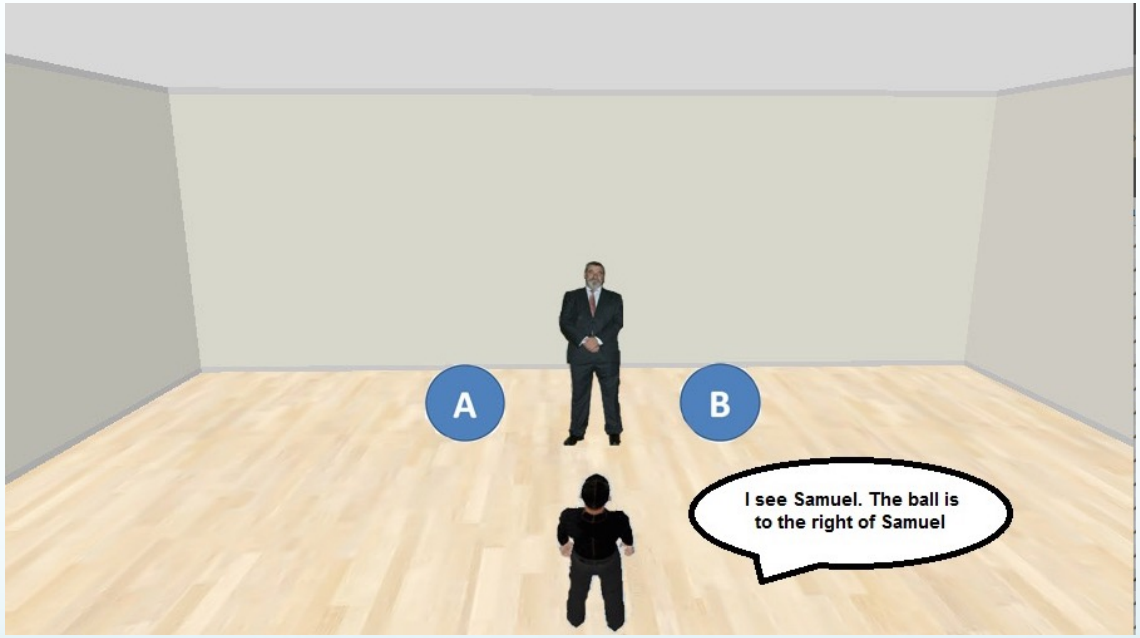
: Spanish speakers choose refe
from English speakers

