

Event structure:
from sign language production to perception

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Outline

- ▶ What are linguistic events?
- ▶ Motion capture studies of event sign production in ASL and HZJ
- ▶ fMRI study of event sign perception/processing

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What is an event?

- ▶ Segmentation of reality into events - pervasive psychological phenomenon¹
- ▶ Exists independently of language

Provides a ground against which linguistic work can be interpreted

¹Zacks, J. M., Speer, N. K., Swallow, K. M., Braver, T. S., & Reynolds, J. R. (2007).

Semantic event types

► Telic –

Composed of at least two subevents, including the final state

Heterogeneous - cannot be divided into identical intervals.

► Atelic –

Does not have a final state

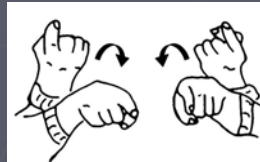
Homogenous - may be divided into identical intervals, each of which is an instance of the event itself, i.e. 'walking' as an instance of 'walking'

Telicity in ASL Signs

Examples of signs denoting Telic events:



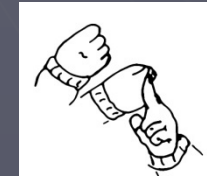
SEND
handshape Δ



HAPPEN
orientation Δ

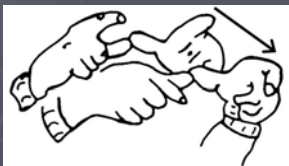


POSTPONE
setting Δ
proximal/distal



HIT
location Δ
with contact

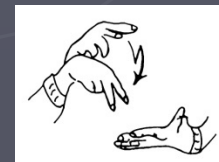
Examples of signs denoting Atelic events:



RUN
[tracing: straight]



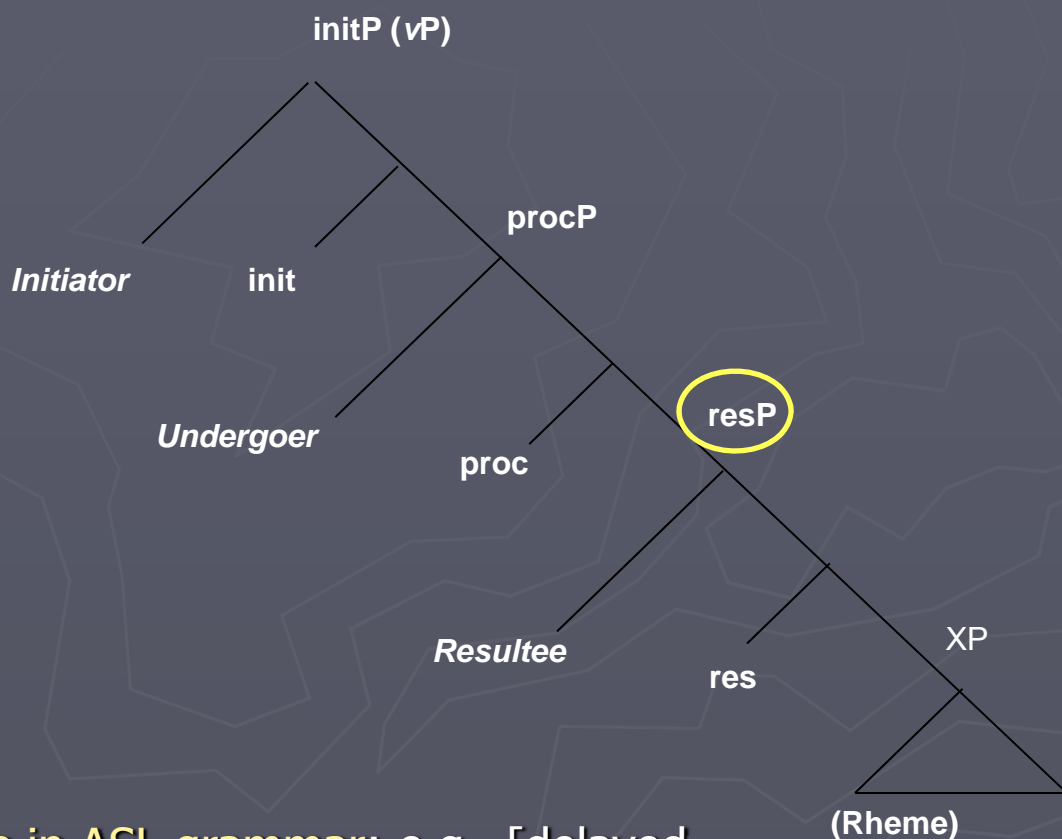
PLAY
[tracing + TM]



READ
[tracing + TM]

