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Investigating grammatical processing in bilinguals: The case of morphological priming

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Bilingualism and Executive Function: An Interdisciplinary Approach
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Overview

Part I: Background

- Grammatical processing in bilinguals
- Linguistic considerations: Inflection vs. derivation
- Methodological considerations: Morphological priming

Part II: Masked morphological priming in Turkish/German bilinguals

- The role of age of acquisition for morphological processing
- Directly contrasting the processing of inflection and derivation
- Discovering age of acquisition effects and a critical period

Why grammar and grammatical processing?

- Research on bilingualism and executive function: Strong focus on vocabulary and verbal fluency
- A linguist‘s perspective: The within-modularity of the knowledge of language with grammar as its core component.
- Perhaps grammar and grammatical processing in bilinguals even benefits from their enhanced executive functioning.

Grammatical processing in late bilinguals

- L2 processing = L1 processing

  but slower, more resource-demanding, and subject to L1 influence (e.g. McDonald, 2006)

- L2 processing ≠ L1 processing

  Problems with real-time grammatical analysis of the L2 input and relatively greater reliance on non-structural information sources (e.g. Clahsen & Felser, 2006)

Beyond the L2 vs. L1 contrast

Investigating the bilingual Turkish/German community in Berlin:

- learn Turkish from birth
- learn German at different ages, some from birth, some in later childhood (kindergarten or primary school), some as adolescents or adults

We ask:

How are grammatical processing skills in German in this population affected by the different ages of acquisition?

Linguistic background

Materials are typically matched for frequency, length, neighbourhood, etc. but not for their linguistic properties.

For example: Kielar & Joanisse (2011):

- 10 different derivational processes collapsed in the same condition.
- Bare nouns collapsed with derived forms, the latter including both prefixed and suffixed word forms in the same condition.
- ‘fully transparent’ included derived words with additional meanings and both items with and without stem changes.

Linguistic background

- Derivational forms can be the input to further word-formation and inflectional processes:
  afford, affordable, affordability, unaffordability

- Inflected forms are islands for further word formation.
  walked cannot be fed into any other word formation processes.

➢ Products of derivational processes take on a linguistic life of their own.
  - recategorization: $[cold]_{Adj} \rightarrow [[cold]\text{-ness}]_{N}$
  - labelling: $[cold]_{Adj} \rightarrow [cold]_{N}$

Realization-based morphology

- Lexical item:
  <[V, walk], walk>

- Inflectional rules:
  <[V, 3sg, pres, ind], X+s>

- Derivational rules:
  <[Adj, lex], X> $\rightarrow$ <[N, lex+ness], X+ness>

Two morphological phenomena of German

1. Past participles

I bought a book → *Ich habe ein Buch gekauft*.

Regular participles: öffnen – geöffn***et*** 'to open – opened'

verkaufen- verkauf***t*** 'to sell- sold'

- are affixed with ***–t***
- never exhibit any stem changes
- *ge-* pure prosody

2. Deverbal nominalizations

- are affixed with ***–ung*** reinigen – Reinig***ung***
- No stem changes ‚to clean – cleaning'
- Highly productive ‚purification, dry-cleaner's'

Investigating morphology in language comprehension

- How are morphologically complex words processed in real time?
- Are inflected and derived words segmented into their morphological components parts during comprehension?
- How are these forms represented in lexical memory?

Morphological priming

- **Repetition priming:**
  walk → walk (IDENTITY) < cook → walk (CONTROL)
- **Morphological priming**:
  walked → walk (RELATED) < cook → walk (CONTROL)
  ≅/> walk → walk (IDENTITY)
- **No priming**:
  kept → keep (RELATED) ≅ cook → keep (CONTROL)

"…the base verb and suffix are partitioned prior to memory access and the base verb is then directly accessed" (Stanners et al., 1979, p. 403).

Masked morphological priming

- **Morphological priming without access to meaning**
  brother → broth ≅ employer → employ
- **No priming for non-affixal segments**
  brothel → broth > brother → broth

Automatic morphological decomposition of segmentable affixes at an early form-level stage of word recognition.