t be related to animacy

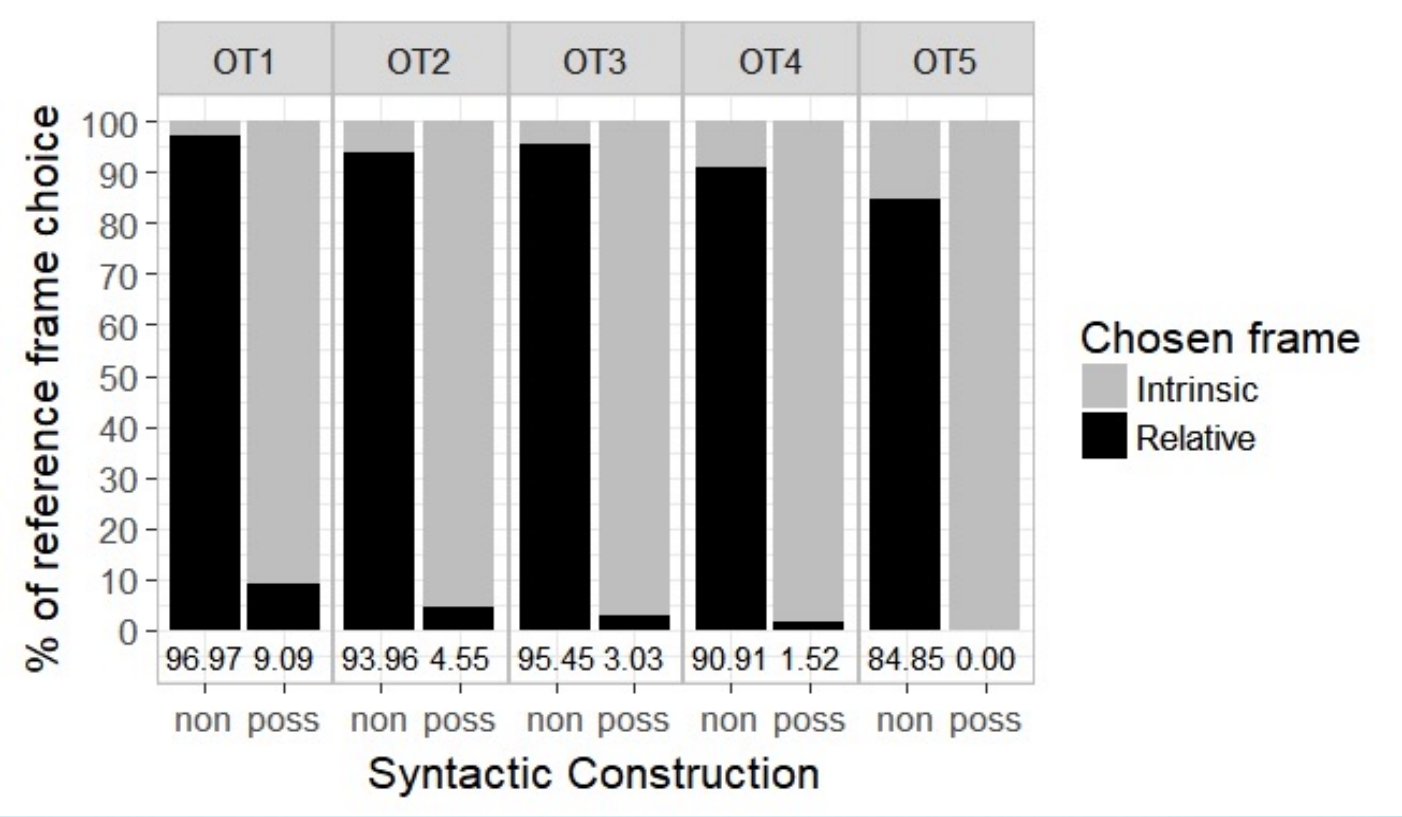
of factors

des, - anthropomorphic, - animate, - human (e.g. a vase)
ides, - anthropomorphic, - animate, - human (e.g. a car)
ides, + anthropomorphic, - animate, - human (e.g. a statue)
ides, - anthropomorphic, + animate, - human (e.g. a dog)
ides, + anthropomorphic, + animate, + human (e.g. a woman)

