UiT

THE ARCTIC
UNIVERSITY
OF NORWAY

Eye-tracking in Linguistics: Online Eye-Tracking Workshop

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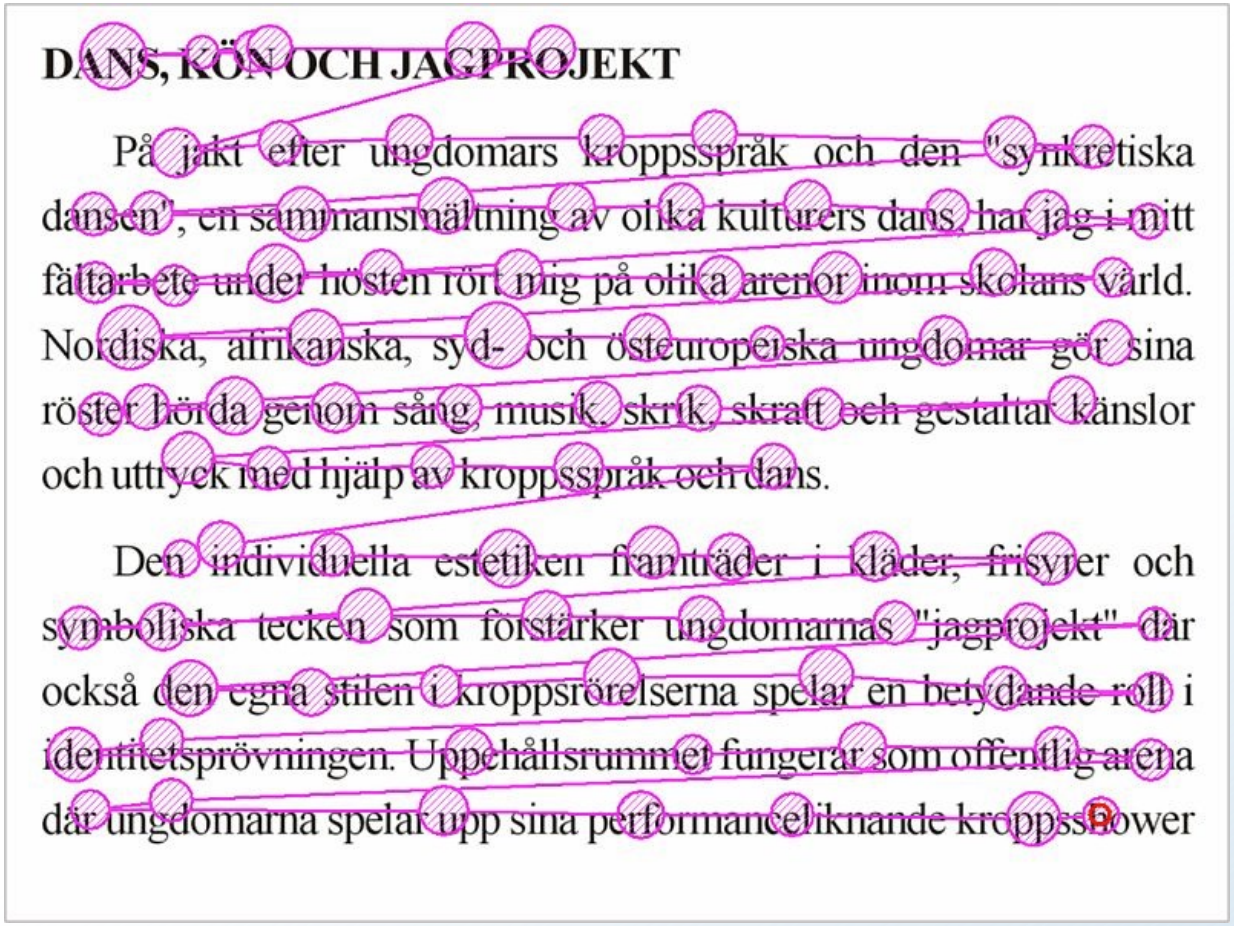
03.05.2021

Once upon a time…

- Louis Emile Javal (1879)
  - Opthamologist
  - Reading involves fixations and saccades

The eyes never move smoothly over still text



DANS, KÖN OCH JAGPROJEKT

På jakt efter ungdomars kroppsspråk och den "synkretiska dansen", en sammansmältning av olika kulturers dans, har jag i mitt fältarbete under hösten rört mig på olika arenor inom skolans värld. Nordiska, afrikanska, syd- och österuropeiska ungdomar gör sina röster hörda genom sång, musik, skrik, skratt och gestaltar känslor och uttryck med hjälp av kroppsspråk och dans.

Den individuella estetiken framträder i kläder, frisyrer och symboliska tecken som förstärker ungdomarnas "jagprojekt" där också den egna stilen i kroppsrörelserna spelar en betydande roll i identitetsprövningen. Uppehållsrummet fungerar som offentlig arena där ungdomarna spelar upp sina performanceliknande kroppsshower

Saccades

- Movement of the eye
  - No visual input
  - Very short duration
  - Fastest movements produced by the body
- Saccade latency
  - Time period to plan and execute a saccade
    - Adults: 200 ms (Matin et al., 1993)
    - Children 4-8y.o.: 300-450 ms (Yang et al., 2002)
    - Infants: 450–600 ms (Gredeback et al., 2006)

Fixations

- Time between two saccades during which eyes are relatively stationary
  - Visual input
  - Duration: 200-400 ms, but can be longer or shorter
- Blinks

The first eye-tracker

- Edmund Huey (1908)
  - Built the first eye-tracker
  - Contact lens with a hole for the pupil

- Alfred L.Yarbus (1950s)
  - Eye gaze is task-dependent
  - Jumps between same parts of a scene

Yarbus's eye-tracker

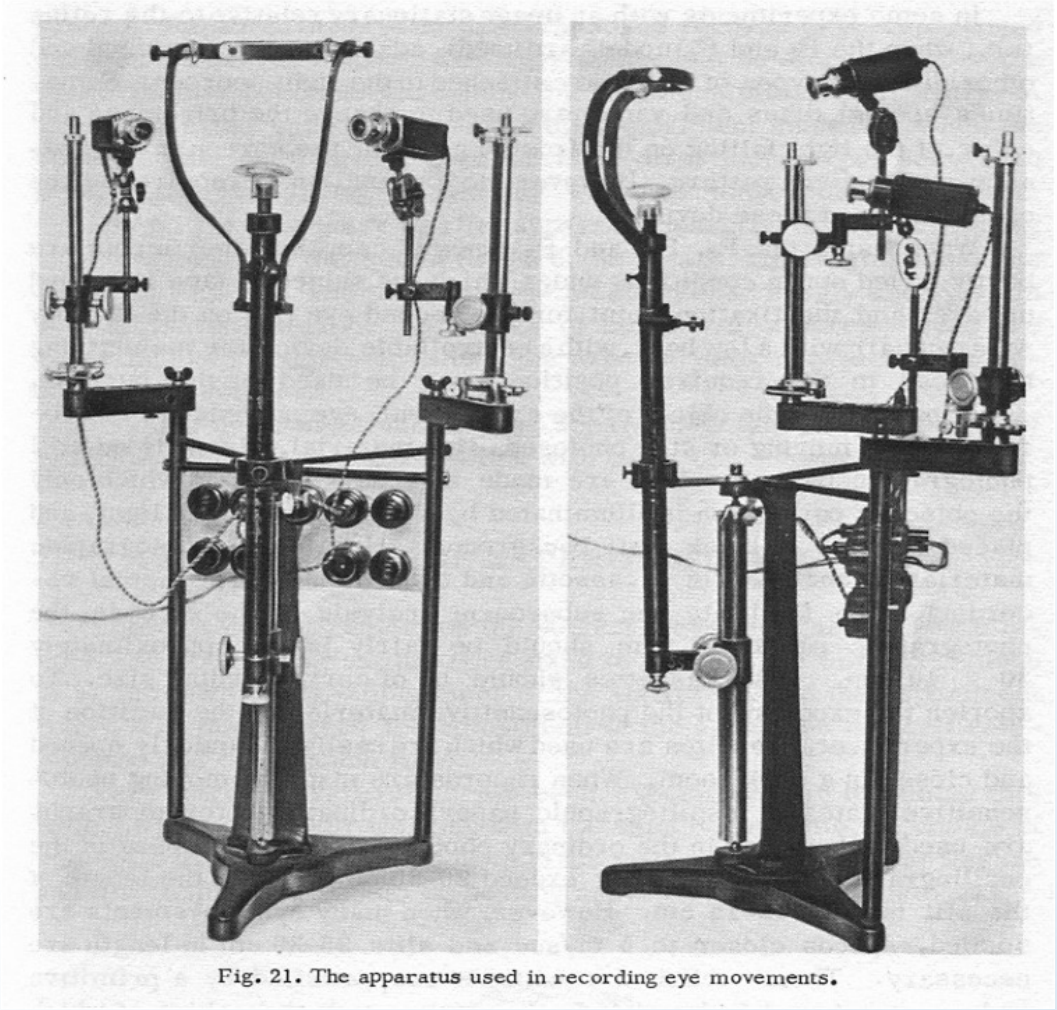
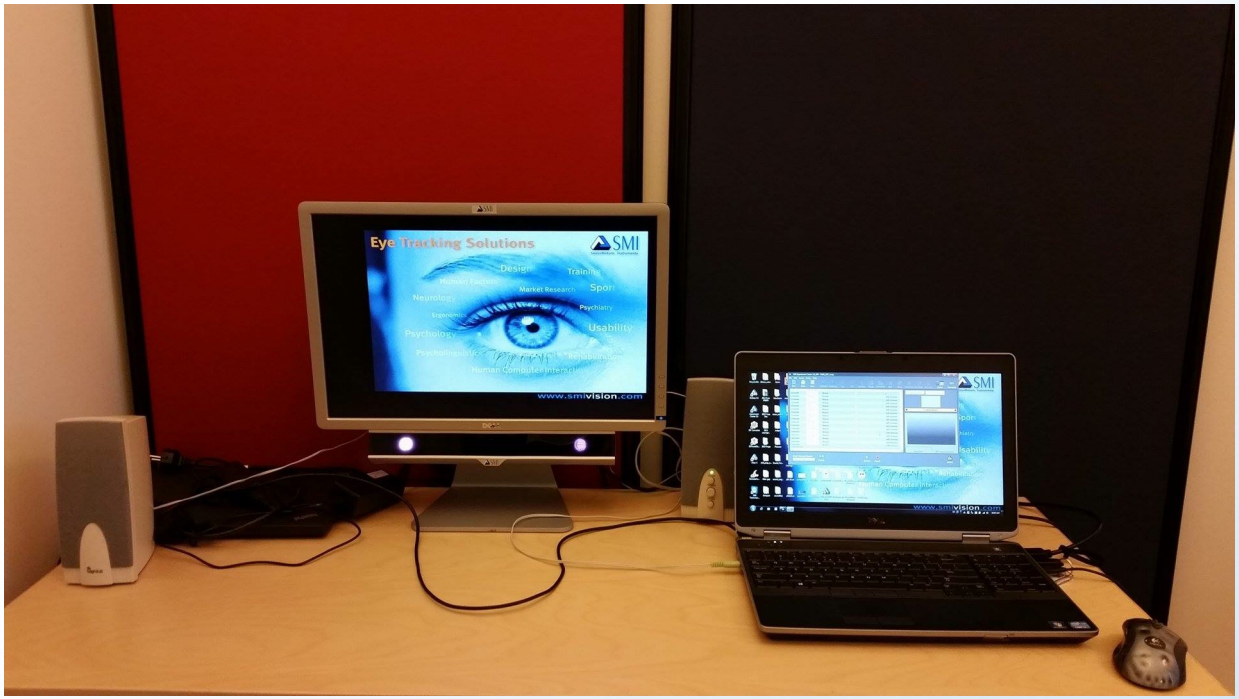


Fig. 21. The apparatus used in recording eye movements.