Rastle et al. (2000, 2004), Longtin & Meunier (2005), Marslen-Wilson (2007)

Data analysis techniques

Research question:
How are Turkish/German bilinguals' morphological processing skills in German affected by their age of acquisition of German?

- Age of acquisition
  - may have gradual, *continuous* effects.
  - may also have *discontinuous* non-linear effects

  ('critical period' for the acquisition of grammatical skills?)

- Data analysis techniques that test for both:
  - Linear effects
  - Non-linear effects

Age of acquisition

- **'Earlier is better'?**
  Age of acquisition (AoA) is a crucial predictor of linguistic performance

"Later age of learning onset predicts. . . decreased levels of ultimate attainment" (e.g. Johnson & Newport, 1989).

- **'Use it or lose it'?**

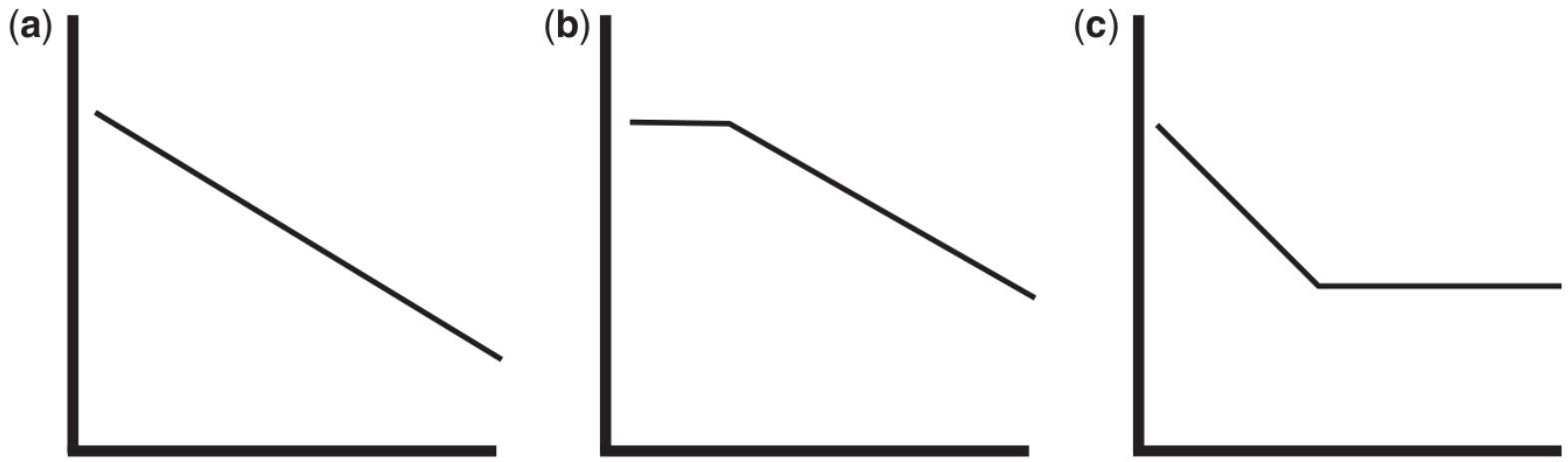
"Acquisition is guaranteed up to the age of six, is steadily compromised from then until shortly after puberty, and is rare thereafter." (Pinker, 1994)

→ **Critical Period Hypothesis (Lenneberg,1967)**

- Early 'window' of heightened sensitivity
- Circumscribed period
- Aligns with maturational stages

Critical Period Hypothesis

Some possible geometries (Birdsong, 2014)



- **What constitutes evidence for a CP?**

"Earlier is better" (i.e., linear effects of AoA) is not sufficient.

"Use it, then lose it" implies a discontinuity, a non-linear function.