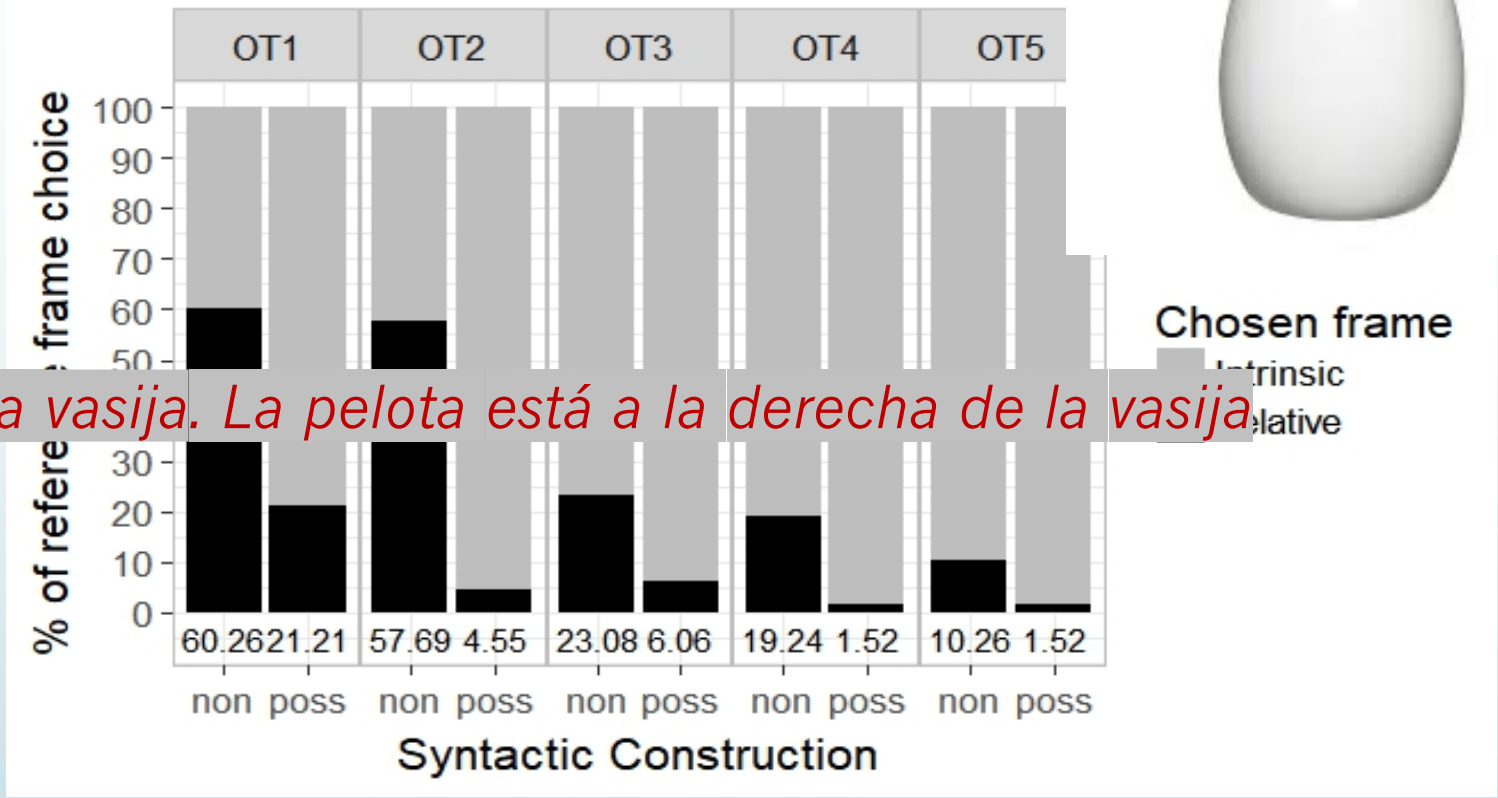
Stimuli



Results for English



Results for Spanish



Veo una vasija. La pelota está a la derecha de la vasija

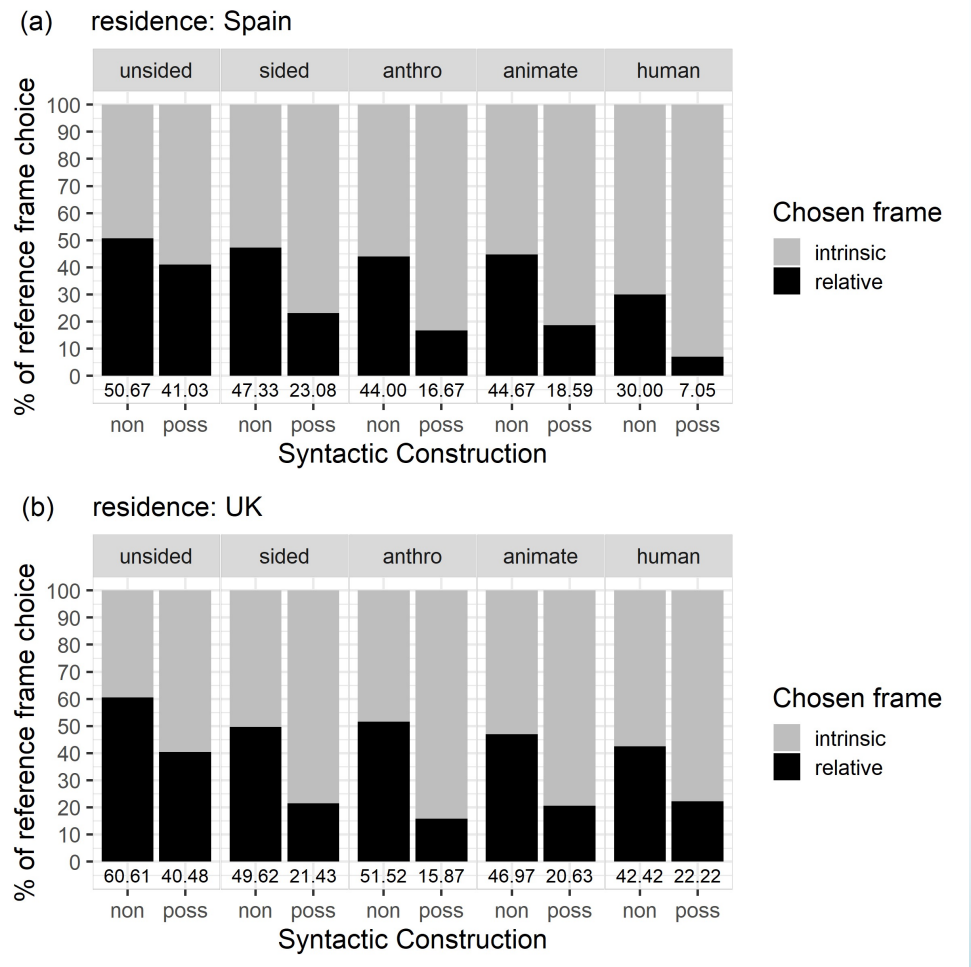
Animacy has an effect in Spanish but not in English