Modern eye-trackers

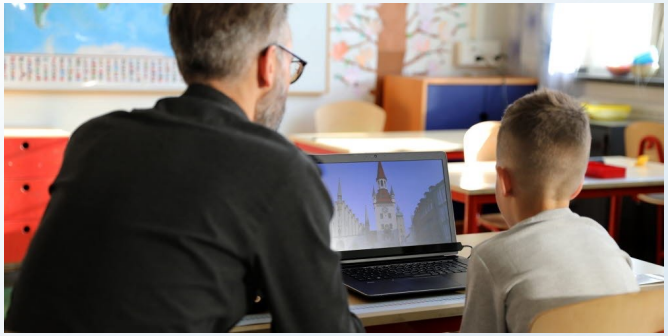


SMI-RED 500

Modern eye-trackers

Eye-Link Portable Duo

Tobii Pro Fusion

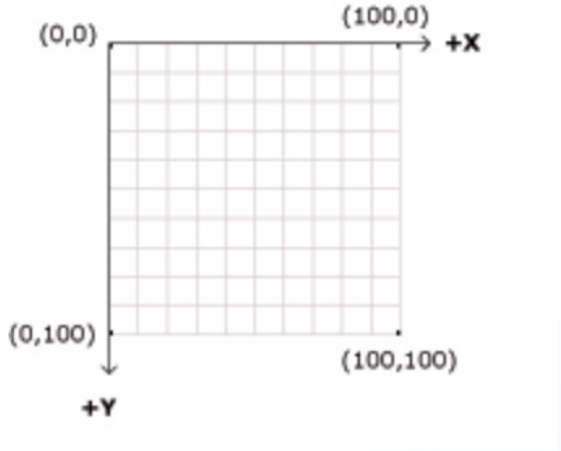


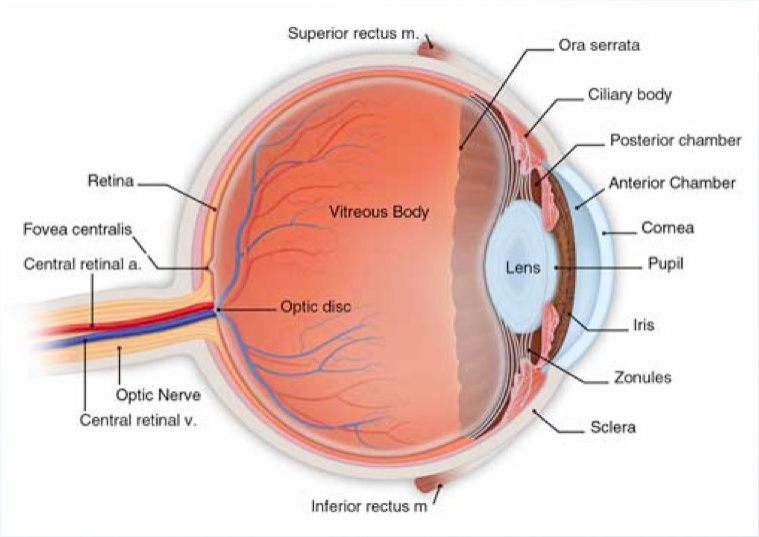
https://www.sr-research.com/eyelink-portable-duo/

https://www.tobiipro.com/product-listing/fusion/

How does infrared eye-tracking work?

- Infrared light reflects off the cornea
- Reflection is captured by high-resolution camera
- Based on the angle of the reflection, gaze position is calculated





Theres Grüter. Eye-tracking in Linguistic Research (ISBPAC 2018 Workshop)

Webcam-based eye-tracking

Webgazer
Labvanced

Pros

- Works with cheap off-the-shelf webcams
- Can reach a huge number of people due to their ubiquity
- Can offer fast turnaround time
- Can be done at home rather than central location testing (i.e. at a lab)

Cons

- Less accurate and precise compared to infrared eye trackers
- Very sensitive to movement, requires the respondent to maintain an unnaturally steady posture throughout a recording
- Will not work well in in low light conditions
- Low framerate / resolution

https://imotions.com/blog/webcam-eye-tracking-vs-an-eye-tracker/

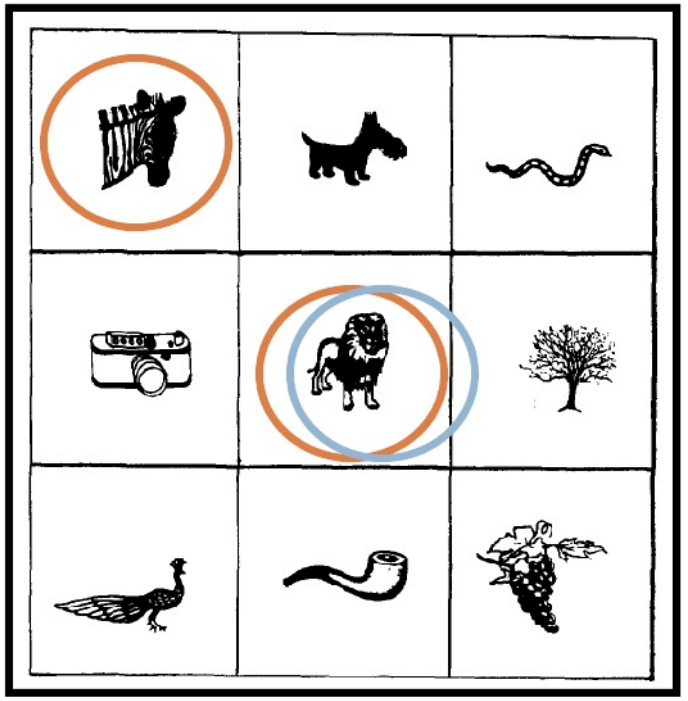
Two types of eye-tracking studies in linguistics

- studies that track eye movements while participants are reading

- studies that track eye movements while participants are viewing scenes (and sometimes manipulating objects in those scenes) (=Visual World Paradigm).

The first VWP study

- Cooper (1974)
- While on a safari in Africa...
  ...when suddenly I noticed a hungry lion, slowly moving through the tall grass.



- **Language processing and eye movements are closely time-locked**

The control of eye fixation by the meaning of spoken language: A new methodology for the real-time investigation of speech perception, memory, and language processing. **Cognitive Psychology**, **6**, 84-107.

The VWP

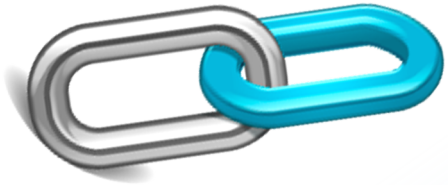
- Cooper (1974)
  - Relationship between eye fixations and the meaning of concurrently spoken sentence
  - Using this relationship as a research tool in cognitive psychology and psycholinguistics
  - The Mind-Eye hypothesis
  - Characteristics of the response system: sensitivity, short latencies, spontaneity
  - Applications:
    - Speech perception and memory;
    - Language processing

"[T]he eye is thought to give researchers a window into the mind."

Conklin & Pellicer-Sánchez (2016)

What does this mean?

What can eye gaze tell us about language processing?

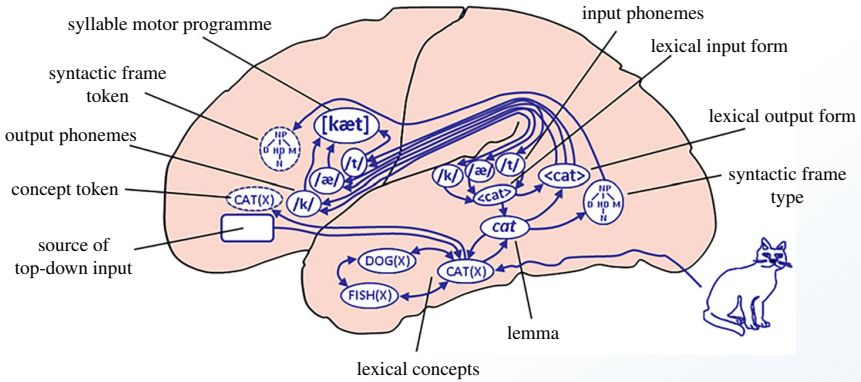


Linking Hypothesis:
Eye-movements ~ activation of a linguistic representation

Informally, we have automated behavioral routines that link a name to its referent; when the referent is visually present and task relevant, then recognizing its name accesses these routines, triggering a saccadic eye movement to fixate the relevant information. (Tannenhaus et al. 2000, p. 565)

Sentence comprehension

- Involves a dynamic interaction between semantic and syntactic processes.
- Prosodic, lexical/semantic, visual context and discourse cues are rapidly integrated and influence online processing.



Hagoort 2019

Godfroid et al. 2020; Trueswell & Tannenhaus, 1995; Saab et al. 2012; van Berkum et al. 1999, 2003; Bornkessel and Schlesewsky 2006, 2008

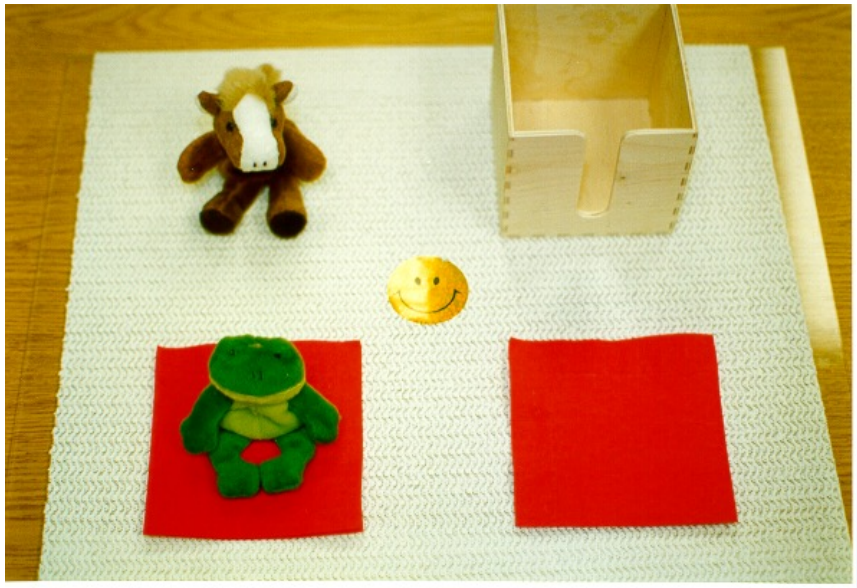
Incrementality

- The sentence processing mechanism (i.e., the parser) makes *incremental* commitments as soon as the relevant cues become available, despite the risk of revisions at a later stage.

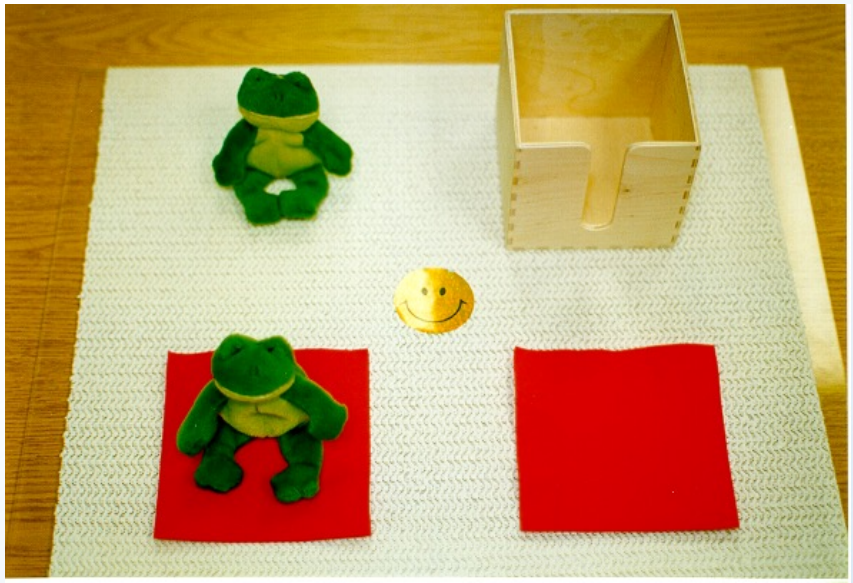
Tanenhaus et al. 1995; Trueswell and Gleitman 2004; Snedeker & Trueswell 2004; Kaiser & Trueswell, 2008; Lew-Williams & Fernald 2007; Lidz & Omaki 2014; Omaki, 2010; Pickering, Traxler, & Crocker, 2000; Staub & Clifton, 2006; DeLong, Urbach, & Kutas, 2005; Zhou et al. 2014

Incremental processing

"Put the frog on the napkin in the box."