The present study

- Masked priming paradigm
  - inflected/derived forms as primes
  - priming of the same target
- Control conditions: orthographic and semantic overlap
- Main predictor: AoA as a continuous factor and with wide range
- Controlling for: measures of proficiency, exposure and usage of German

Masked priming: Method

➢ Participants

- 91 Turkish/German bilinguals, native speakers of Turkish
- AoA of German (range: 0–38 years, mean: 6.6 years)
- Proficiency: Goethe Placement Test (mean: 25.0/30)
- Exposure: Length of Residence (mean: 22.2 years)
- Use of German: Percentage in typical week (mean: 44.3%)

Masked priming: Method

- Procedure
  - Visual primes; lexical decision on visual targets
  - Subliminal prime, presented for 50 ms
  - German -*t* participles vs. -*ung* nominalizations
  - Forward mask → prime → target
  - ######## → geöffnet/Öffnung → öffnen

Masked priming: Method

➢ Materials

- 28 morphologically related prime-target pairs
- Primes: Control, Related(Inflection/Derivation), Identity
  - *ändern* '(to) change' (Identity)
  - *geändert* '(has) changed' (Inflection)
  - *Änderung* '(the) change' (Derivation)
  - *klein* 'small' (Control)
- 24 orthographically related prime-target pairs
  - Word-initial: *Kasten* 'box' → *Kasse* 'cash register'
  - Non-initial: *Engel* 'angel' → *Geld* 'money'
- 24 semantically related prime-target pairs

Masked priming: Method

- Data cleanup
  - 2 items, accuracy below <70% (1 orthographic, 1 semantic)
  - 2 participants, extremely slow (mean RT >1,100 ms, >3 SDs)
  - Incorrect responses or timeouts (5.1 %)
  - Extreme values: < 200 ms and > 2,000 ms (0.38%)
  - Transformation: log(RT)

Masked priming: Method

- Two types of analyses
  - Linear effects: Mixed-effects linear regression
  - Non-linear effects: Regression w/ breakpoints and LOESS
- Mixed-effects regression
  - Crossed random effects for Participants and Items
  - *Prime Type* (Baseline=Control) and *AoA* (uncentered)
  - Covariates: *Proficiency*, *Length of Residence*, *Use of German* (centered)
  - Interactions between *Prime Type* and each of these continuous predictors
  - *Trial position*

Masked priming: Results

- Morphological set

Factor	*Estimate*	*SE*	*t statistic*	*p value*
Intercept (Unrelated primes, AoA=0)	6.4410	0.0323	199.61	<.001
Prime Type INF (inflectional priming, AoA=0)	-0.0355	0.0172	**-2.06**	**.040**
Prime Type DER (derivational priming, AoA=0)	-0.0515	0.0172	**-2.99**	**.002**
Prime Type ID (repetition priming, AoA=0)	-0.0952	0.0172	**-5.55**	**<.001**
AoA (age of acquisition, Unrelated primes)	0.0013	0.0034	0.39	.694
Proficiency (Goethe score, Unrelated primes)	-0.0007	0.0063	-0.11	.910
LoR (length of residence in years, Unrelated primes)	-0.0032	0.0029	-1.11	.268
Use (percentage of German use, Unrelated primes)	0.0009	0.0014	0.64	.522
Trial Position	-0.0001	0.0000	-1.94	.052
Prime Type INF : AoA	0.0041	0.0019	**2.13**	**.034**
Prime Type DER : AoA	0.0008	0.0019	0.42	.676
Prime Type ID : AoA	0.0014	0.0019	0.72	.470
Prime Type INF : Proficiency	0.0039	0.0037	1.07	.286
Prime Type DER : Proficiency	0.0039	0.0037	1.07	.284
Prime Type ID : Proficiency	0.0037	0.0036	1.02	.308
Prime Type INF : LoR	0.0002	0.0017	0.12	.904
Prime Type DER : LoR	0.0007	0.0016	0.41	.682
Prime Type ID : LoR	-0.0007	0.0016	-0.40	.688
Prime Type INF : Use	0.0001	0.0008	0.07	.944
Prime Type DER : Use	-0.0008	0.0008	-1.05	.296
Prime Type ID : Use	-0.0007	0.0008	-0.91	.364