- Spanish speakers choose the intrinsic reference frame more often than English speakers when a non-possessive construction is used.
- Only objects that were neither anthropomorphic nor animate triggered the relative frame of reference in Spanish
- The notion of 'inalienable possession' is also reflected in Spanish in other ways
- The linguistic repertory affects conceptual choices

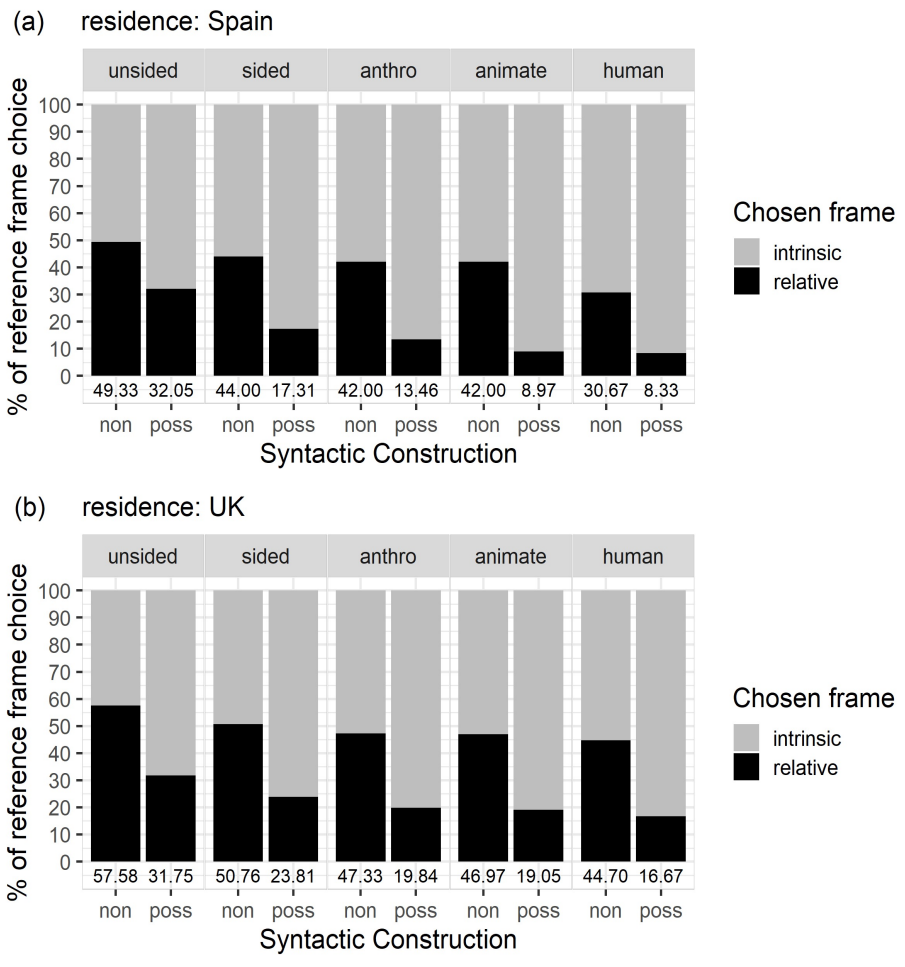
But what about Spanish-English bilinguals?