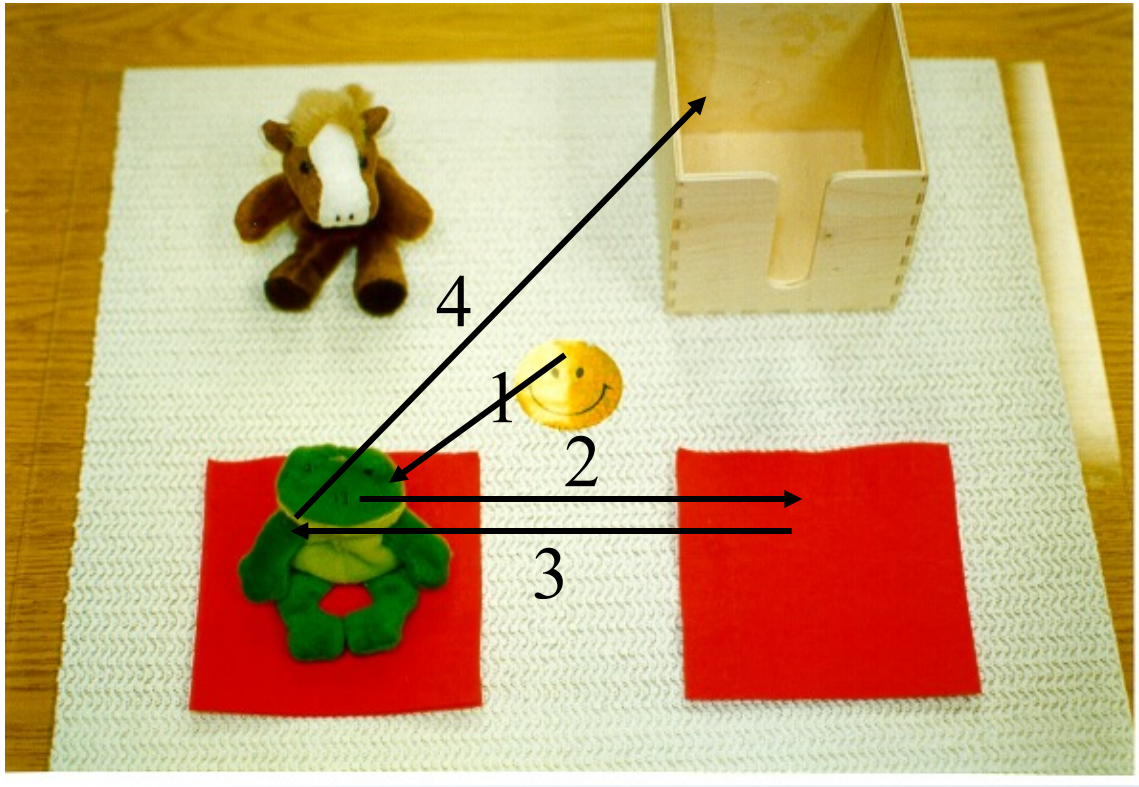
1-Referent Context
supports Destination



2-Referent Context
Supports Modification

Tannenhaus et al. (1995), Trueswell et al. (1999)

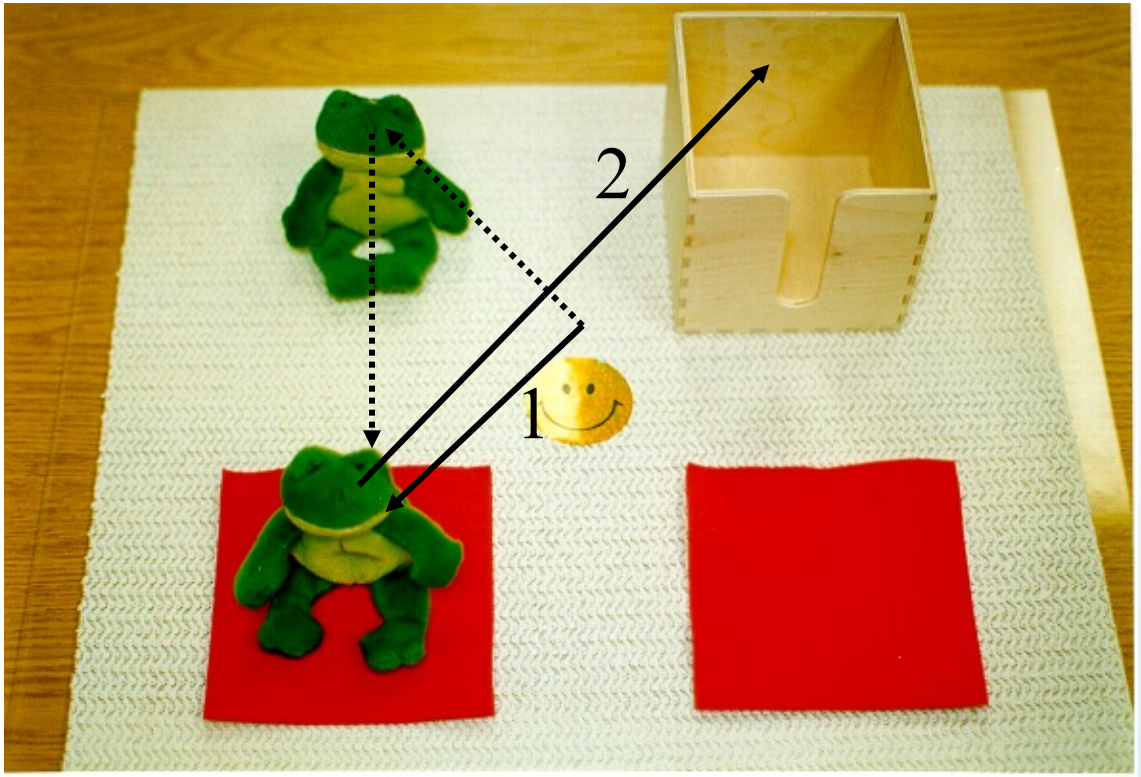
Adults' Eye Movements for 1-Referent



"Put the frog on the napkin in the box."

1 2 3 4

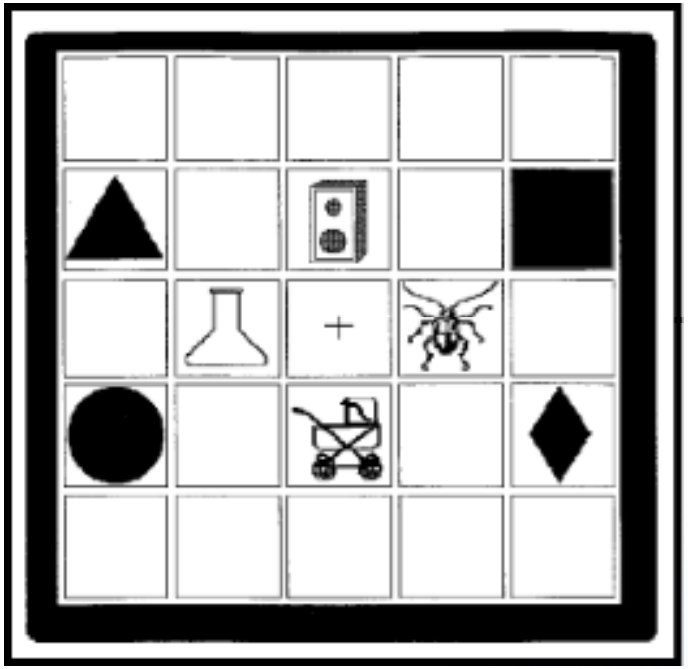
The role of the visual context: Adults' Eye Movements for 2-Referent

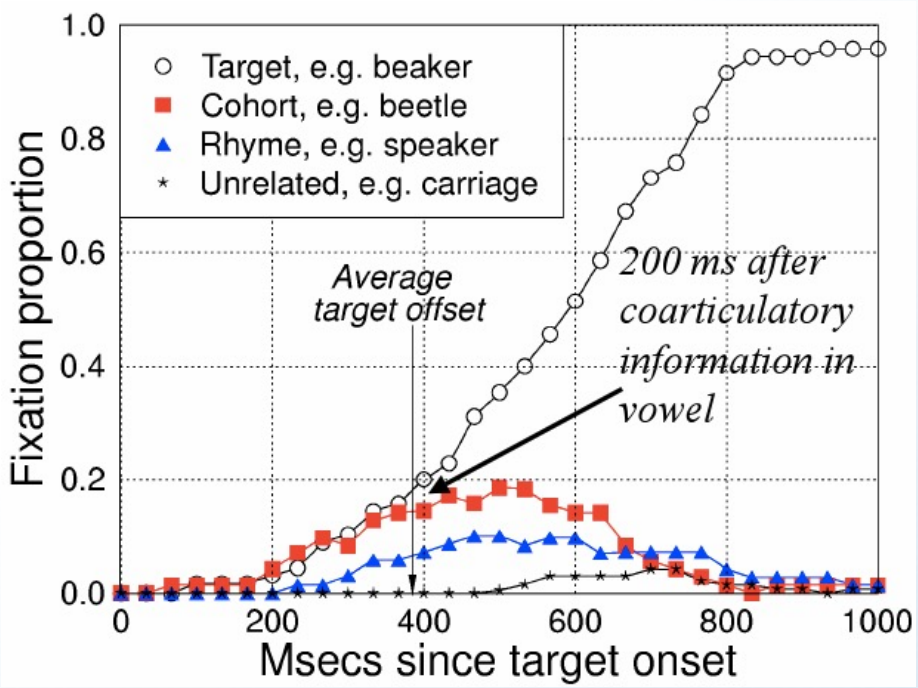


"Put the frog on the napkin in the box."

1 **2**

Incrementality all the way down: Allopenna et al. (1998)

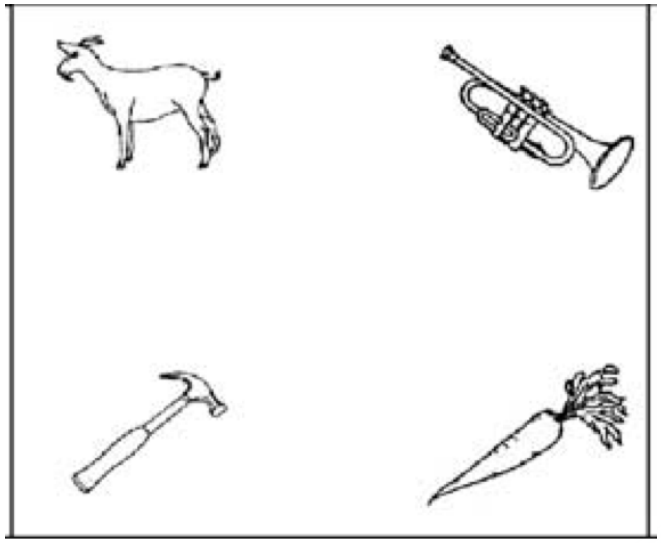




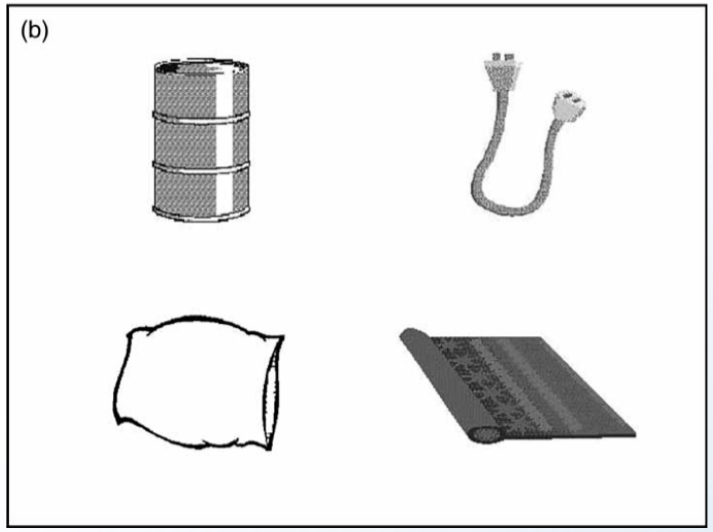
"Pick up the BEAKER, now put it below the diamond"

People look at words which match in onset (**bee**tle) and offset position (spea**ker**)

Not only *phonological* competition effects



Target: PIANO



Target: SNAKE

Where do you think the participants looked at? Why?