Masked priming: Results

- Semantic set

Factor	*Estimate*	*SE*	*t statistic*	*p value*
Intercept (Unrelated primes, AoA=0)	6.3960	0.0318	201.35	<.001
Prime Type RELATED (semantic priming, AoA=0)	-0.0274	0.0172	-1.59	.112
Prime Type ID (repetition priming, AoA=0)	-0.0939	0.0195	**-4.83**	**<.001**
AoA (age of acquisition, Unrelated primes)	0.0014	0.0031	0.46	.646
Proficiency (Goethe score, Unrelated primes)	-0.0021	0.0058	-0.37	.712
LoR (length of residence in years, Unrelated primes)	-0.0049	0.0027	-1.86	.064
Use (percentage of German use, Unrelated primes)	0.0012	0.0013	0.92	.358
Trial Position	-0.0002	0.0000	**-4.41**	**<.001**
Prime Type RELATED : AoA	0.0008	0.0020	0.40	.686
Prime Type ID : AoA	0.0005	0.0022	0.25	.806
Prime.Type RELATED : Proficiency	0.0013	0.0036	0.37	.714
Prime Type ID : Proficiency	0.0003	0.0040	0.07	.944
Prime Type RELATED : LoR	0.0025	0.0016	1.53	.126
Prime Type ID : LoR	0.0011	0.0018	0.60	.546
Prime Type RELATED : Use	0.0007	0.0008	0.95	.344
Prime Type ID : Use	0.0000	0.0009	-0.01	.988

Masked priming: Results

- Orthographic set

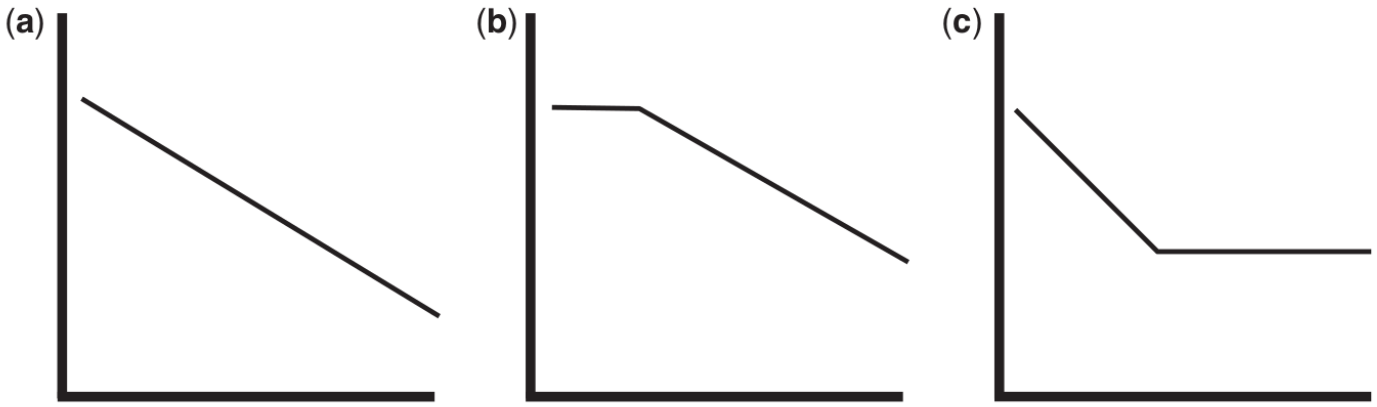
Factor	*Estimate*	*SE*	*t statistic*	*p value*
Intercept (Unrelated primes, AoA=0)	6.3870	0.0320	199.64	<.001
Prime Type TEST (orthographic priming, AoA=0)	0.0200	0.0177	1.13	.258
Prime Type ID (repetition priming, AoA=0)	-0.0970	0.0180	**-5.40**	**<.001**
AoA (age of acquisition, Unrelated primes)	0.0027	0.0032	0.84	.404
Proficiency (Goethe score, Unrelated primes)	-0.0011	0.0060	-0.19	.850
LoR (length of residence in years, Unrelated primes)	-0.0019	0.0028	-0.68	.496
Use (percentage of German use, Unrelated primes)	0.0013	0.0013	0.98	.328
Trial Position	-0.0001	0.0000	-1.73	.084
Prime Type TEST : AoA	-0.0016	0.0020	-0.81	.418
Prime Type ID : AoA	0.0003	0.0020	0.13	.896
Prime.Type TEST : Proficiency	0.0027	0.0037	0.73	.468
Prime.Type ID : Proficiency	0.0038	0.0037	1.02	.310
Prime.Type TEST : LoR	-0.0020	0.0017	-1.19	.234
Prime.Type ID : LoR	-0.0010	0.0017	-0.56	.574
Prime.Type TEST : Use	-0.0003	0.0008	-0.40	.688
Prime.Type ID : Use	-0.0006	0.0008	-0.76	.446

