When Children Process Ambiguity Faster Than Adults: Evidence from Eye Movements

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Theoretical Background

Operators and Scope

Logical operators, like $\forall$ (all), $\exists$ (some), $\neg$ (not), $|x|=2$ (two), may generate ambiguity in two ways.

Scope Inversion: Surface scope $\forall\neg$ vs. Inverse scope $\neg\forall$

(1)   All politicians are not corrupt.

Pragmatic Enrichment:

(2)   Some politicians are corrupt. $\neg\forall$ $\exists$

When combining scopal configuration and pragmatics, a sentence with two scope-taking operators is 4-way ambiguous.

Intonation (focus) and topicalization can determine scope configuration and pragmatic enrichment, such as indirect scalar inferences, (4):

(3) All politicians did not defraud tax money.
   $\neg\forall x$ [politician(x) → defraud_tax_money(x)] (direct SI) &
   $\exists x$ [pirate(x) & return_to_the_ship(x)] (indirect SI)

(4) a. All the students DIDN'T fail the exam.
      → someone passed
   b. All the stUDEnts didn't FAIL the exam.
      → everyone passed

but other factors such as context, QUD, and entailment properties do also play a role.

The Story So Far

Previous studies (Musolino 1998; Musolino, Thornton & Crain 2000) suggested that children can only access surface scope, whereas adults prefer inverse scope.

Later investigations (Musolino & Lidz 2006; Gualmini, Hulsey, Hacquard & Fox 2008; Viau, Lidz & Musolino 2010) showed that scope shift is difficult to derive but children's computation can be facilitated via priming, contextual bias, salient alternatives, and prosody.

Recently, however, usage of the Semantic Decision Task (Lohiniva & Panizza 2016; Panizza, Lohiniva & Foppolo in prep.) demonstrated that children struggle more with surface scope and adults have no inverse scope preference. Furthermore, surface scope is accessed faster because of the costly inferential process underlying scope-shift readings; but note that pragmatics serves to boost comprehension irrespective of age.

This paradigm shift also occurred in the studies on the acquisition of pragmatic enrichment. While Noveck (2001) proposed that children cannot access implicatures at all, Katsos & Bishop (2011) observed that they are merely tolerant of pragmatic violations. In the same vein, Foppolo, Guasti & Chierchia (2012) and Panizza, Onea & Mani (under review) conclude that, while accessible to children, enrichments are preferred by adults. As determined by Bill, Romoli, Schwarz & Crain (2016) implicatures are not homogeneous: Children are more tolerant with direct scalar implicatures (DSI) than with indirect scalar implicatures (ISI), the latter of which boosted comprehension in young children.

Experiment

Design

Methodology:
Semantic Choice Task (cf. Lohiniva/Panizza 2016)
Two scenarios displayed alongside each other, to be evaluated by the participants
Collection of
(i)   Offline Judgments: access and preference conditions (Picture Selection Task)
(ii) Eye-tracking Data (online): disambiguation; identification of target depending on the age bracket (see participants)
Experimental task: reward the group of pirates (either red or green) which best acted out the target sentence or don't reward either group

Stimuli:
Sentences with universally quantified object and negation, i.e., two scope-taking operators, recorded with unbiased intonation to control prosody effects

(5) Der Kapitän hat nicht mit allen Meerjungfrauen getanzt.
   The captain has not with all mermaids danced
   'The captain did not dance with all the mermaids.'

Participants

Groups:
a. 50 4- to 5-year-old German preschoolers
storyline was acted out by an experimenter and participants were asked to repeat the target sentence
b. 50 6- to 10-year-old German elementary school children
story was displayed on a computer screen as 2 simultaneous stop-motion videos with auditory narration of the story
c. 50 Adult controls German students at Göttingen university
storyline was displayed on a computer as 2 simultaneous stop-motion videos

Conditions

4 items each generated by altering available pictures (see Fig. 1–3):
a. ACCESS to interpretation enriched via indirect SI $\neg\forall + \exists$ inverse scope (NALL)
b. ACCESS to interpretation without strengthening $\neg\forall / \forall\neg$ surface or inverse scope (NONE)
c. PREFERENCE for implicature   NALL vs NONE
d. Control without negation (2 True vs. 2 False) $\forall$ FALSE

Fig. 1: FALSE   Fig. 2: NALL   Fig 3: NONE

Hypotheses:

Offline:
ACCESS
   Children: pragmatic boost when implicature is supported

PREFERENCE
   Children: pragmatic tolerance: weaker preference in supporting contexts