Huettig & Altmann, 2005; 2007

Predictive processing

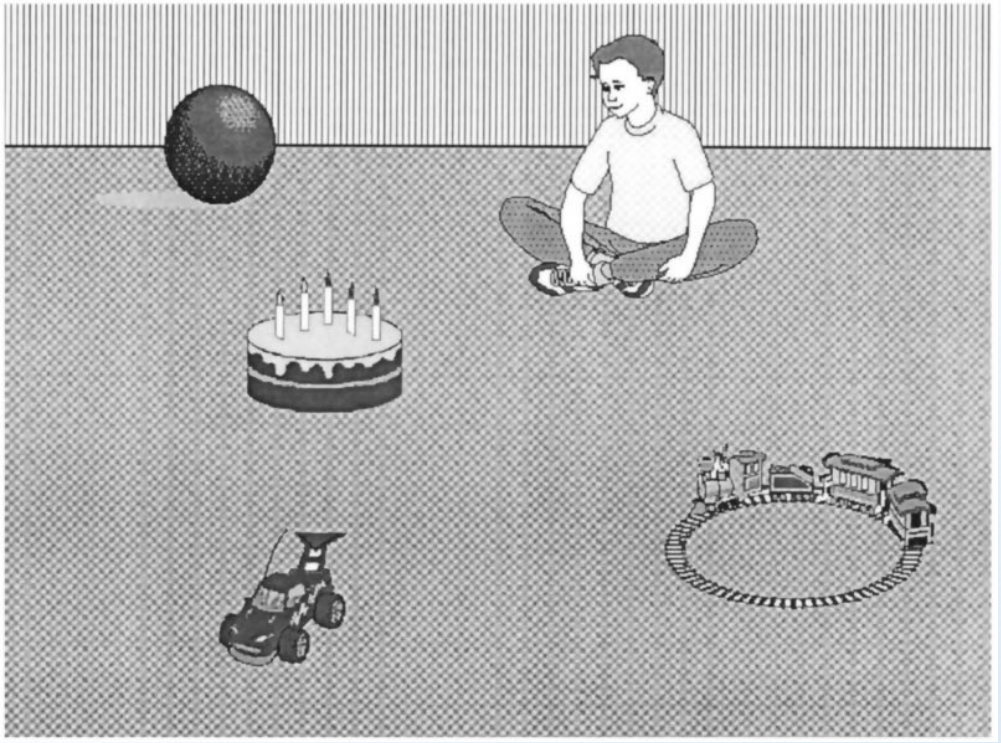
- Listeners are often able to *predict* upcoming elements of the sentence even before these elements become available.

Altmann and Kamide 1999; Kamide et al. 2003a,b; Altmann & Kamide 2007; Lew-Williams & Fernald 2007; Ozge et al. 2016, 2019

Anticipation

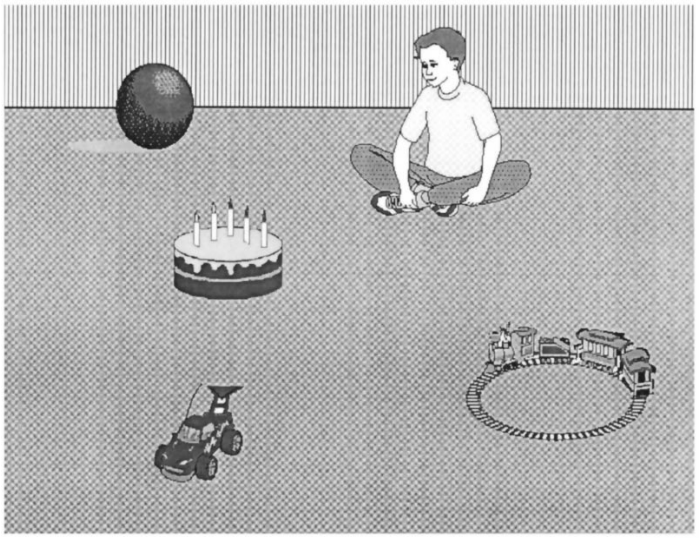
The boy will eat the cake

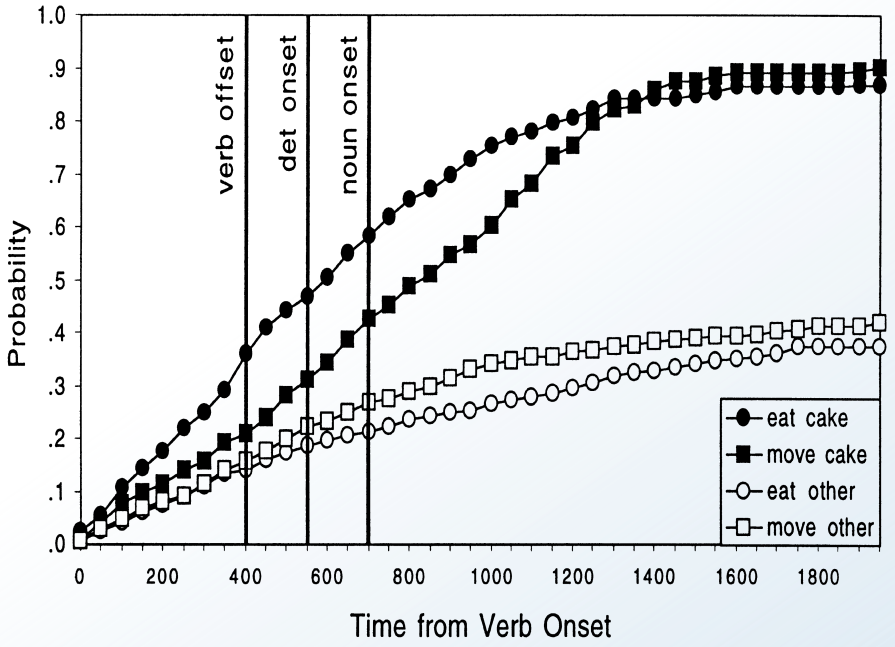
The boy will move the cake



Altmann & Kamide (1999)

Anticipation





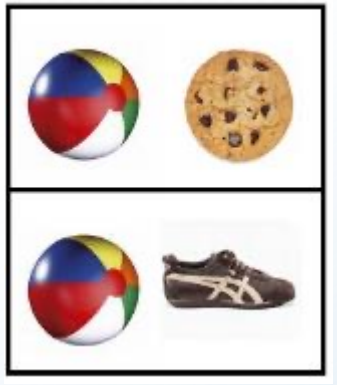
VERB INFORMATION CAN BE USED TO ANTICIPATE UPCOMING THEME

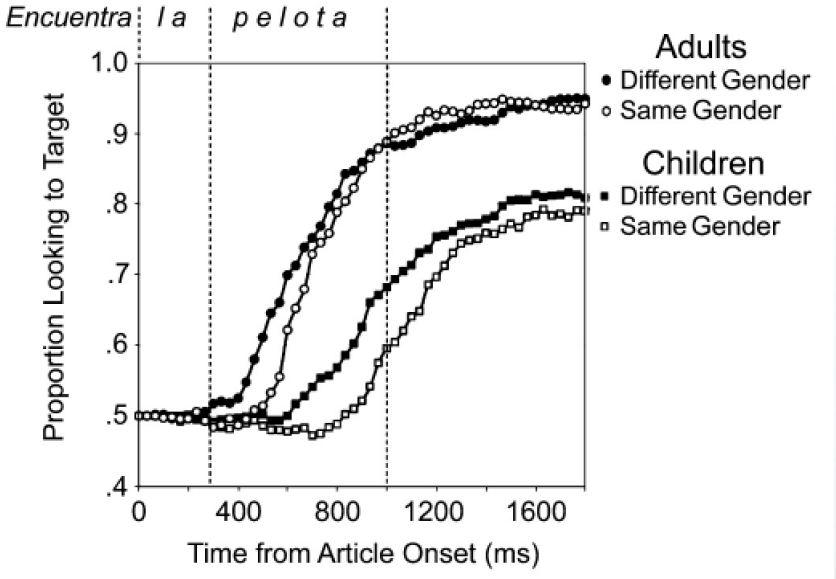
Altmann & Kamide (1999)

Grammatical gender

Encuentra	la	pelota
Find	the-FEM	ball

- Same gender: la pelota *ball* and la galleta *cookie*
- Different gender: la pelota *ball* and el zapato *shoe*



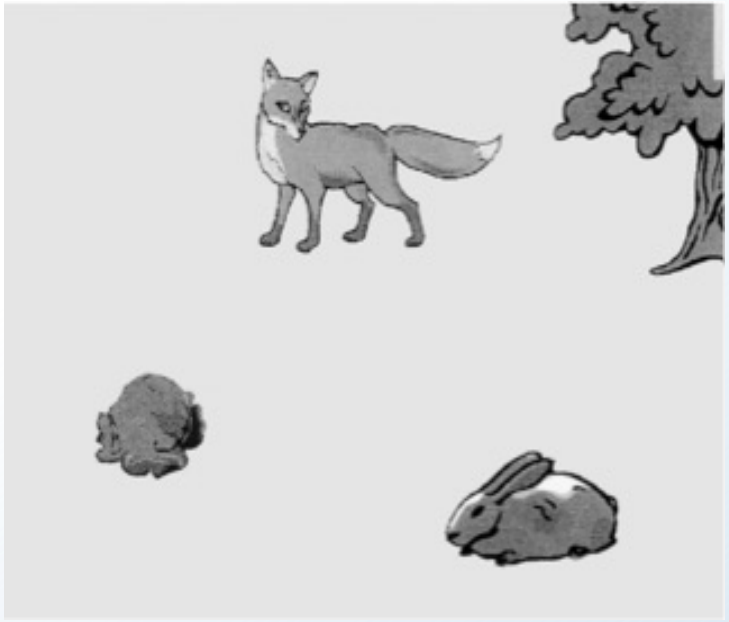


Lew-Williams & Fernald, 2007

Case marking

Der Hase frißt gleich den Kohl.
The hare-nom eats shortly the cabbage-acc.
“The hare will shortly eat the cabbage.”

Den Hasen frißt gleich der Fuchs.
The. hare-acc eats shortly the fox-nom.
“The fox will shortly eat the hare.”



Kamide, Scheepers & Altmann 2003

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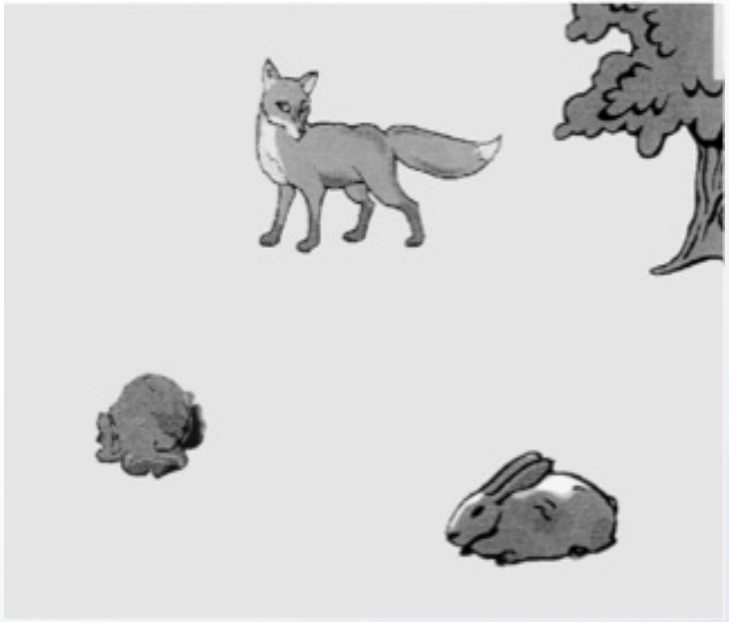


MORE ANTICIPATORY LOOKS TO THE 'FOX' IN THE ACC CONDITION THAN NOM CONDITION

Kamide, Scheepers & Altmann 2003

Activation of event representations

Cognition 133 (2014) 262–276

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Grammatical aspect and event recognition in children's online sentence comprehension

Peng Zhou [a,*], Stephen Crain [a], Likan Zhan [a,b]

[a] Macquarie University, Sydney, NSW 2109, Australia
[b] Beijing Language and Culture University, Beijing 100083, China

Laonainai zhong-**ZHE** / zhong-**LE** yi-duo xiaohua.

old lady plant-DUR / plant-PERF one-CL flower

'The old lady is planting / has planted a flower.'

Grammatical Aspect

- Grammatical aspect is a central verbal category in many languages. It specifies whether the situation is represented as a completed whole (Perfective aspect) or as ongoing/underspecified in terms of completeness (Imperfective aspect).