https://www.caribbeannationalweekly.com/caribbean-breaking-news-featured/editorial-bilingual-america-become-necessity/

Spanish-English bilinguals



Reference frame choice in Spanish



Reference frame choice in English

Spanish-English bilinguals

- Syntactic construction: pattern akin to monolingual Spanish data in both English and Spanish

- Animacy: pattern akin to monolingual English data in both English and Spanish
  - No effects of residence (in contrast to previous research)

So…

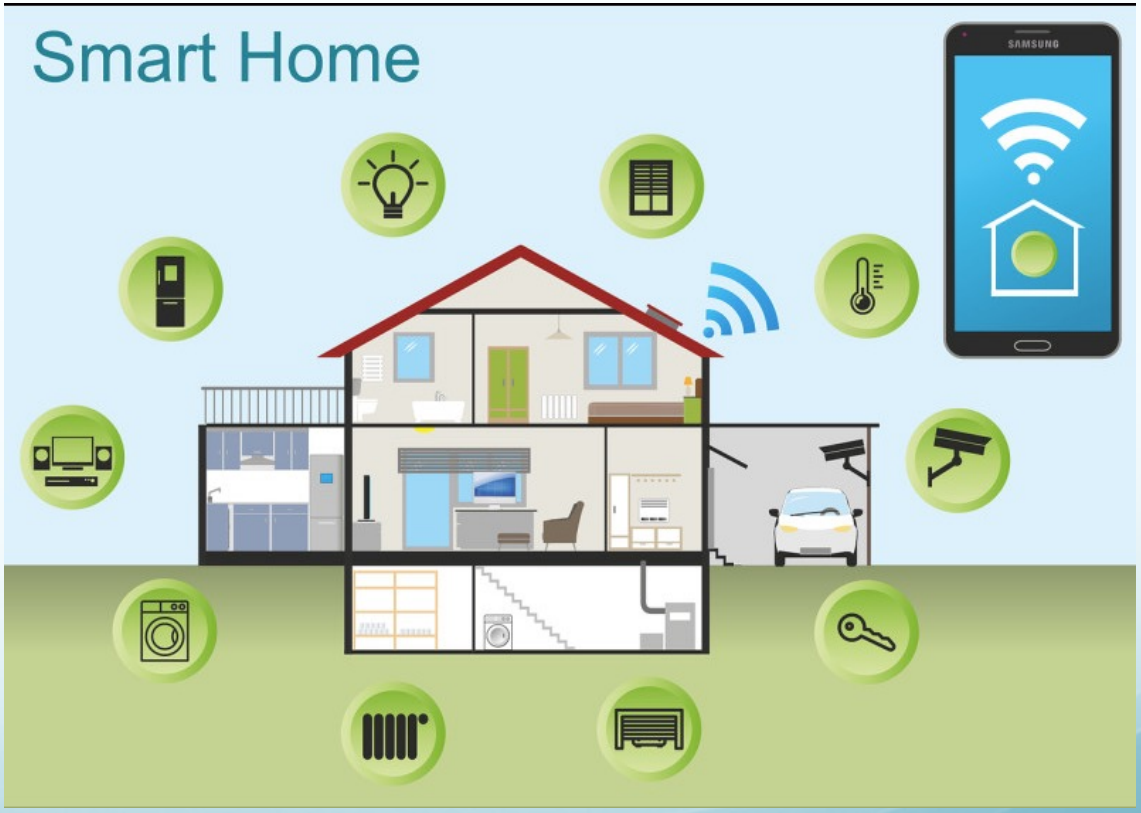
1. Agreeing on a reference frame requires common ground – because speakers are rarely fully explicit
2. Agreeing on a reference frame is difficult when the situational context provides complex and contradictory information (e.g., in sailing)
3. Agreeing on a reference frame is difficult when the normal perceptions are distorted (vertical dance)
4. Agreeing on a reference frame is difficult when the speakers don't share the same cultural/conceptual/linguistic background