Masked priming: Discussion (Linear model)

- Main results
  - Early bilinguals show morphological priming…
  - …but no semantic or orthographic priming.
  - Inflectional priming decreases with increasing AoA
- Highly **selective** effect
  - AoA modulates *inflectional* priming
  - … but not *derivational* priming,
  - … nor *repetition* priming
  - … nor *orthographic* or *semantic* priming.

Non-linear AoA effects?

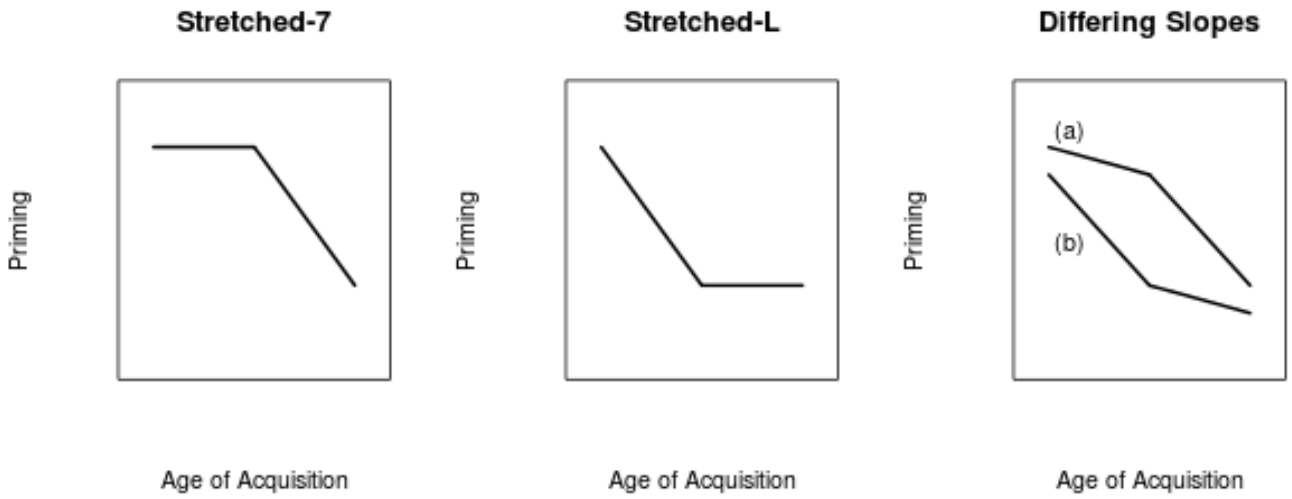
Some possible geometries (Birdsong, 2014)



- Generalized to priming effects
- Types of models (relating AoA to dependent variable)
  - Linear
  - Stretched-7
  - Stretched-L
  - To these we added: Differing Slopes