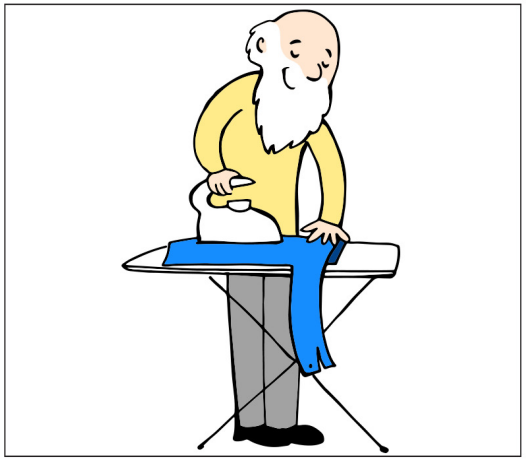
- In Russian, all verbs are classified as either Perfective or Imperfective.

  Typically verbs occur in aspectual pairs, with two related verbs being used to express the Imperfective and Perfective meanings.

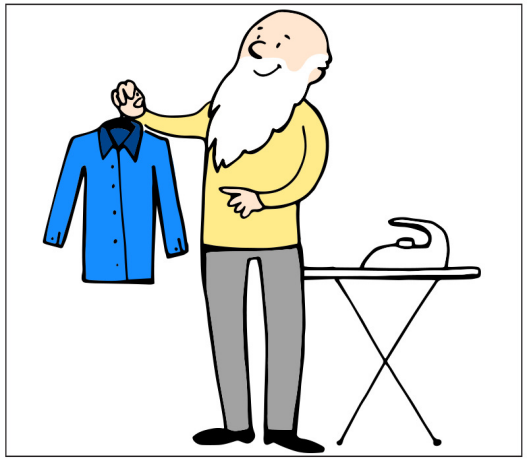
Grammatical aspect in Russian

Minor et al. (in prep)

Ongoing Event (OE)



Completed Event (CE)

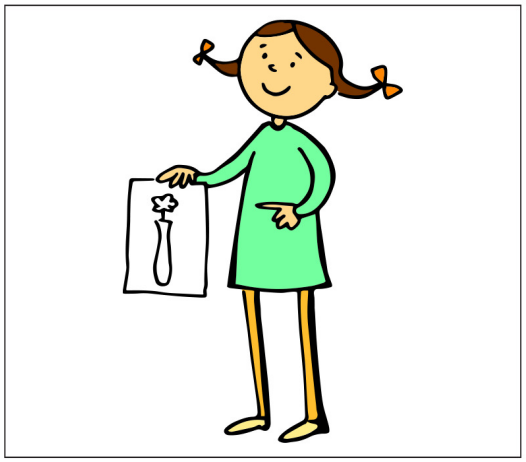


Byl prazdnik. Deduška gladil[ipf] *novuju rubašku.*
It was a holiday. Grandad was ironing a new shirt.

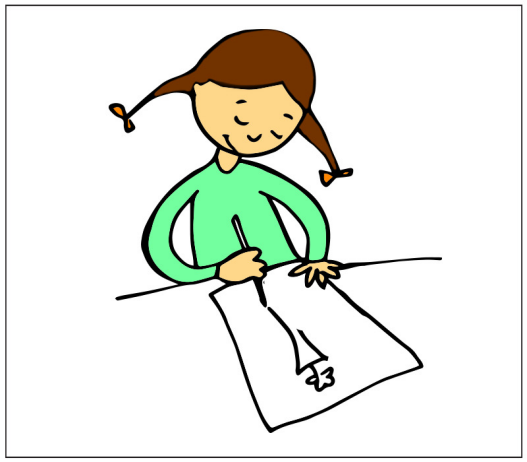
Byl prazdnik. Deduška pogladil[pf] *novuju rubašku.*
It was a holiday. Grandad ironed a new shirt.

Visual stimuli

Completed Event (CE)



Ongoing Event (OE)



Šël pervyj urok. Devočka risovala*ipf* tonkuju vazu.
It was the first lesson. The girl was drawing a thin vase.

Šël pervyj urok. Devočka narisovala*pf* tonkuju vazu.
It was the first lesson. The girl drew a thin vase

Morphological Structure

Prefixal aspectual pairs: Prefix + Imperfective = Perfective

čita-l	**pro**-čita-l
read.IMP-PAST	PFV-read-PAST
stroi-l	**po**-stroi-l
build.IMP-PAST	PFV-build-PAST

Suffixal aspectual pairs: Perfective + Suffix = Imperfective

otrkry-l	otkry-***va***-l
open.PFV-PAST	open-IMP-PAST
raskrasi-l	raskraši-***va***-l
colour.PFV-PAST	colour.IMP-PAST

Test Items

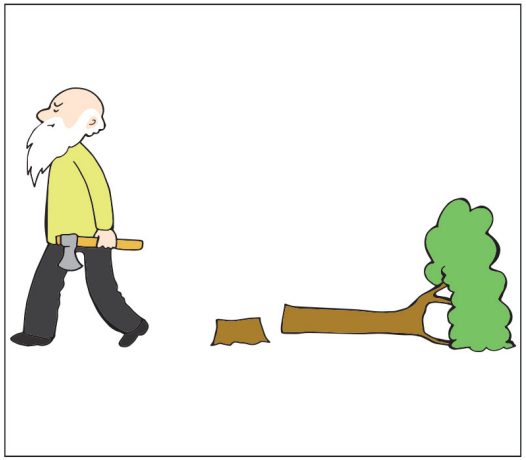
24 test items.
2 types:

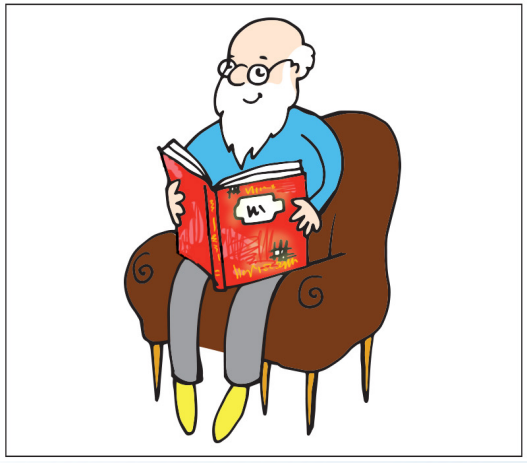
- Basic Imp vs Prefixed Perf (Prefixal Aspectual Pairs)
- Secondary Imp vs Prefixed Perf (Suffixal Aspectual Pairs)

	Imperfective	**Perfective**
'build'	*stroi-t'*	*po-stroi-t'*
'draw'	*risova-t'*	*na-risova-t'*
'iron'	*gladi-t'*	*po-gladi-t'*
'drill'	*sverli-t'*	*pro-sverli-t'*
'inflate'	*na-du-va-t'*	*na-du-t'*
'water'	*po-li-va-t'*	*po-li-t'*
'construct'	*so-bira-t'*	*so-bra-t'*
'sweep'	*pod-meta-t'*	*pod-mes-ti*

The mean log-transformed frequencies of the verbs in the prefixal and the suffixal pairs did not differ significantly (t = 1.12, p = 0.27) .

Fillers





Byl solnečnyj den^{j}. Deduška srubil^{pf} vysokoje d^{j}erevo.
It was a sunny day. Grandad chopped down a tall tree.

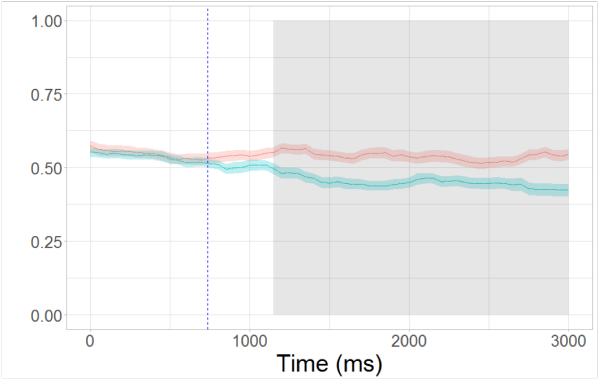
Adults: 24 Test Items + 24 Fillers
Children: 24 Test Items + 11 Fillers

Participants

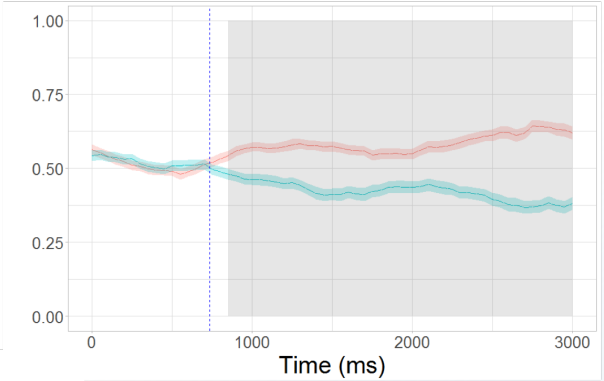
3-4 y.o.	67
5-6 y.o.	69
7-8 y.o.	38
Total children	174
Adults	124
Total Participants	**298**

Proportion of looks to Ongoing Event by Aspect

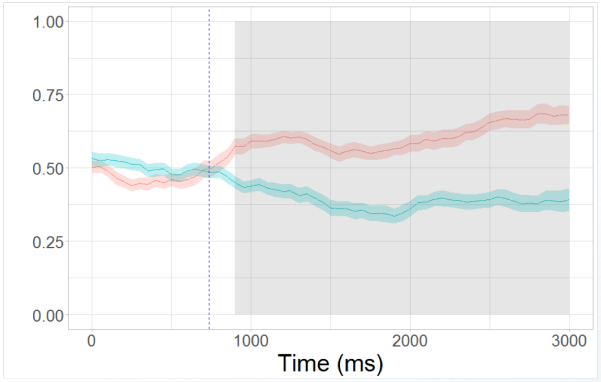
3-4 y.o.



5-6 y.o.

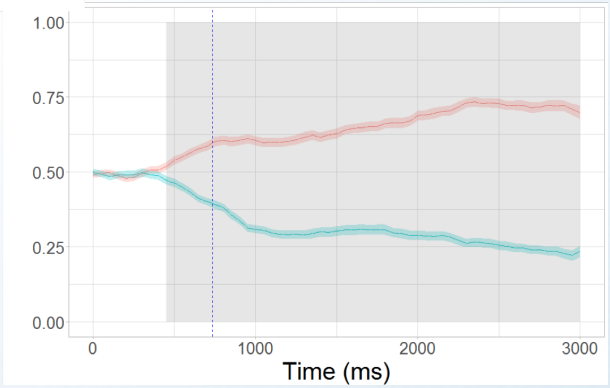


7-8 y.o.