Event representation in syntax

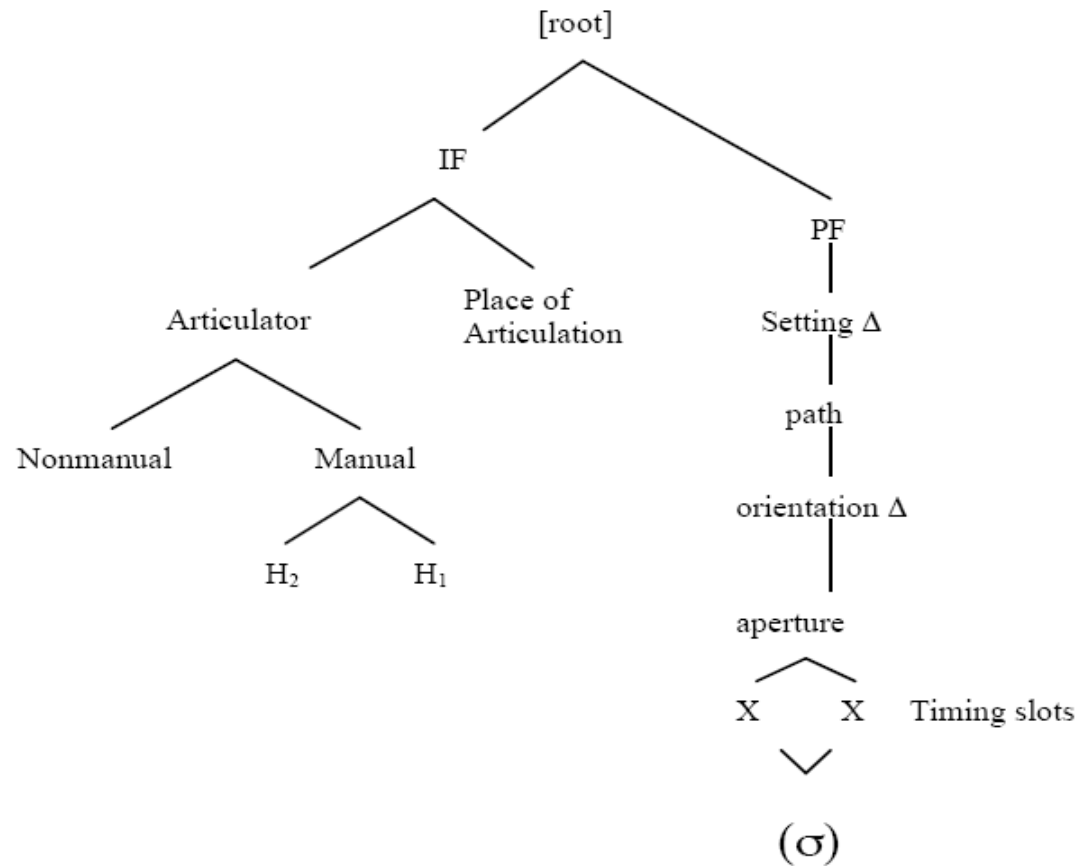
Syntactic event structure tree of telic predicates includes a Result State phase (resP); atelic predicates do not have it.¹



Telicity plays a recognizable **role in ASL grammar**: e.g., [delayed completive] aspect only applies to telic stems².

¹Ramchand (2008); ²Brentari (1998)

Event representation in phonology¹



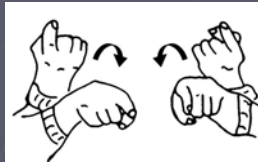
¹Brentari (1998)

Telicity in ASL Signs

Examples of signs denoting Telic events:



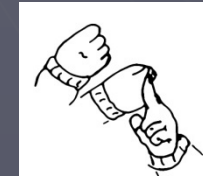
SEND
handshape Δ



HAPPEN
orientation Δ

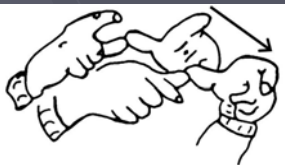


POSTPONE
setting Δ
proximal/distal



HIT
location Δ
with contact

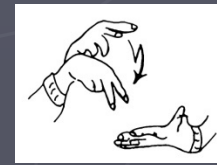
Examples of signs denoting Atelic events:



RUN
[tracing: straight]



PLAY
[tracing + TM]



READ
[tracing + TM]

Event Visibility Hypothesis (EVH)¹

- “The semantics of event structure is visible in the phonological form of predicate signs.”
- Movement that stops at **points (p)** in space maps semantically to the **final State of telic events (e_n)** and its individual **argument semantic variable (x)**.

¹Wilbur (2003)

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Why consider event signs in HZJ?

- ▶ It has Slavic language substrate
- ▶ Event structure and aspect (perfective vs. continuous) are often **conflated** in spoken Slavic languages
- ▶ Telicity is expressed at the **lexical level** in ASL. But can it be **grammaticalized**?

What is 'end marking'?

- Given prior research on event perception, we identified 5 variables of interest:
 - **Duration** of verb sign in milliseconds;
 - Peak instantaneous speed achieved within each predicate (**maxV**);
 - Minimum instantaneous acceleration (i.e. maximal deceleration) within each predicate (**minA**);
 - Overall slope of deceleration (**slope**);
 - Percent of sign movement elapsed to the moment where peak speed occurred (**% elapsed**).