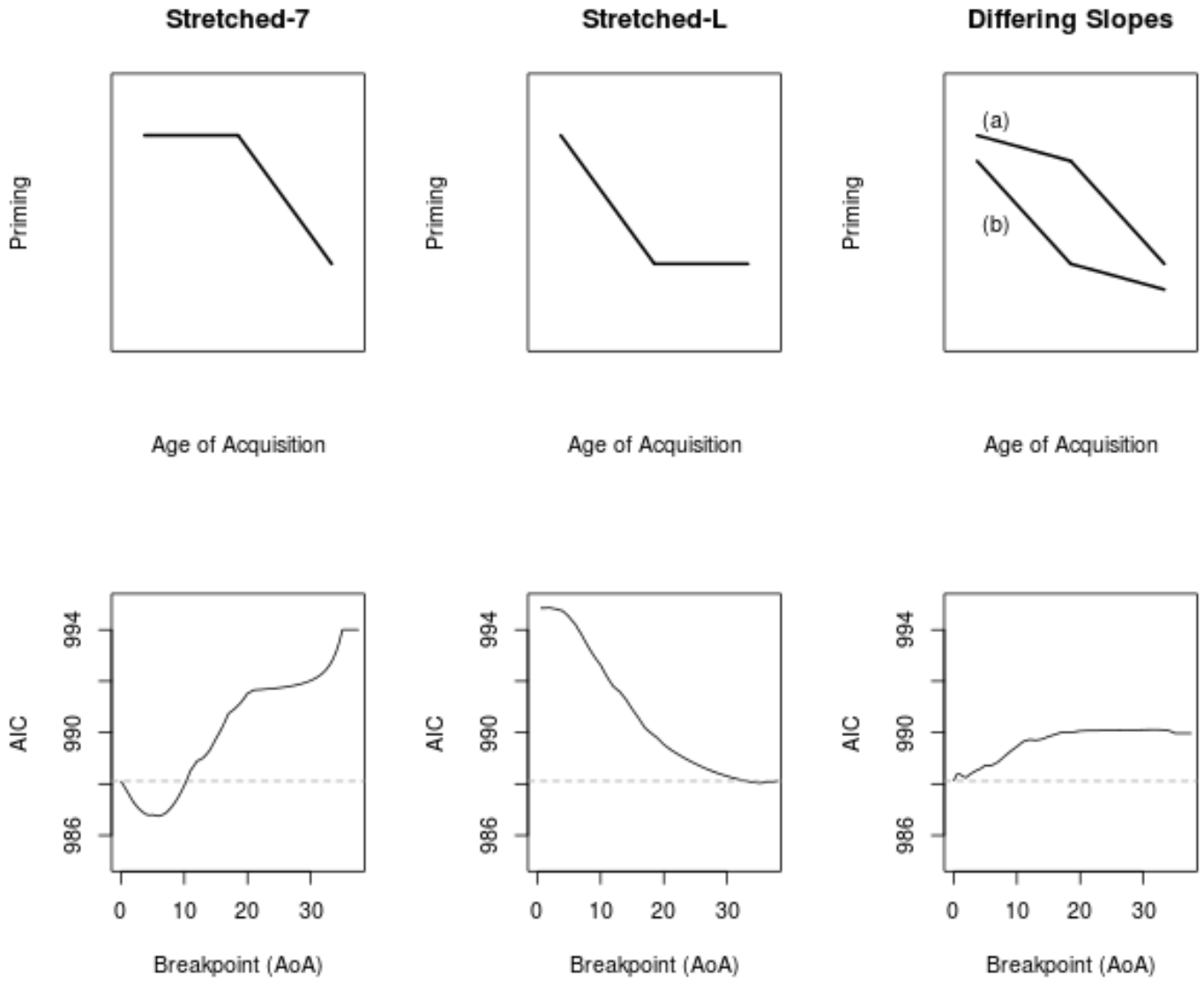
Regression with breakpoints

- Types of non-linear models tested

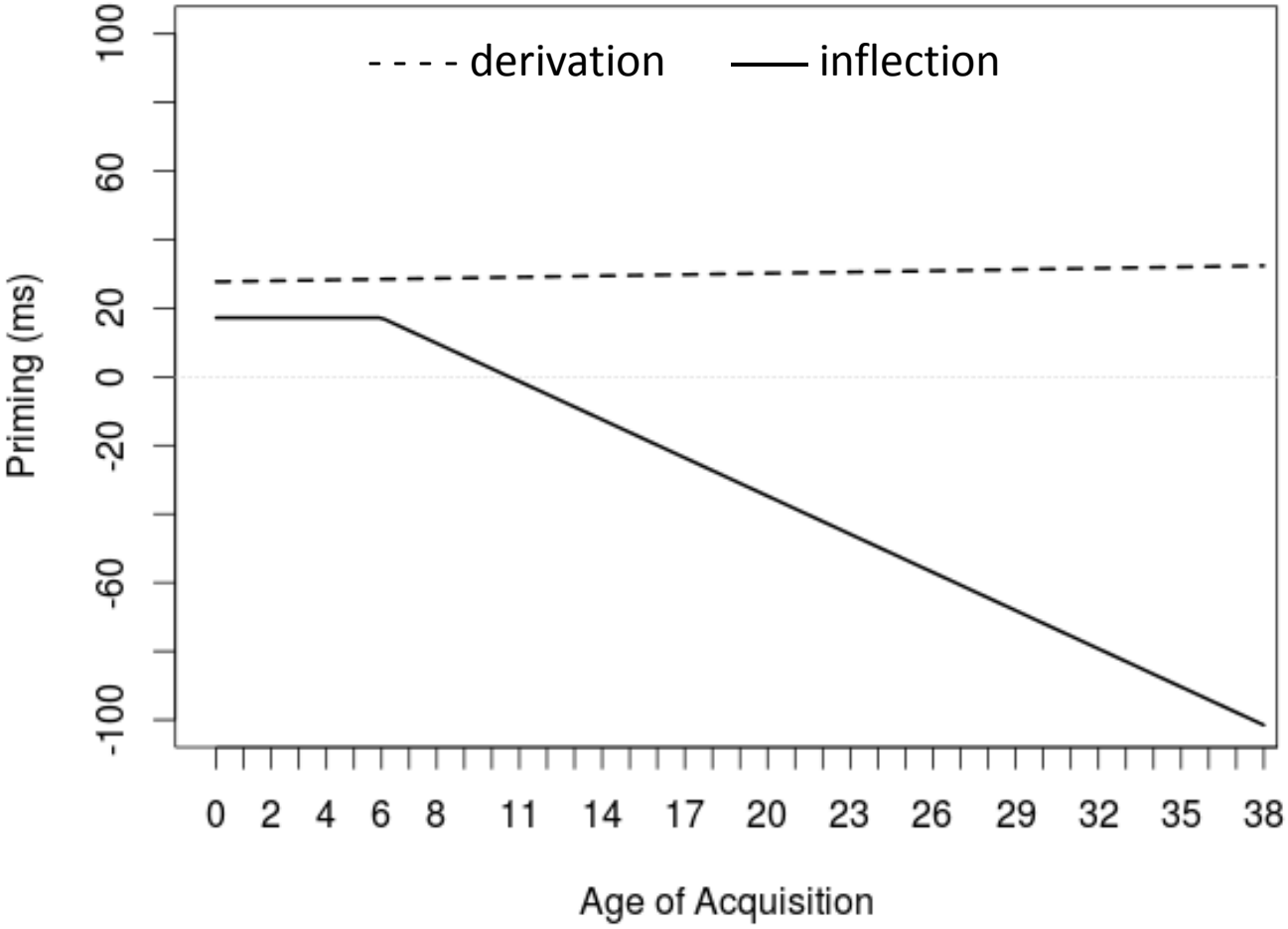


- First method: Regression with breakpoints
  - Combination of two linear regressions
  - With “flat” part on either side, or with two slopes
  - AoA and covariates predicting by-participant priming
  - Iterated procedure for every AoA value
  - Goodness of fit measured by AIC