Imp
Pf

Adults

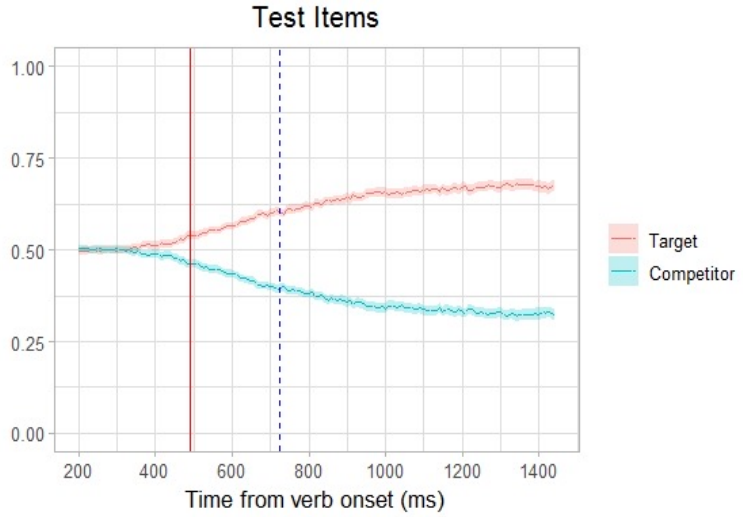


*Dotted blue line = Average Verb offset

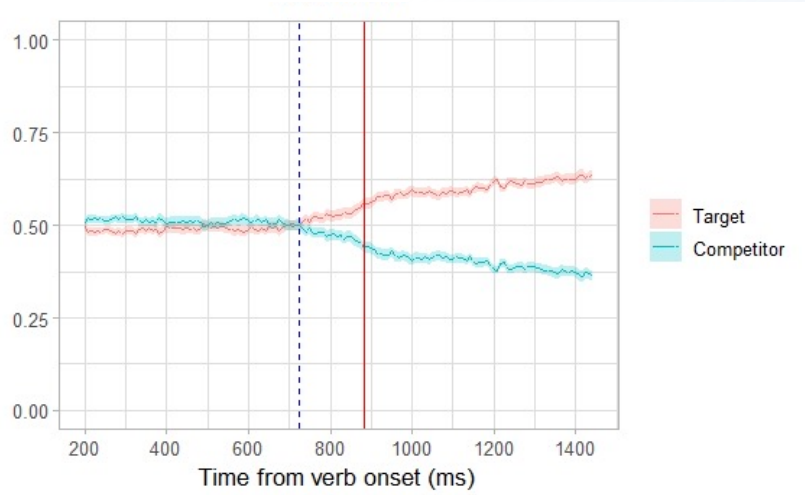
Significant clusters of difference for all groups, but different effect sizes

Time-course of Effect

Adults
(>.85 acc., n=118)

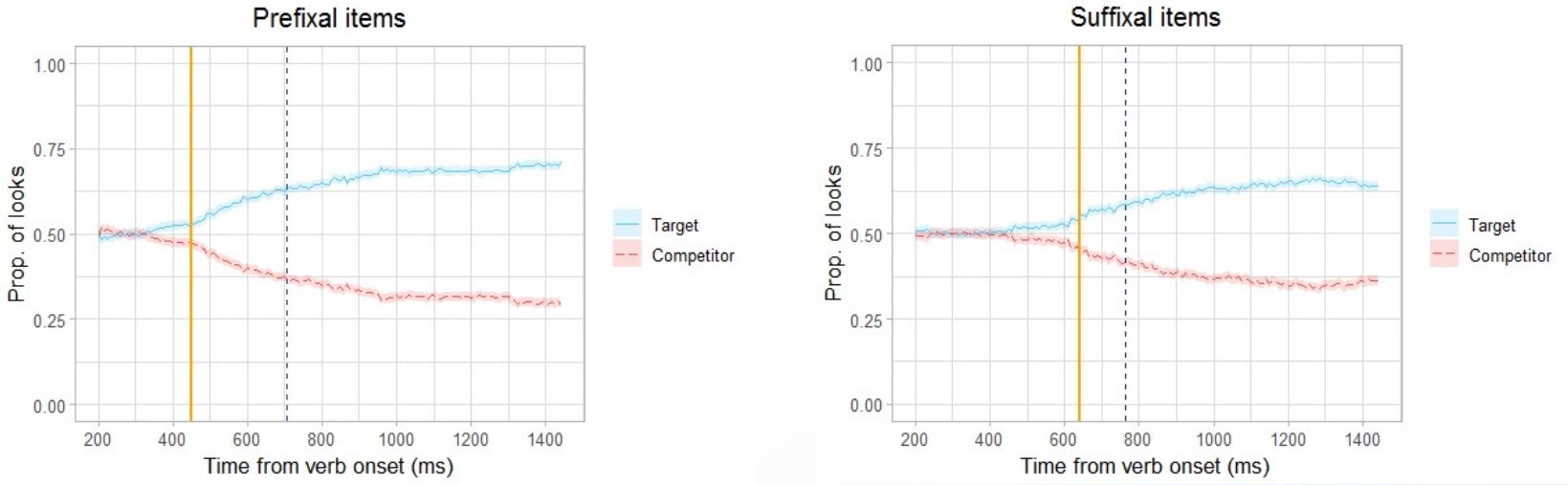


Children
(>.85 acc., n=73, M age 5;10, range 3-8)



Upper estimate of the effect latency after Holm-Bonferroni correction
492 ms after the Verb onset for the adults, 883 ms for the children Average verb offset: 734 ms
Time to plan and execute the saccade for 4-8y.o. = 300-450 ms (Yang et al., 2002)

Prefixal vs Suffixal aspectual pairs: Adults



Average verb offsets: Prefixal items = 706 ms; Suffixal items = 763 ms.

Estimates of effect latency: Prefixal items = 450 ms ; Suffixal items = 641 ms (**Δ** = 192 ms).

The *(lower) estimate of effect latency* was taken to be the first of five consecutive time points with above-chance looks to the Target picture (cf. Borovsky et al., 2012; Ito et al., 2018).

Russian aspect: Conclusions

- The timing of aspectual processing is sensitive to the specific location of aspectual marking within the verb. The adults showed an online preference for the target picture significantly earlier in Prefixal aspectual pairs, as compared to Suffixal aspectual pairs.

- This result further supports the conclusion that the processing and integration of grammatical aspect information in Russian occurs rapidly and incrementally, already at the sub-word level.

Grammatical case in child L1 and 2L1 Russian and German (Mitrofanova et al., in prep.)

- 2 x 2 design
- Task (3-REF vs. 2-PIC)
  - Case (NOM:Subject-first vs. ACC:Object-first)

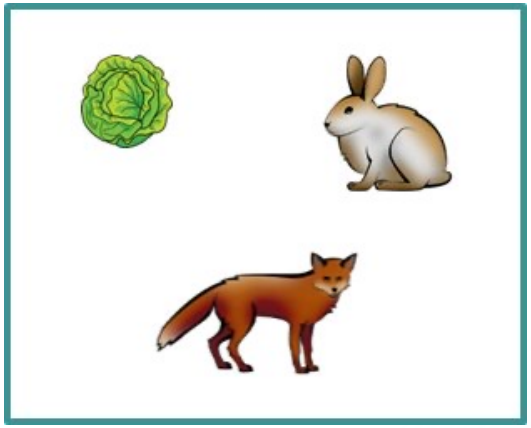
- In the 2-PIC task the children viewed pictures of transitive events, and not pictures of individual referents

Joint work with Irina Sekerina, Serge Minor, Antje Sauermann, Natalia Gagarina, Duygu Ozge and Marit Westergaard.

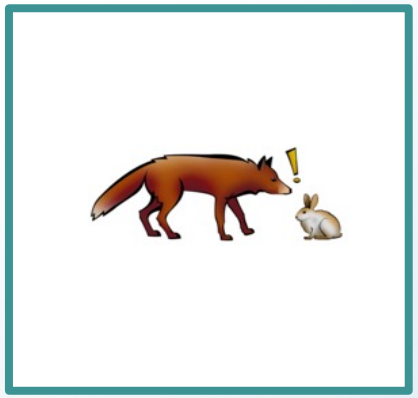
Conditions

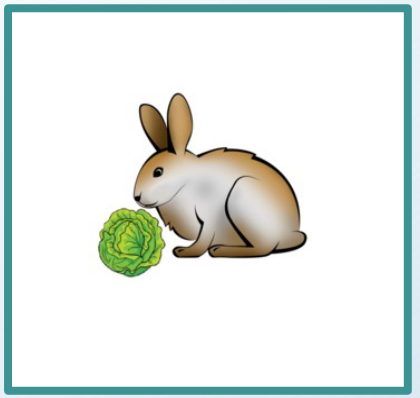
SVO: *Rabbit*$_{NOM}$ *will now eat cabbage*$_{ACC}$.
OVS: *Rabbit*$_{ACC}$ *will now eat fox*$_{NOM}$.

3-Referent



2-Picture





Materials: Russian spoken stimuli

Preamble: *Zajchik. Lisa. Kapusta.*
Rabbit. Fox. Cabbage.

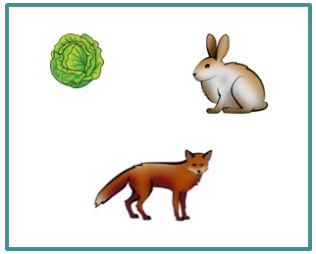
ROI	ADJ	N1	Adv	V	N2
SVO:	Pushistyj	zajchik	sejchas	s'est	kapustu.
N1=NOM	$\text{Fluffy}_{\text{NOM}}$	$\text{rabbit}_{\text{NOM}}$	now	will eat	$\text{cabbage}_{\text{ACC}}$
OVS:	Pushistogo	zajchika	sejchas	s'est	lisa.
N1= ACC	$\text{Fluffy}_{\text{ACC}}$	$\text{rabbit}_{\text{ACC}}$	now	will eat	fox_{NOM}

Materials: German spoken stimuli

Preamble: Das ist der Hase. Der Fuchs. Der Kohl.
Rabbit. Fox. Cabbage.

ROI	N1	Aux	PP	N2	V
SVO:	*Der Hase*	*wird*	*im nächsten Moment*	*den Kohl*	*aufspühren.*
N1=NOM	The rabbit$_{NOM}$			cabbage$_{ACC}$	find
OSV:	*Den Hasen*	*wird*	*im nächsten Moment*	*der Fuchs*	*aufspühren.*
N1=ACC	The rabbit$_{ACC}$			fox$_{NOM}$	find