Smart Environments

Features – and more challenges

Smart environment

- A ubiquitous assistance system – for instance in somebody's home – that:
  - Knows the user and their needs
  - Does not require a specific position
  - Has no physical presence
  - Relies on sensors spread through the house
  - Talks to the user



“Where are my pills?”

- Pointing gestures? Won’t work – no physical presence
- Spatial IDs in the system’s database? Won’t work – the user won’t understand them
- Visual representation on a display? Requires user-adequate displays and a situation-adaptive database
- Reference to past actions – ‘you took them at breakfast’? Requires a lot of world knowledge and invites inferences rather than providing answers
- Route directions? Can easily be misunderstood and may require tracking and gradually updating the user’s movements
- **Describe the object’s location? Let’s look at that!**

Spatial reference types

- Schematic and function-based: Not a system's strength!
- Topological terms: extremely context dependent, presuppose proximity notions and topological reasoning
- Path-related terms: geometrical constraints, inference processes
- Distance-related terms: issues with granularity; vagueness
- Projective terms: Yes! Relatively context- and function-free, models exist...

But...

1. Agreeing on a reference frame requires common ground – because speakers are rarely fully explicit
   A smart environment does not share much (specific) common ground with a human speaker – everything needs to be implemented or machine-learned

2. Agreeing on a reference frame is difficult when the situational context provides complex and contradictory information (e.g., in sailing)
   A household context is surprisingly complex when common ground is not established

3. Agreeing on a reference frame is difficult when the normal perceptions are distorted (vertical dance)
   The perception of an automatic assistance system is fundamentally different from that of a human – there is not even a physical body with an orientation!

4. Agreeing on a reference frame is difficult when the speakers don't share the same cultural/conceptual/linguistic background
   In a sense, smart environments and humans speak different languages, draw on different conceptual systems

A solution (?)

How do we refer to object orientation?

- The sofa's back is along the left wall.
- The chair is oriented towards the table.

→ Establishes orientation information by reference to a relatum

- The chair points to the right.

→ Uses a projective term. Whose perspective is being used?

- The chair's back points north.

→ Uses an absolute reference frame (compass based), **unambiguous**

Talking about space

- Speakers of different languages do this in surprisingly different ways:

https://www.outsidethebeltway.com/language_shapes_thought/

Pormpuraaw community:
Kuuk Thaayorre

Could it work?

- Maybe not with compass terms: most of us don't have this knowledge (awareness) indoors
- But why not agree on a directional system that does work indoors
  - Give walls a colour: 'towards the green wall', 'next to the blue wall', 'on the table at the red wall', 'between the trashcan and the yellow wall' …
  - Might require a bit of practice – but speaks to human's conceptual and linguistic strengths
  - And is compatible with the way systems 'think'

A solution?

– Open for discussion!

References

- This talk was inspired from (but did not retrace)
  - Tenbrink, Thora. 2017. Situated interaction with a smart environment: Challenges and opportunities. *KI - Künstliche Intelligenz (Artificial Intelligence)*, *31*(3), 257-264.

- Other cited work:
  - Foltz, Anouschka, Beatriz Martín-Gascón, Florencia Paz Silva Marytsch, Javier Olloqui-Redondo, and Thora Tenbrink (subm). Syntax and object types contribute in different ways to bilinguals' comprehension of spatial descriptions.
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  - Tenbrink, Thora, Andonova, Elena, Schole, Gesa, and Coventry, Kenny R. 2017. Communicative success in spatial dialogue: The impact of functional features and dialogic strategies. *Language and Speech 60*:2, 318–329.
  - Tenbrink, Thora and Dylla, Frank. 2017. Sailing: Cognition, action, communication. *Journal of Spatial Information Science 15*:3-33.