Regression with breakpoints: Results



Regression with breakpoints: Results



➢ Best model for inflection

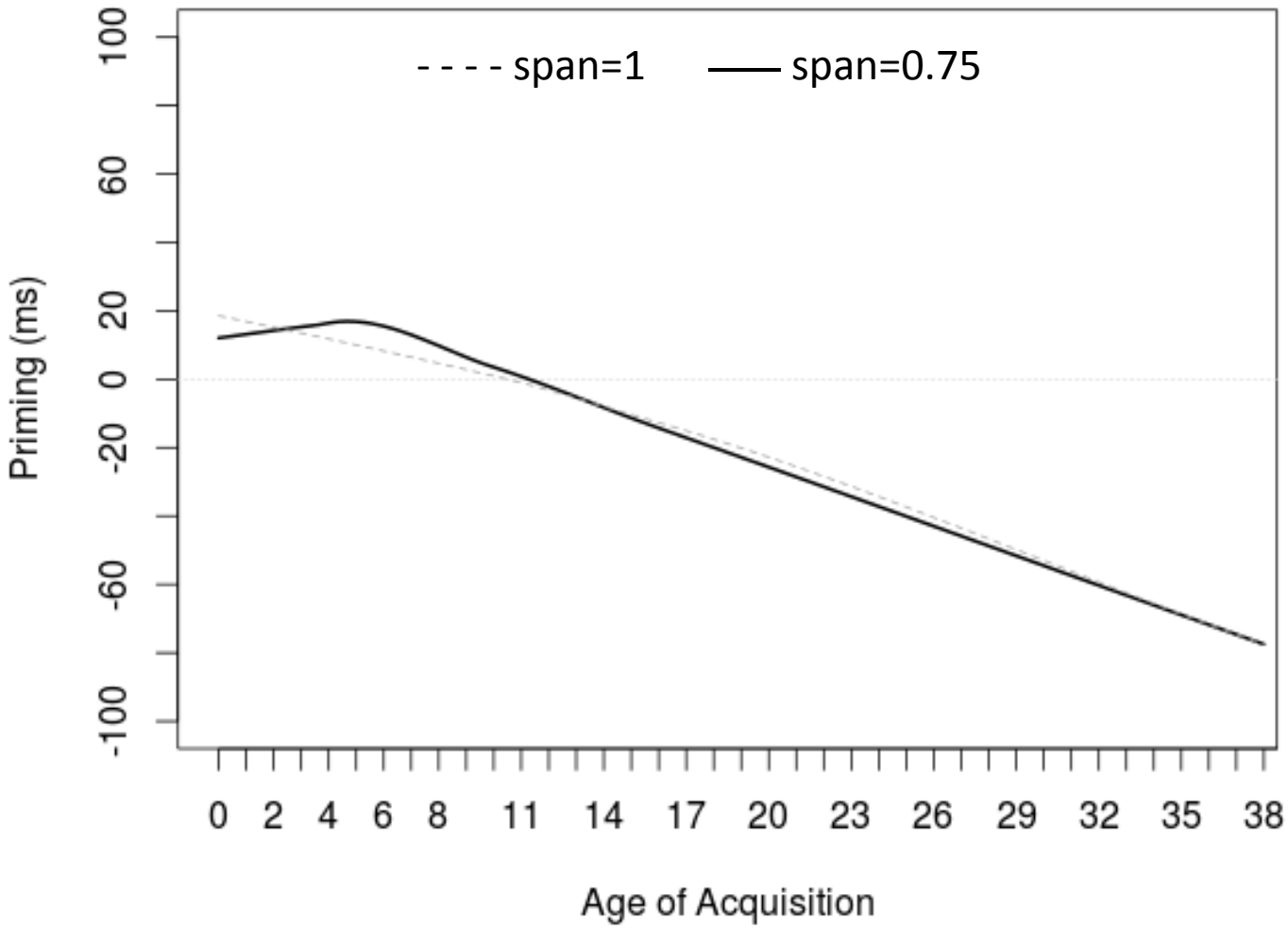
- Clarke test w/ linear model
  p=.011
- Priming until AoA=6
  t=2.34, p=.022
- Descending slope
  t=-2.85, p=.006
- No effect of any covariates
  all ps>0.3

Non-linear AoA effects: LOESS

- Second method: LOESS ("local regression")
  - Locates a smooth curve through the data points …
  - … without requiring any advance specification of its shape
  - Great flexibility for visualization of non-linearities

- Span parameter
  - Large spans $\rightarrow$ more smoothness of the curve
  - Smaller spans $\rightarrow$ greater wiggliness
  - Typical spans: 0.25 to 0.75

LOESS regression: Results



Summary & Discussion

Summary

- AoA effects are bounded, discontinuous
- Peak sensitivity starts decreasing around age 6
- AoA effect on early automatic stages of morphological processing
- AoA effect is highly specific, restricted to inflected forms

Discussion

- A critical period for the acquisition of inflection?
- Separate mechanisms for inflection and derivation?
- L2 grammatical processing not native-like?

Conclusions

Conclusions

- The within-modularity of language:
  - AoA effects may be subtle, rather than affecting ‘language performance’ or ‘proficiency’ as a whole.
  - Likewise for L1/L2 differences: derivational but not inflectional priming is native-like.

- Advantages in executive functioning do not explain the selective AoA effect for morphology in bilinguals.

Two sources for masked priming