3-REF RUSSIAN



--- N1 onset

----N2 onset

Looks to 'FOX' from Adj Onset

Cluster-based permutation analysis

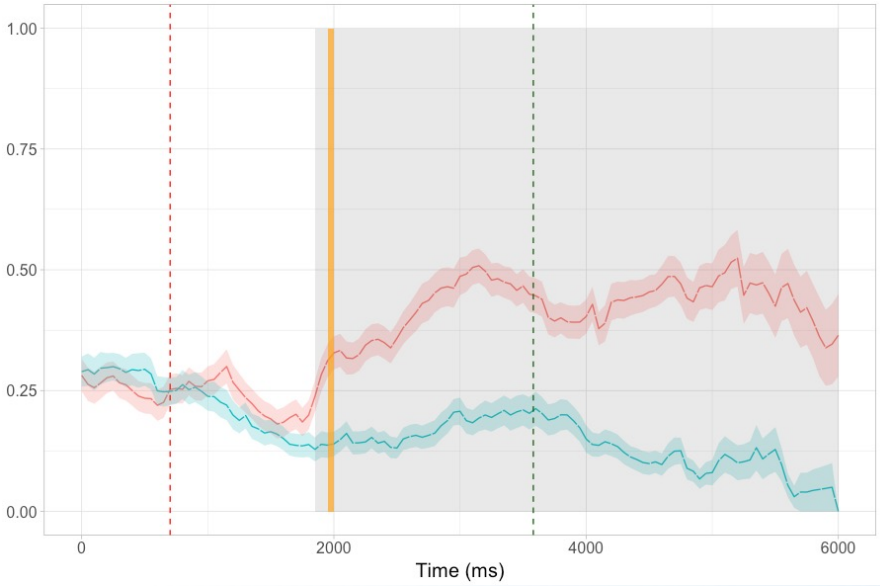
– Holm-Bonferroni correction

CASE

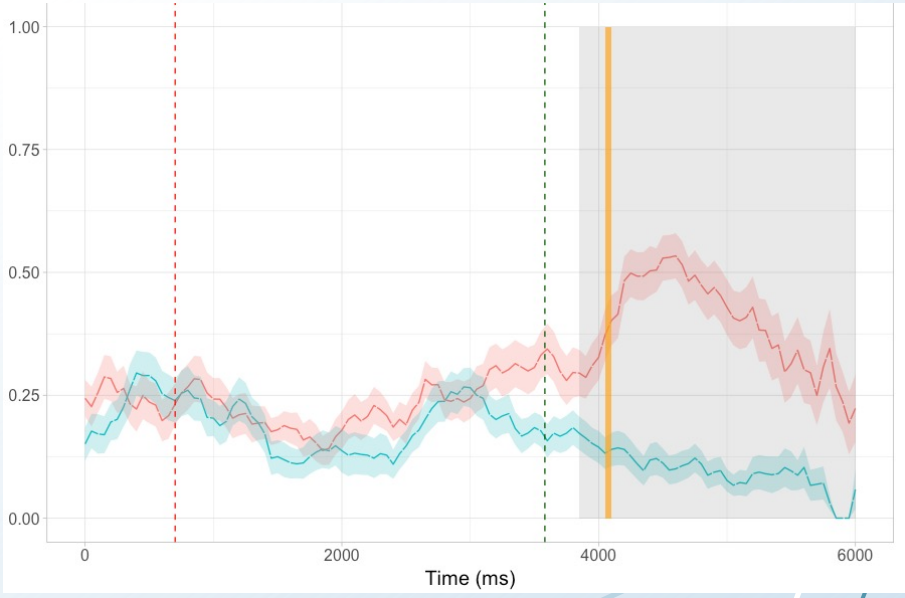
A

N

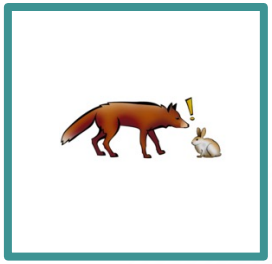
MONOLINGUALS



BILINGUALS



2-PIC RUSSIAN



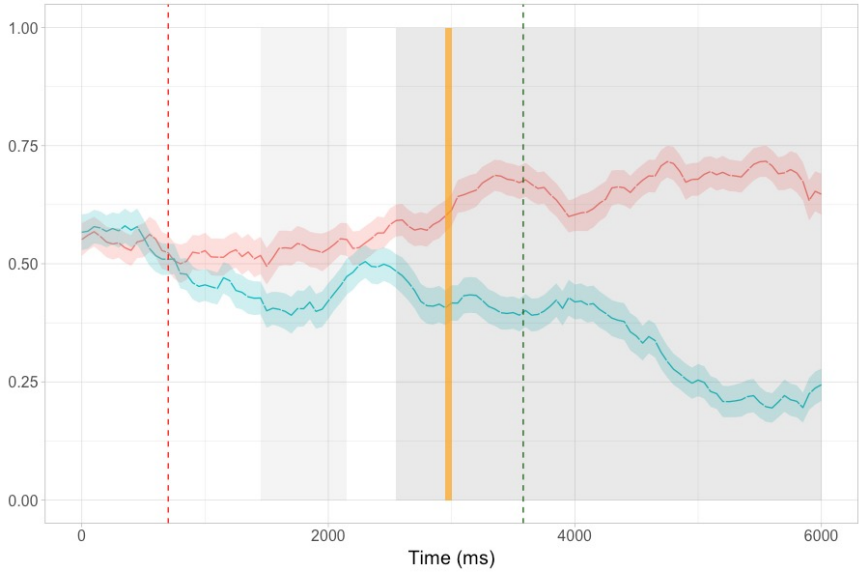
--- N1 onset
----N2 onset

Looks to 'FOX-RABBIT' from Adj Onset

Cluster-based permutation analysis
– Holm-Bonferroni correction

CASE
A
N

MONOLINGUALS



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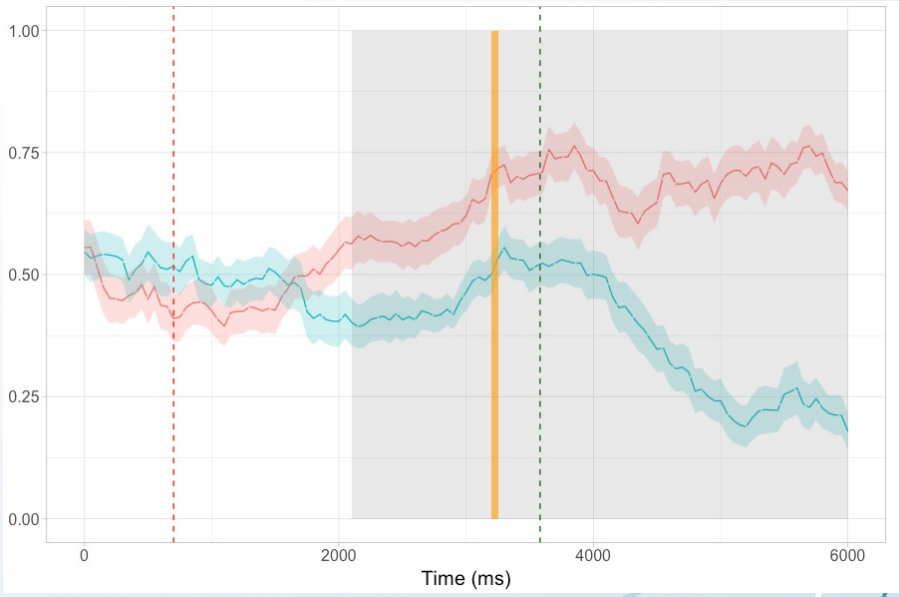
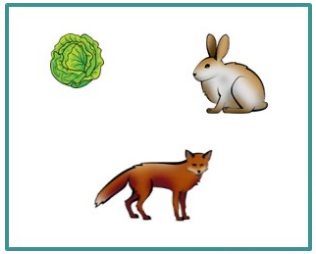


3-REF GERMAN



----N2 onset

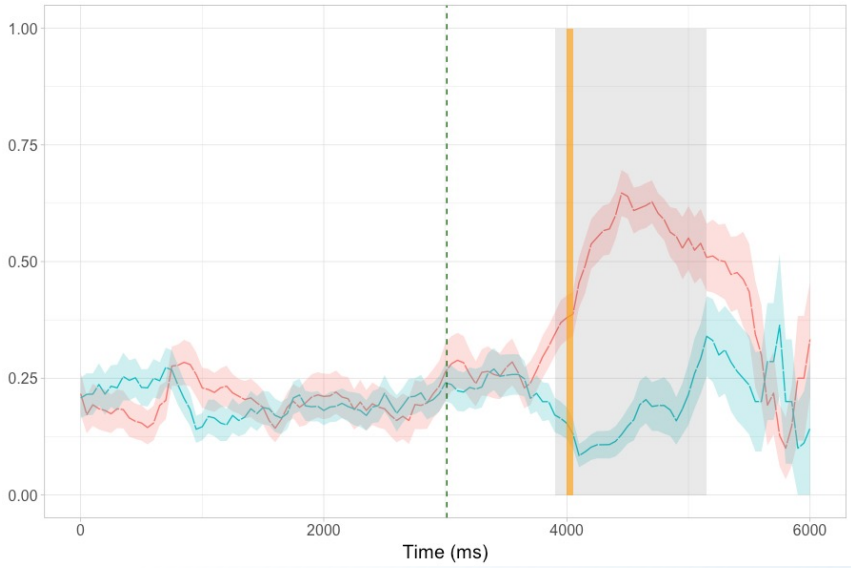
Looks to 'FOX' from NP1 Onset

Cluster-based permutation analysis

– Holm-Bonferroni correction

CASE
A
N

MONOLINGUALS



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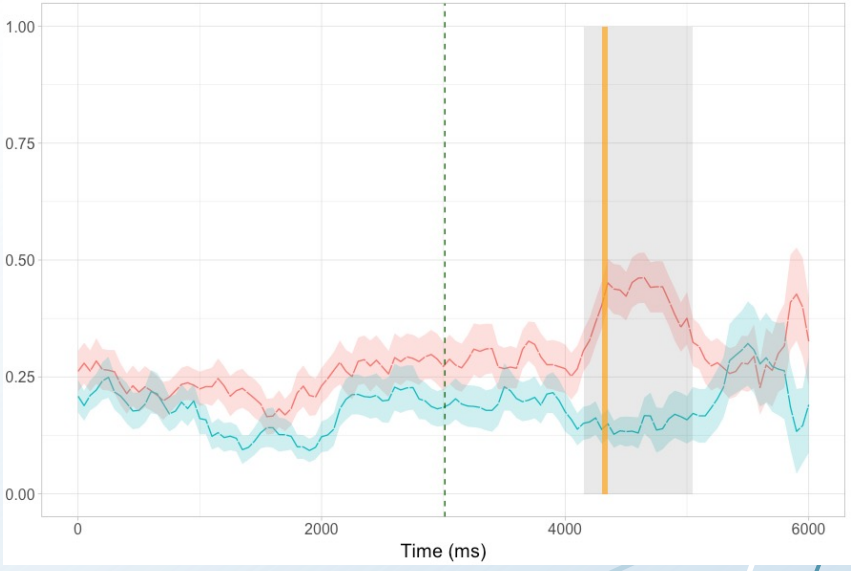
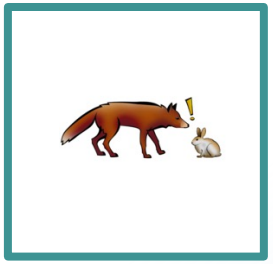


2-PIC GERMAN



----N2 onset

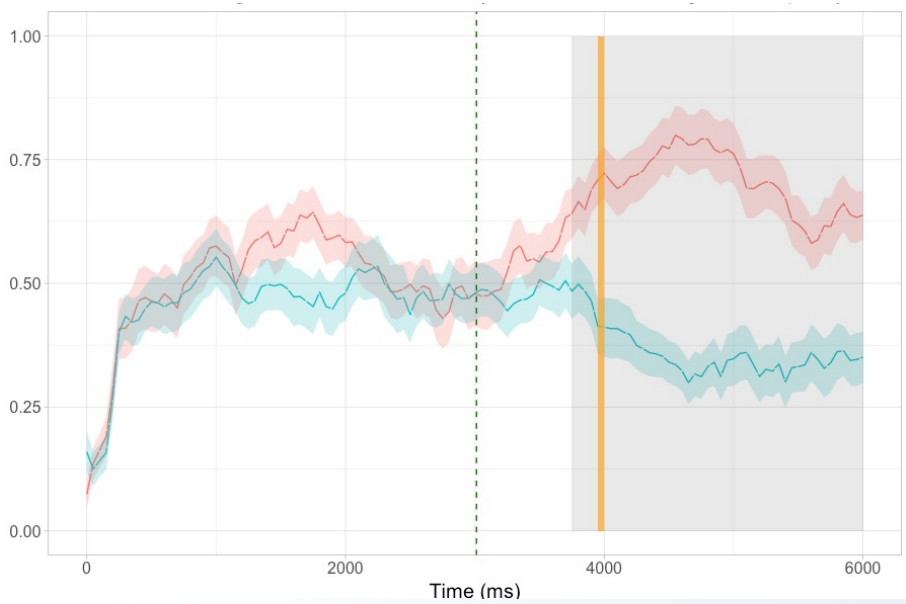
Looks to 'FOX' from NP1 Onset

Cluster-based permutation analysis

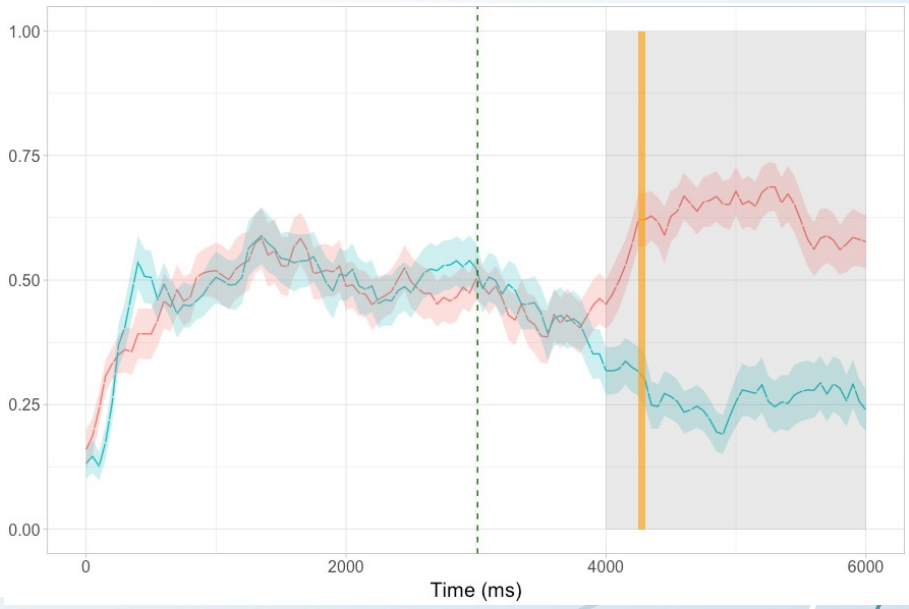
– Holm-Bonferroni correction

CASE
A
N

MONOLINGUALS



BILINGUALS

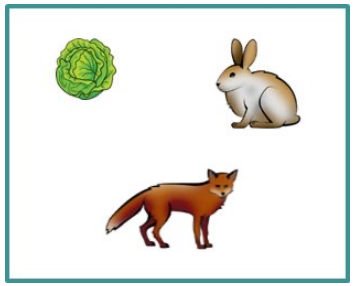


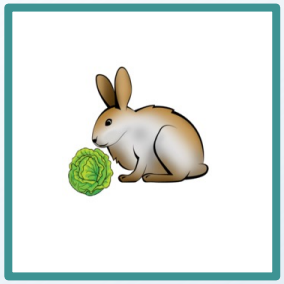
Summary of the results

Russian	German
3-Ref	3-Ref
– YES : Monolinguals	– NO : Monolinguals
– NO : Bilinguals	– NO : Bilinguals
2-Pic	2-Pic
– YES : Monolinguals	– NO : Monolinguals
– YES : Bilinguals	– NO : Bilinguals

2-Pic vs 3-Ref
Incremental vs predictive processing?