   Adults: pragmatic enrichment: stronger preference in contexts that support implicatures

Online (assuming covariance of online and offline data):
   Children: Is tolerance associated with cost of inference computation or with the lack thereof? if implicature is free: NALL = NONE

   Adults: does the retrieval of inference incur a cost? (cf. Cremers & Chemla 2014) if implicature is costly: NALL > NONE

Results

Offline Selection Task

ACCESS

4–5 y/o ignored negation although they always repeated the sentence correctly
possible causes: (i) PP increased synt. complexity (ii) bad prosody (iii) object-alle requires QR (iv) control condition priming (v) other
little pragmatic boost in 4—5y/o and no boost in 6—10y/o

6–10 y/o and adults do not tolerate the NONE context

■ wrong
■ correct
■ reject
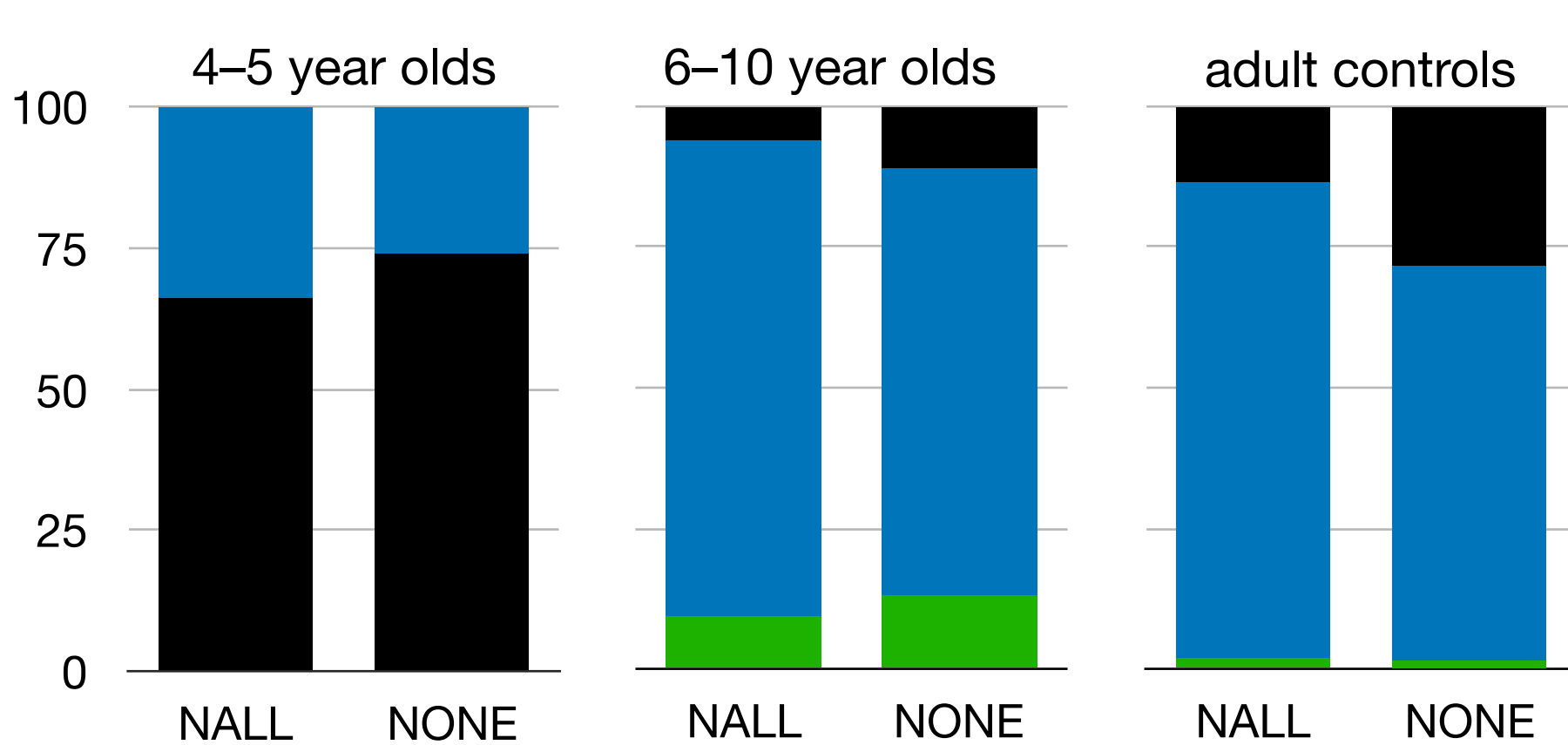
PREFERENCE

adults show stronger preference for contexts that supports implicature
children are tolerant of implicature violations: replicates Musolino & Lidz, 2006