HIT

Measurements

a = duration of mvt

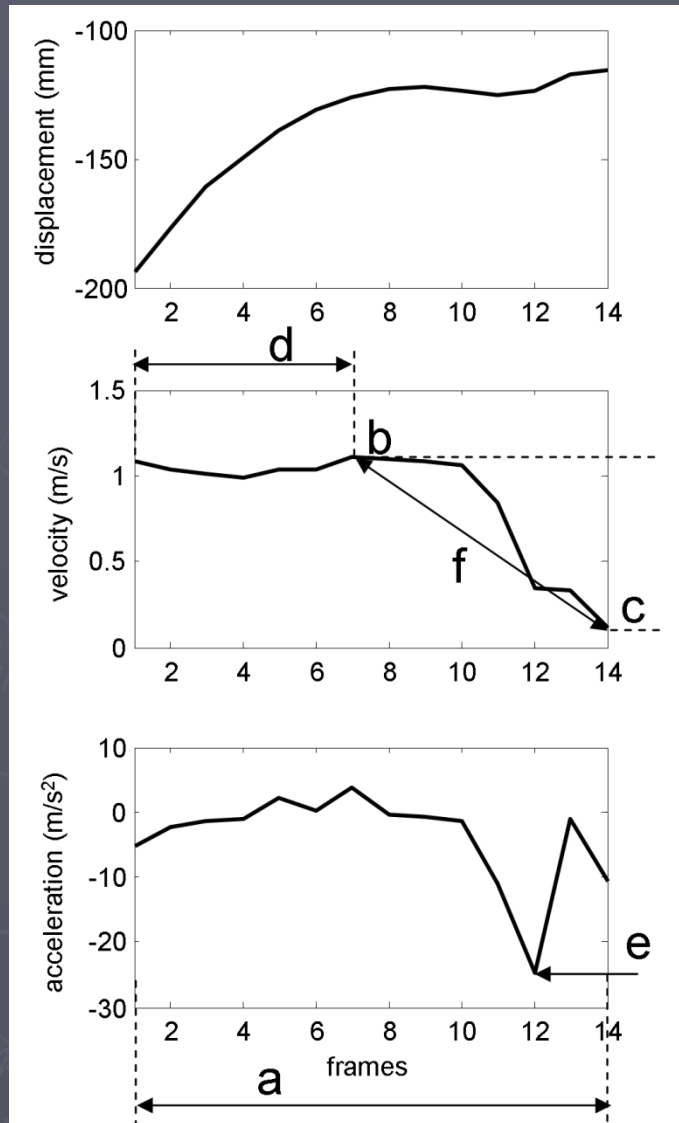
b = maxV

c = minV after maxV

d = elapsed pct to maxV

e = minA (max neg accel)

f = slope of deceleration at end of sign movement

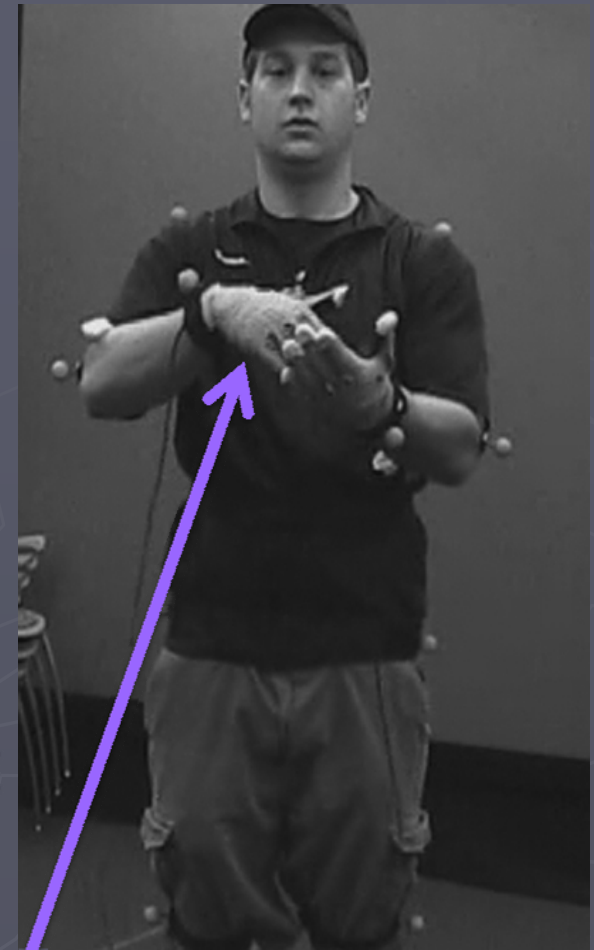


Kinematic study ASL: Data collection

A group of 24 telic and 16 atelic signs were determined by linguistic tests, randomized and presented to 6 native ASL signers.

- ▶ Signs produced:
 - in isolation
 - once in a carrier phrase 'SIGN X AGAIN',
 - once in medial sentence position 'SHE X TODAY'
 - once in final sentence position 'TODAY SHE X'

Signers wore a Gypsy 3.0 motion capture suit.



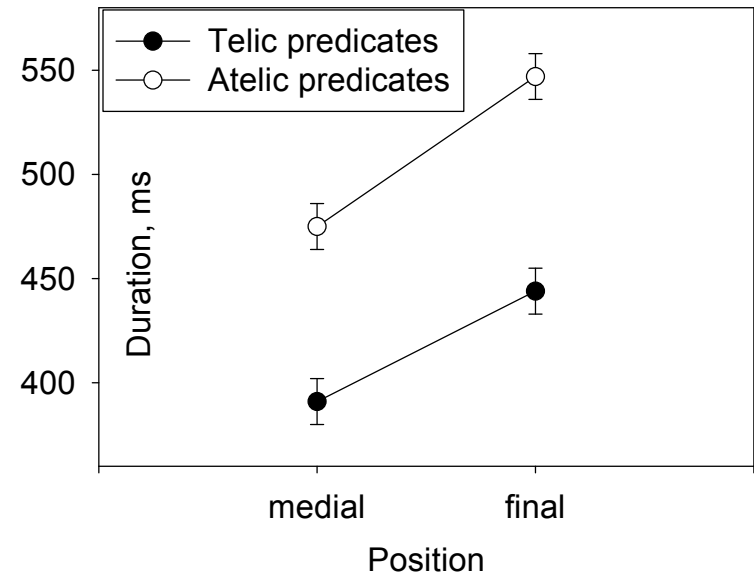
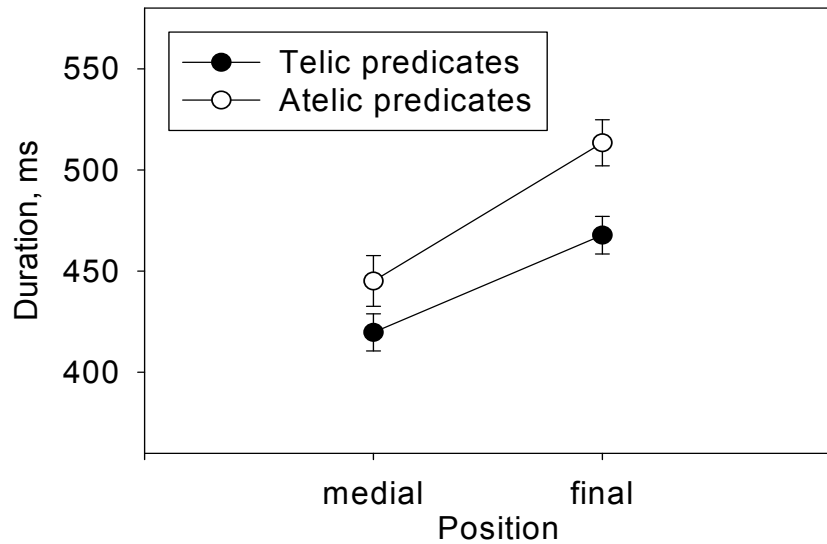
Kinematic study of HZJ

- ▶ Same equipment, 1 HZJ native signer; recorded 5 sessions on separate days
- ▶ In HZJ, the same root can appear in atelic or telic form with productive changes in movement
- ▶ Recorded 31 minimal pair of atelic-telic signs

ASL

vs.