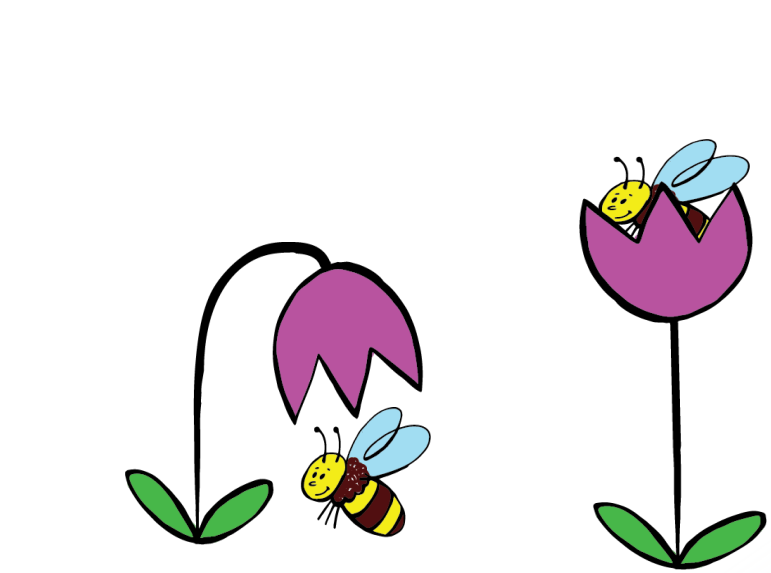
- In the 3-REF task, the listeners need to correctly interpret case marking, associate Acc with *theme*, predict an upcoming subject with the *agent* role and choose a potential agent in a given visual context





- In the 2-PIC task, the listeners need to correctly interpret case marking, associate Acc with *theme*, choose a picture where the referent is the *theme.*

Study 3:
Comprehension of Locative PPs by Young Children



PP contrast

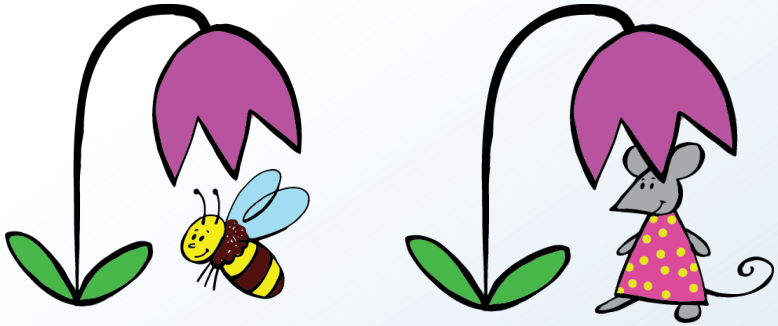
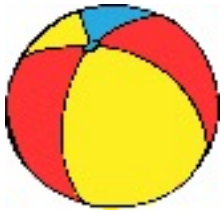


Figure contrast

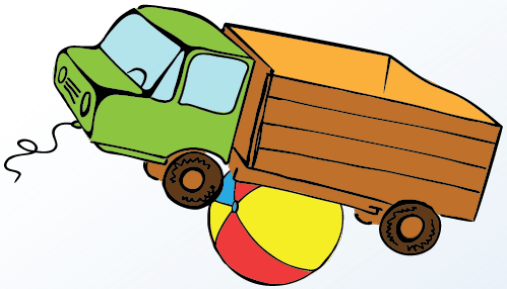
General design

Control Condition



Knizhka. Mjachik.

$book_{DIMIN}$ $ball_{DIMIN}$



Posmotri! *Knizhka pod*

Look! $book_{NOM}$ under

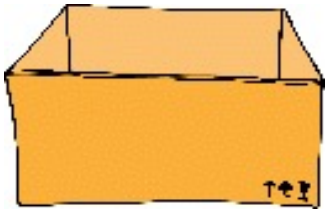
igrushechnoj *mashinoj.*

toy_{INST} $truck_{INST}$

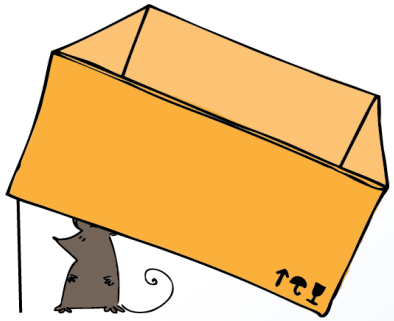
‘Look! The book is under a toy truck’

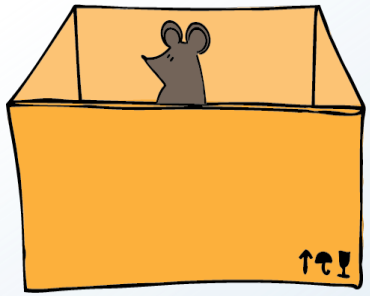
Experimental items

Experimental Condition



Myshonok. Korobka.
baby.mouse box





Posmotri! *Myshonok* *pod*
Look! $\text{mouse}_{\text{NOM}}$ under

bol'shoj *korobkoj.*
big_{INST} box_{INST}

'Look! The mouse is under a big box'

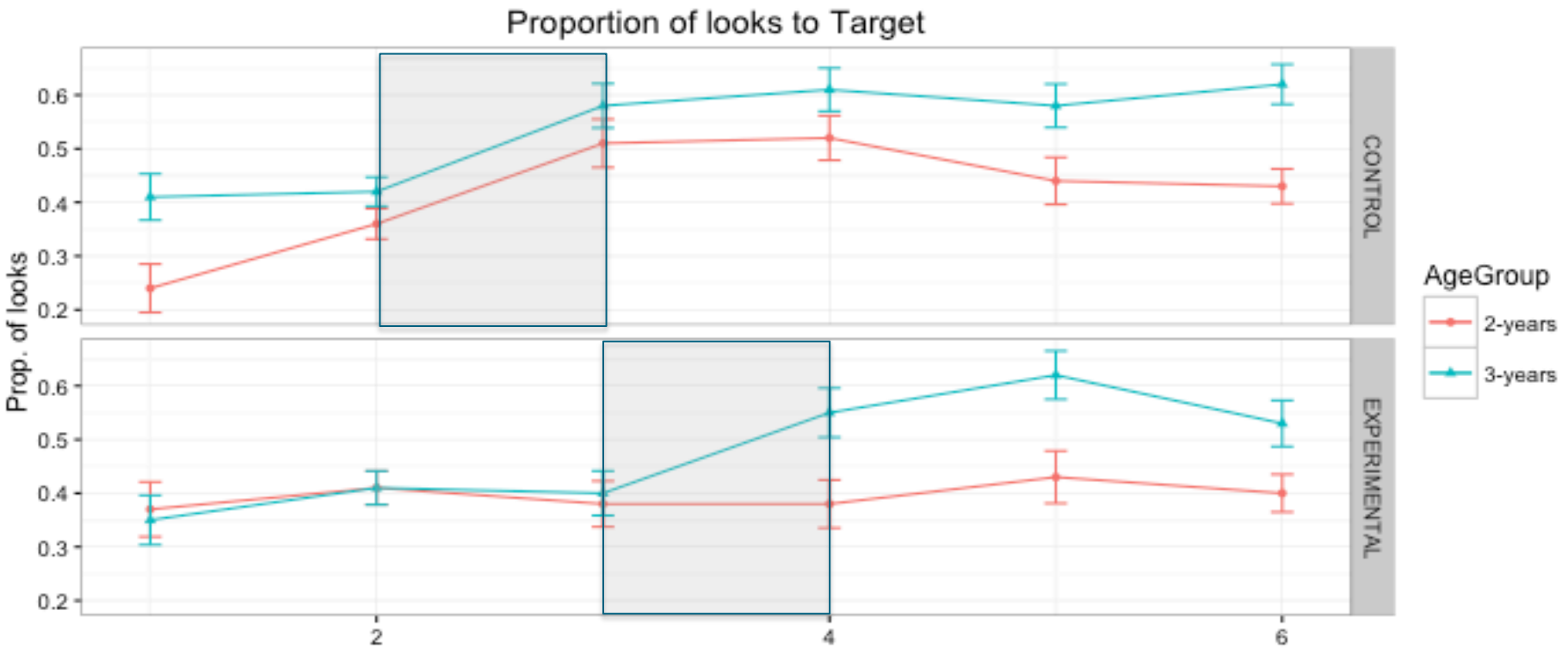
Eye movements

- The time of the critical word onsets (figure noun and locative preposition) varied slightly across sentences. We therefore divided the audio stimuli into five regions of interest (ROI) corresponding to the main meaningful units.

1	2	3	4	5
Pause	**Tag region**	**NP1**	**P+Adj**	**NP2**
539 ms	2111 ms	1076 ms	1235 ms	1175 ms
	Posmotri,	*myshonok*	*pod bolshoj*	*korobkoj*
	look	mouse.NOM	under big.INSTR	box.INSTR

Mean duration of regions of interest in the sentence, in milliseconds (ms).

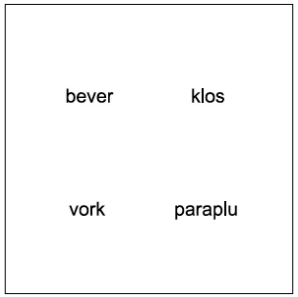
Eye-movements



Proportions of looks to target picture as a function of Condition, Age, and ROI

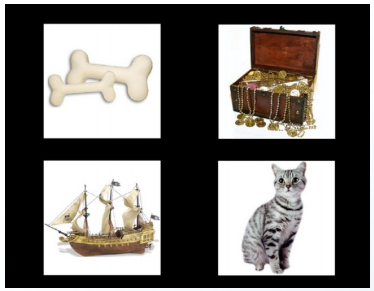
How to design a VWP experiment

1. RQ and linking hypothesis
2. Choice of participants
3. Stimuli and design
4. Data analysis and statistics



Huettig & McQueen (2007)

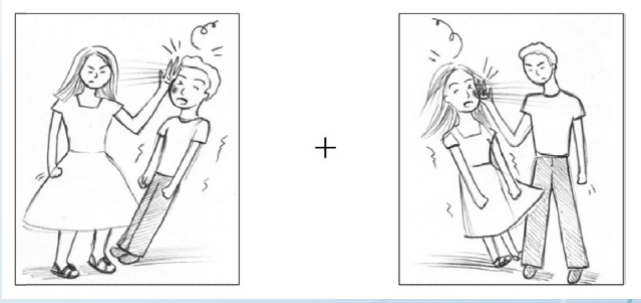
Creating visual scenes
Things to consider



Borovsky et al. (2012)

- How many Areas of Interest (AOIs)?
- What does each AOI consist of?
  - an object
    - individual, or part of (semi)coherent scene
  - an event
  - a participant in an event
  - a written word
- What style of image?
  - color, black-and-white
  - clipart, line drawing, photo

Kamide et al. (2003)



Mitsugi (2017)

Adapted from Theres Grüter. Eye-tracking in Linguistic Research (ISBPAC 2018 Workshop)

Creating visual scenes
Things to consider

- Be aware of non-linguistic biases that could influence looking to one AOI more than another!
  - animacy
  - left/right orientation
  - potential contingencies between images
  - “visual salience”…
  - …

Creating a Visual World study
More things to consider

- What is the participant's task?
  - look and listen
  - follow an instruction in the linguistic stimulus ("Click on the candle")
  - answer a question following the critical sentence

    (by mouseclick on scene; by keypress; by naming)

(see Salverda et al., 2011, Acta Psychologica)

- Do you need to norm the pictures, run a name agreement test or control for imageability before the experiment?


謝謝
Thank you
Спасибо
Teşekkür
Merci
mahad
Mahalo
Tusen takk
شكرا
ευχαριστώ
תודה
धन्यवाद
Muchas Gracias
Bedankt
Giitu
kiittää
Vielen Dank
Asante