● NONE –impl
● NALL +impl

55 % / 45 %   6–8 y/o
68 % / 32 %   9–10 y/o
77 % / 23 %   adults

Eye Movement Data
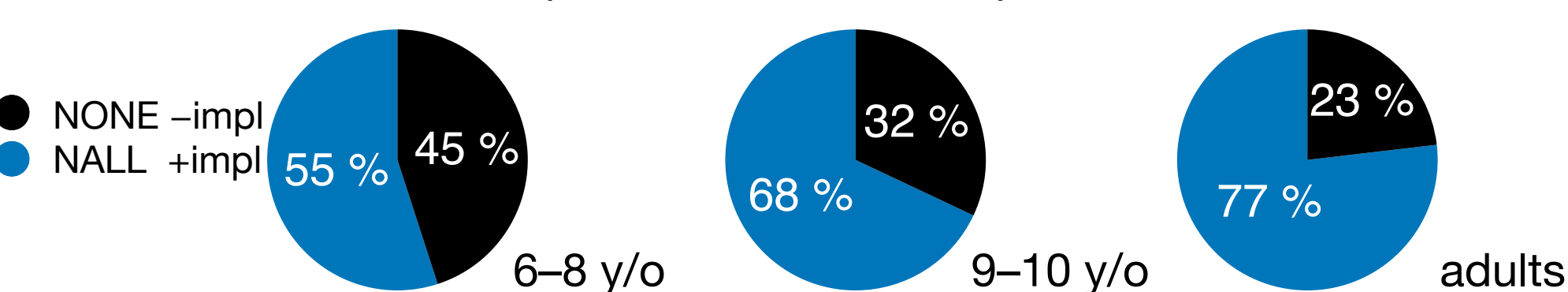
more rapid increase in looks to the target for implicature-supporting context (NALL), this effect only shows up in children during sentence presentation. Can this effect be explained in terms of general bias for NALL context?
no: in the preference condition, there is more uncertainty
not only are ISIs not costly, they facilitate online disambiguation in ambiguous contexts (greater processing facilitation in younger children than older ones).
However, preference for implicature support is inversely proportional to age.

in ambiguous scenarios (NALL vs NONE), children are more tolerant of pragmatic violation of ISIs, while adults prefer the reading enriched via ISI; with the online disambiguation being slow compared to younger participants.
in unambiguous scenarios, while not enhancing comprehension,
the boost serves online disambiguation in implicature-supporting contexts. Crucially, this selective effect decreases with age.

Children thus display faster online processing faculties than adults.