HZJ

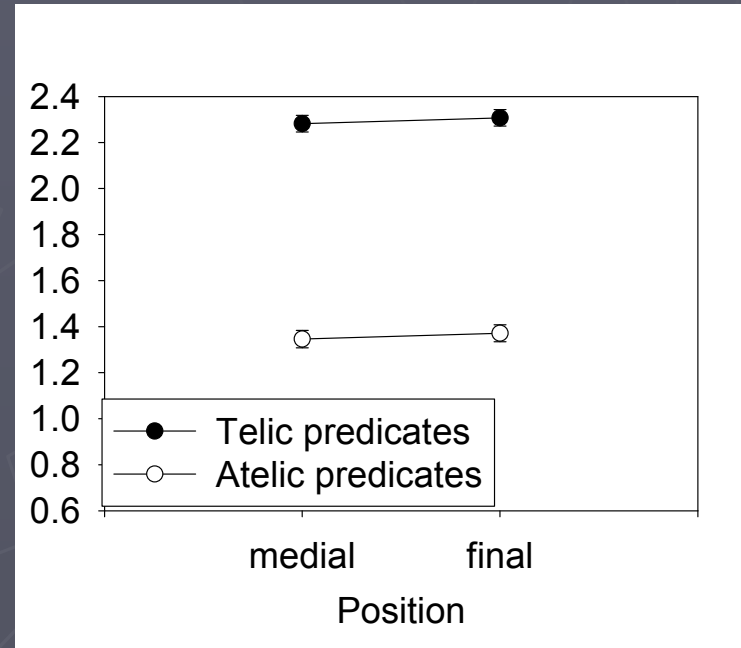
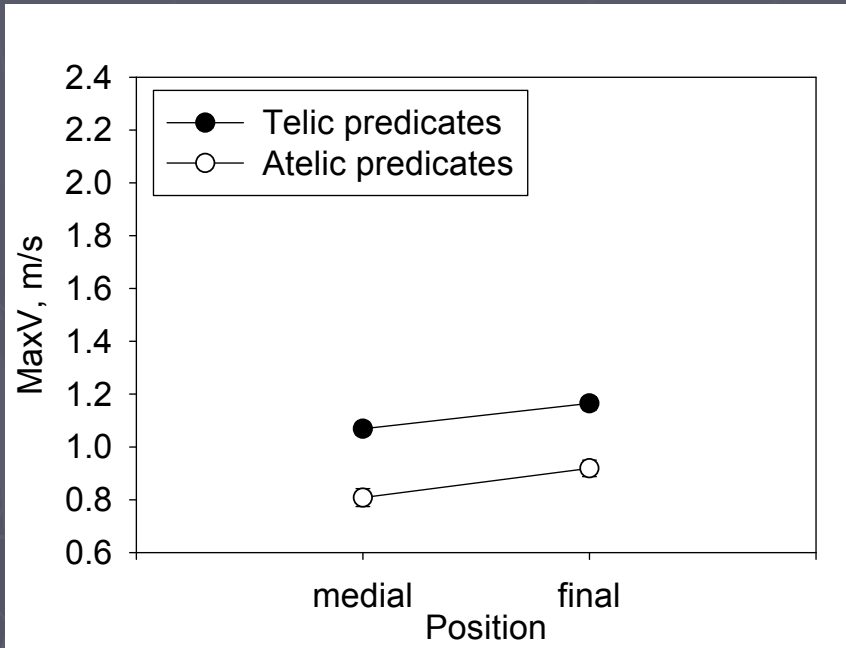


Duration, ms

ASL

vs.