pragmatic tolerance decreases with age
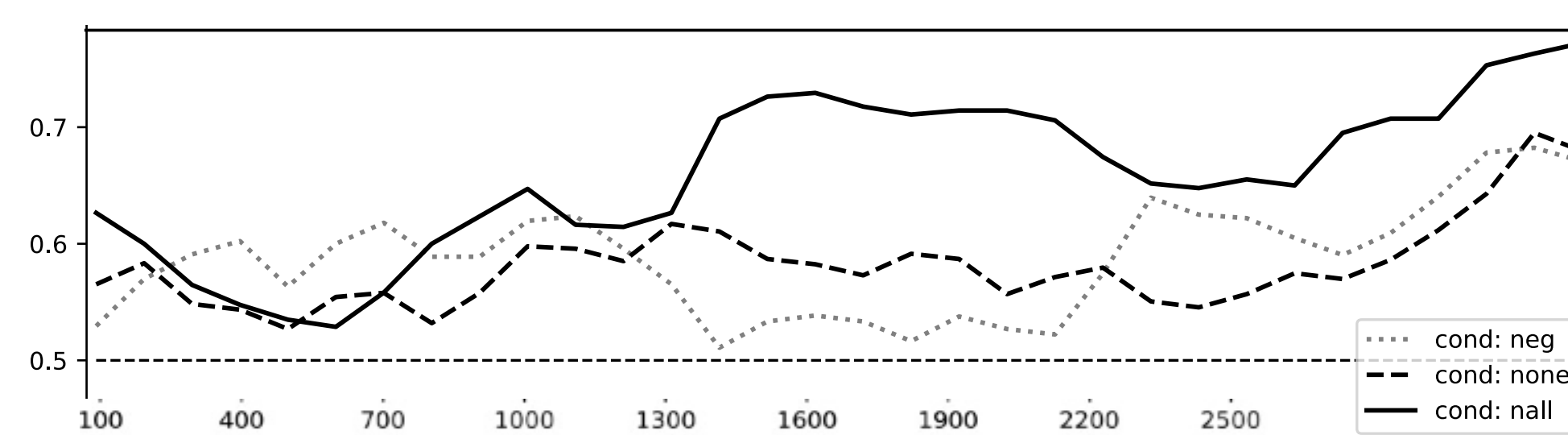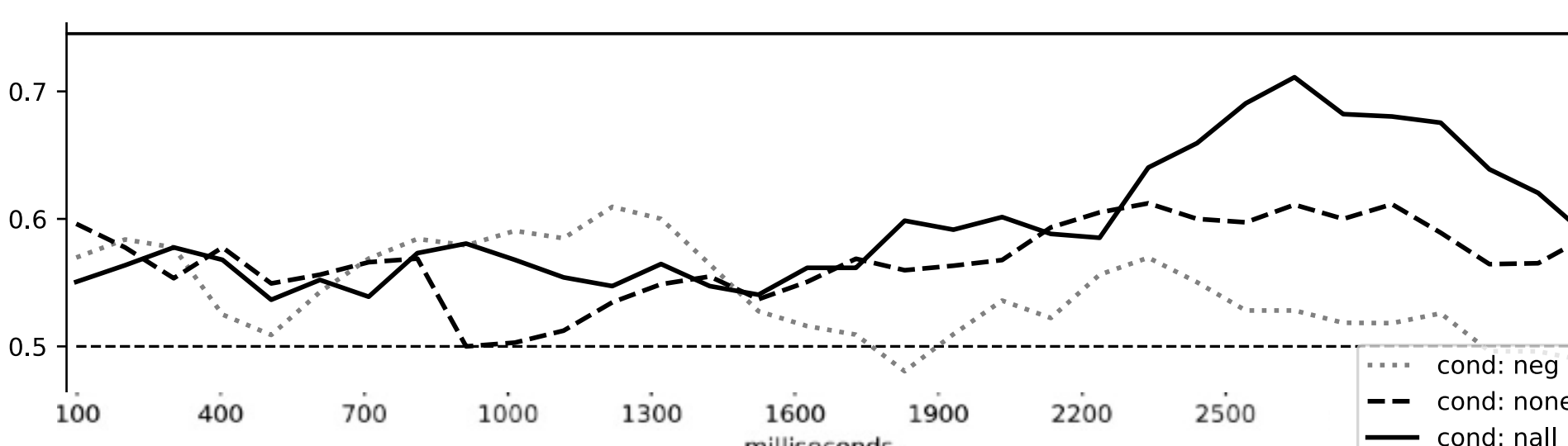adults show stronger preference for context that supports implicature

Fig. 4: Prop. of looks to the target for 4—5y/o time-locked at the onset of alle

Fig. 5: Prop. of looks to the target for 6—10y/o time-locked at the onset of alle

Fig. 6: Prop. of looks to the target for adults time-locked at the onset of alle

Discussion

Better performance of children in online processing possibly due to:
weaker competition between readings: when both readings ($\neg\forall + \exists$ and $\neg\forall$) are derived, one clashes with the context in the NONE scenario.
if implicature is more often derived by older participants no matter what (i.e. regardless of the context), it interferes with the target identification.
4-5 y/o fail to understand sentences including object-alle and negation presented with unbiased intonation, while 6-10 yo access the reading enriched by indirect scalar implicature and suspend it if not supported.
pragmatic tolerance in children it is not due to the lack of online implicature computation.
scope inversion + implicature facilitates comprehension in some cases: $\forall\neg$, and disrupts it in others: $\neg\forall$

either offline comprehension and online processing are totally dissociated,
or implicature processing is different depending on the alternatives you see in the context, and we have to understand exactly how,
or pragmatic boost in children because they have different parting strategies (that we have to understand), or reduced competition of alternative readings (scope-shift? weaker readings) in kids than adults.

References:
Musolino 1998; Musolino, Thornton & Crain 2000; Musolino & Lidz 2006; Gualmini, Hulsey, Hacquard & Fox 2008; Viau, Lidz & Musolino 2010; Lohiniva & Panizza 2016; Panizza, Lohiniva & Foppolo in prep.; Katsos & Bishop (2011); Foppolo, Guasti & Chierchia (2012); Panizza, Onea & Mani under review; Bill, Romoli, Schwarz & Crain (2016).

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