HZJ

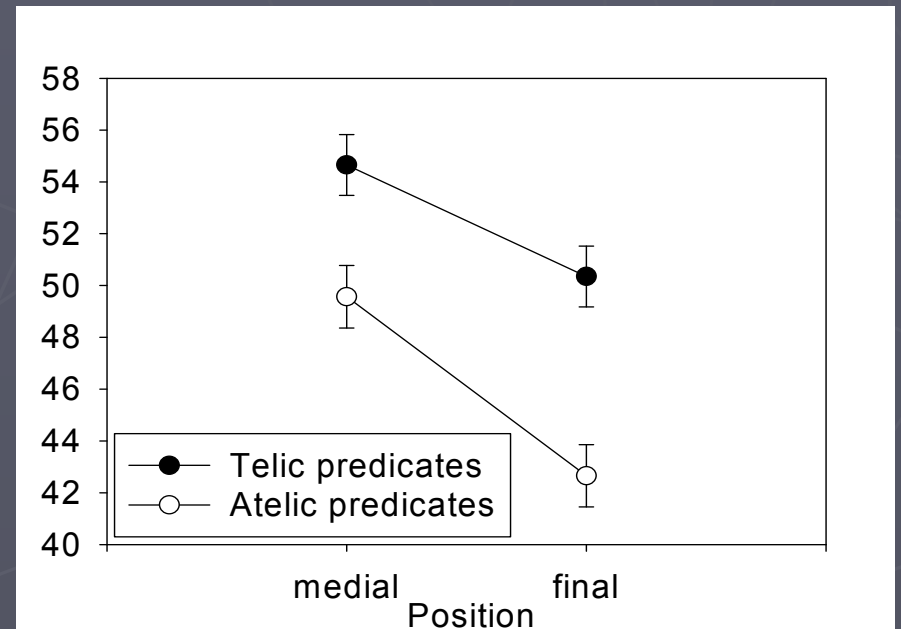
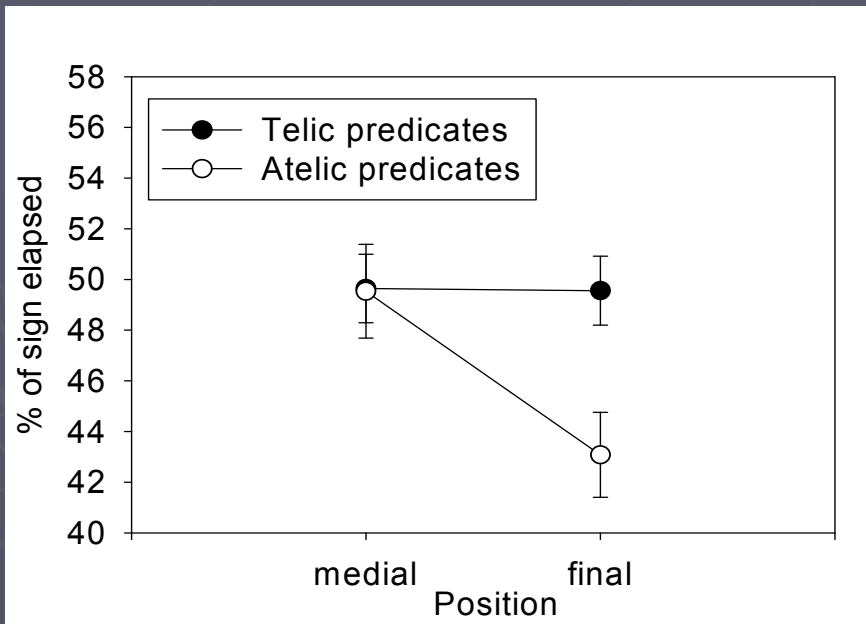


MaxV, m/s

ASL

vs.

HZJ

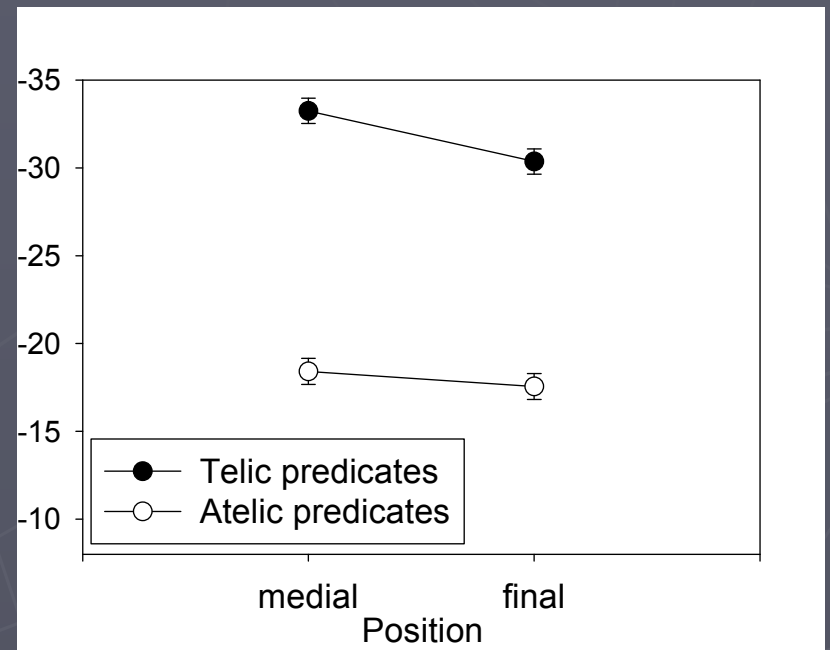
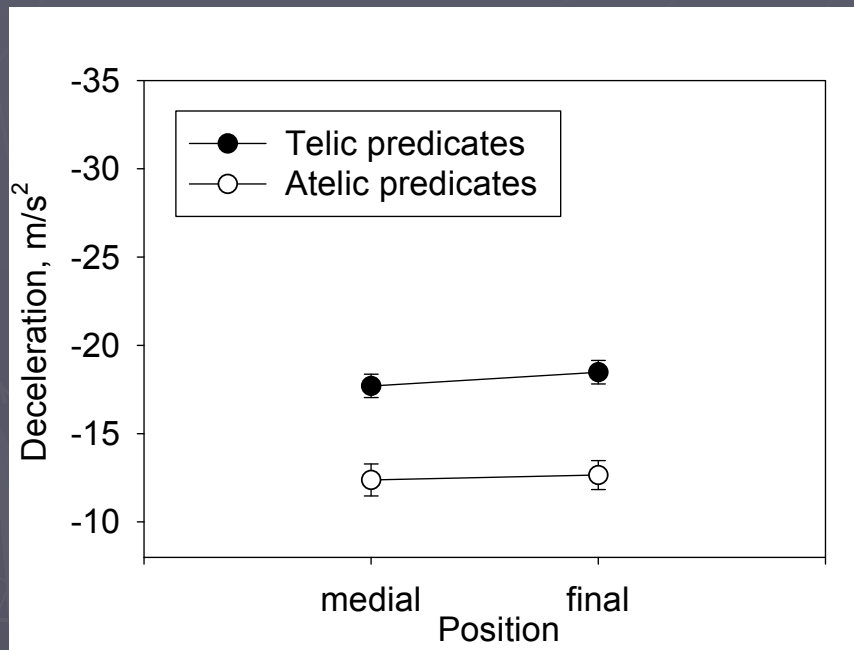


% of sign elapsed

ASL

vs.

HZJ



Deceleration

Kinematic study: ASL Results_(df=1,1916)

<i>Kinematic variable</i>	Predicate Type	Position	Predicate Type x Position
	$p <$	$p <$	$p <$
Duration	.001	.001	
maxV	.001	.001	
% elapsed	.036	.038	.043
Slope	.001		
minA	.001		

Kinematic study: HZJ results

(df=1,1170)

<i>Kinematic variable</i>	Predicate Type	Position	Predicate Type x Position
	$p <$	$p <$	
Duration	.001	.001	
maxV	.001		
% elapsed	.001	.001	
Slope	.001	.003	.033
minA	.001	.011	

Same as ASL

Different from ASL

Conclusion

- 1) The x_2 part of the syllable in **telic** signs is marked by a rapid deceleration, as compared to verb signs denoting *atelic* events.
- 2) These overt kinematic distinctions map onto a complex representation of event structure at the *syntax-semantics-phonology interface*.
- 3) more complex kinematic profiles of *telic* verbs correspond to a more complex phonological representation, as compared to that of *atelic* verb signs.

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- ▶ What is linguistic event structure?
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fMRI study of ASL

Questions:

- 1) **How** do Deaf signers process **kinematic** differences between telic and atelic signs?
- 2) Does the need to assess velocity and acceleration of motion for linguistic purposes affect **bottom-up processing of visual stimuli** in Deaf signers (vs. hearing non-signers)?

What could we reasonably predict?

Processing of telic and atelic signs might elicit differences in:

- language-processing regions (e.g. IFG)
- regions processing (biological) motion
MT+ (BA 19/37)¹

¹Zacks, Tversky, & Iyer, 2001; Speer et al., 2003; Zacks, Swallow, et al, 2006; Speer, Reynolds, Swallow, & Zacks, 2006

Stimuli

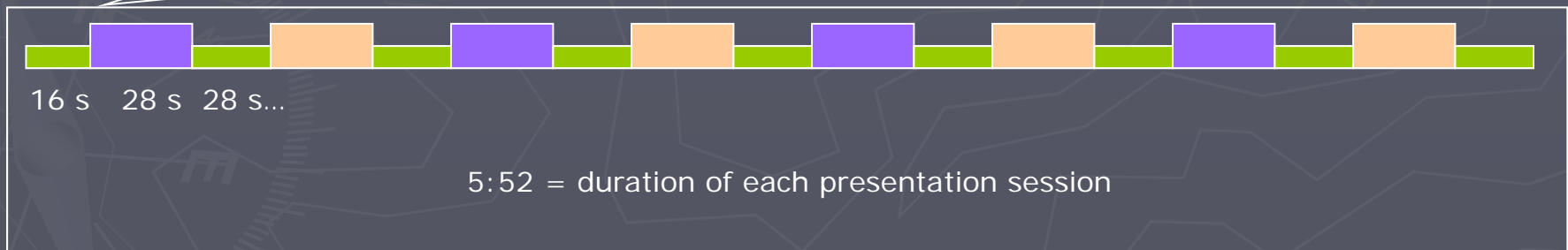
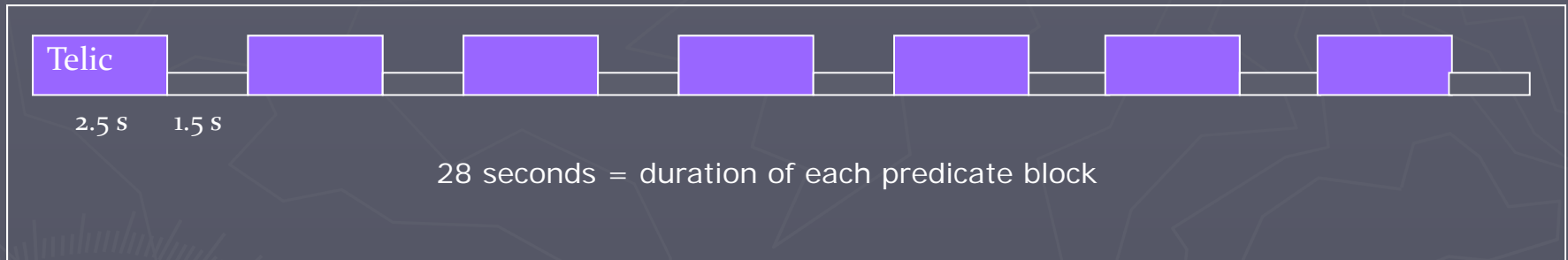
- Stimuli: ASL verb signs and non-communicative gesture (T-pose), produced by a native signer.
- Same verbs as where recorded for the motion capture experiment.

Participants

- 13 healthy Deaf adults, native ASL signers (8 Deaf of Deaf parents; 18-58 years old) and 12 hearing non-signers (7 male, 5 female, 19-36 years old, mean age 24.1, SD=4.5) All right-handed.

Block design

 Telic predicate sign  Atelic predicate sign  Non-intentional gesture



4 sessions per subject

Data Collection

- ▶ 3 T GE magnet (Purdue MRI Facility);
- ▶ 3D FSPGR high-resolution anatomical images (FOV = 24cm, 186 sagittal slices, slice thickness = 1mm) acquired prior to functional scans.
- ▶ gradient echo EPI sequence (TE = 22ms, TR=2s)
- ▶ 26 contiguous slices with 4 mm thickness
- ▶ 3.8 mm x 3.8 mm in-plane resolution.

Data Analysis

- ▶ GLM in SPM5; individual contrasts were used as the input to one-sample t-test random effects analysis in SPM5 to obtain group results. Uncorrected, $p < .001$.

Brain activation for the telic vs. atelic ASL signs

Anatomical region	cluster size	hemi	BA	Z-value	MNI coordinates
Cerebellum	12	R		3.83	8 -62 -20
Posterior cingulate/precuneus	14	R	31	3.56	18 -54 10
Superior temporal gyrus	17	R	22	4.43	50 -20 4

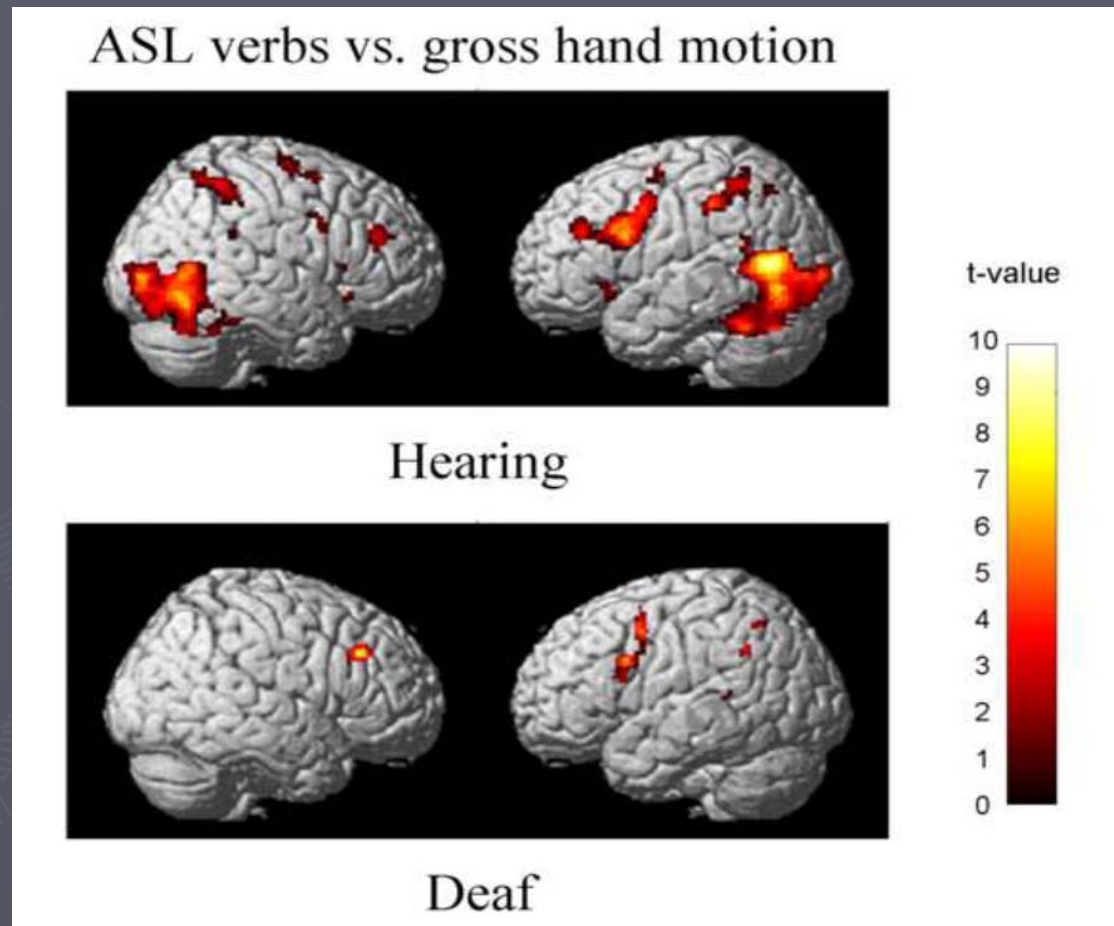
How do other studies interpret similar results?

- ▶ **Posterior cingulate / precuneus, R (T > A)** activation previously related to time-context specific memory encoding (Fujii et al., 2002; Whitney et al., 2009)
 - **Result State (reference timepoint) in Telic events**
- ▶ **Cerebellum, R (T > A)** – connected to left IFG, modulates reciprocal activity, possibly phonological processing (Xiang et al., 2003; Stoodley & Schmahmann, 2010)
 - **phonological timing slots**
- ▶ **STG (T > A)** – modality-independent extraction of abstract linguistics features (Petitto, et al., 2000)

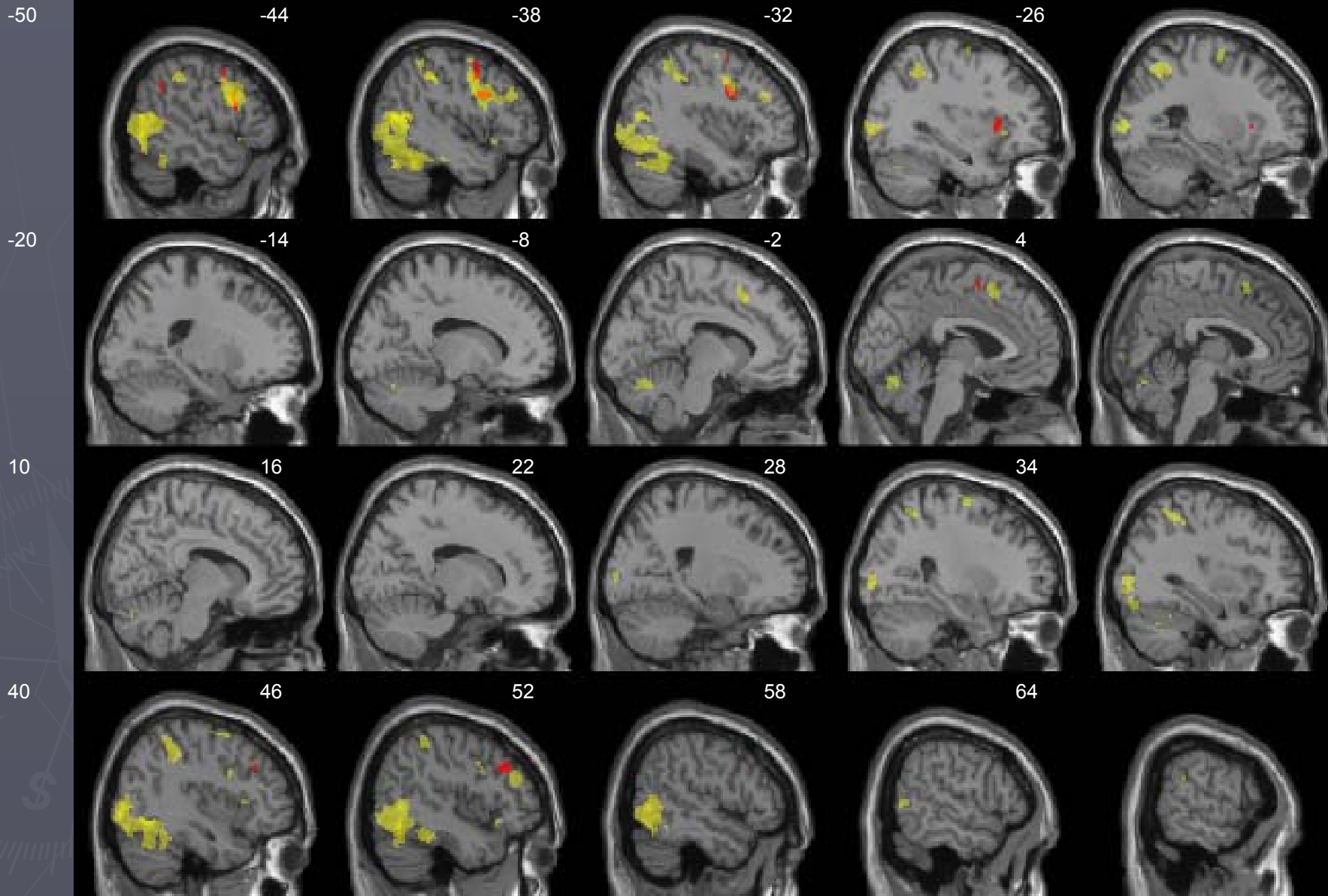
What about the second hypothesis?

- ▶ No differential activation of MT+ (BA 19/37) region for Deaf participants, even in comparison of ASL and gesture.
- ▶ However, hearing participants showed strong bilateral activation of this region!

Activation for ASL predicates in contrast to gross hand motion in hearing non-signers and Deaf native signers.



T & A > Gesture: Deaf and Hearing compared



Neuroimaging data supports EVH

Telic verbs provide Result State time for further (aspectual) computations¹

Kinematic differences in sign production are processed as linguistic features by native signers²

¹cf. perceptual event segmentation: Zacks, J. M., Swallow, K. M., Vettel, J. M., & McAvooy, M. P. (2006).

²cf. linguistic tone processing: Krishnan, A., & Gandour, J. T. (2009).

Acknowledgements

- ▶ Our ASL and HZJ signers – people of enormous patience and energy!
- ▶ The staff at the Envision Center for Data Perceptualization at Purdue for recording and turning the data into files we can use.
- ▶ Robin Shay and Iva Hrastinski, the coders who worked with the video
- ▶ National Institutes of Health DC005241 and NSF BCS-0345314 for support of our research.

And Thank You!

► Questions?



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ASL signs used for Motion capture

- ▶ Telic predicates (N=24): STING, THROW, HIT, PLUG-IN, APPEAR, CATCH-UP, OPEN-DOOR, RUIN, EAT-UP, CHECK, TAKE-FROM, ZIP, CLOSE-DOOR, SEIZE, DISAPPEAR, ARREST, BECOME, LOOK-AT, ARRIVE, DIE, RELAX, STEAL, SUGGEST, SHUT-DOWN-COMPUTER.
- ▶ Atelic predicates (N=16): TRAVEL, RIDE-IN, COLLECT, LIVE, PROCEED, SHAVE, FOLLOW, WRITE, STAY, INTERRUPT, DRAW, SEW-WITH-MACHINE, SEND, HAVE, INVESTIGATE, SWIM.

HZJ sign pairs

Imperfective form

buditi

putovati

putovati

gledati

gurati

brisati

crtati

češljati

čistiti

čitati

dijeliti

brijati

bježati

disati

dizati

dolaziti

donositi

English Translation

to be waking up

to be travelling

to be travelling

to be looking at

to be pushing

to be wiping

to be drawing

to be coming

to be cleaning

to be reading

to be dividing

to be shaving

to be fleeing

to be breathin

to be lifting

to be coming

to be carrying

Perfective form

probuditi

otputovati

doputovati

ugledati

gurnuti

obrisati

nacrtati

počešljati

očistiti

pročitati

podijeliti

obrijati

pobjeći

udahnuti

dignuti

doći

donijeti

English Translation

to wake up

to take off

to arrive

to spot, to notice

to give a push

to wipe off

to draw up

to comb through

to clean up

to read through

to split

to shave

to run away

to breathe in

to pick up

to show up

to bring

Signs used for fMRI

- ▶ Telic: STING, SHUT-DOWN-COMPUTER, HIT, PLUG-IN, APPEAR, CATCH-UP, OPEN-DOOR, STOP, CHECK, TAKE-FROM, CLOSE-DOOR, DIE, SEIZE, DISAPPEAR, ARREST, UNZIP, BECOME, LOOK-AT, SEND, ARRIVE.
- ▶ Atelic: TRAVEL, RIDE-IN, SWIM, LIVE, PROCEED, SHAVE, FOLLOW, VISIT, WRITE, KNOW, FALL-BEHIND, SMELL, TOLERATE, HATE, DRAW, SEW-BY-MACHINE, RELAX, LIKE, HAVE, MEAN, SUGGEST.