Vorlesung

Sprachdialogsysteme

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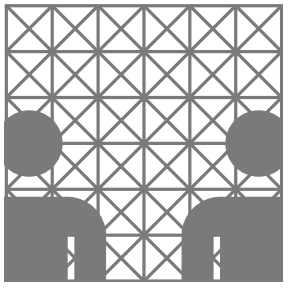

Heute

- Fragen zum Dialogmanagement?
- inkrementelle Sprachverarbeitung

Warum inkrementelle Sprachverarbeitung?

Mensch-Computer Interaktion

Mensch-Computer Interaktion

Navigationsgerät:

„Biegen Sie rechts in 60 Metern ab.“

Mensch-Computer Interaktion

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Gesprochene Sprache

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Menschen sprechen *responsiv*.

ein guter Beifahrer reagiert und passt sich an:

„vorne rechts musst du abbiegen.“

Menschen sprechen *responsiv*.

1. internes Umplanen

ein guter Beifahrer reagiert und passt sich an:

„vorne rechts ...

Menschen sprechen *responsiv*.

1. internes Umplanen

ein guter Beifahrer reagiert und passt sich an:

„vorne rechts … gradeaus quasi.“

also die zweite.“

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„vorne rechts ...

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2. externe Ereignisse

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„vorne rechts ...

Menschen sprechen *responsiv*.

2. externe Ereignisse

ein guter Beifahrer reagiert und passt sich an:

„vorne rechts … dem blauen Golf hinterher.“

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„vorne rechts ...

Menschen sprechen *responsiv*.

3. angepasst an den Zuhörer

a) Verhalten

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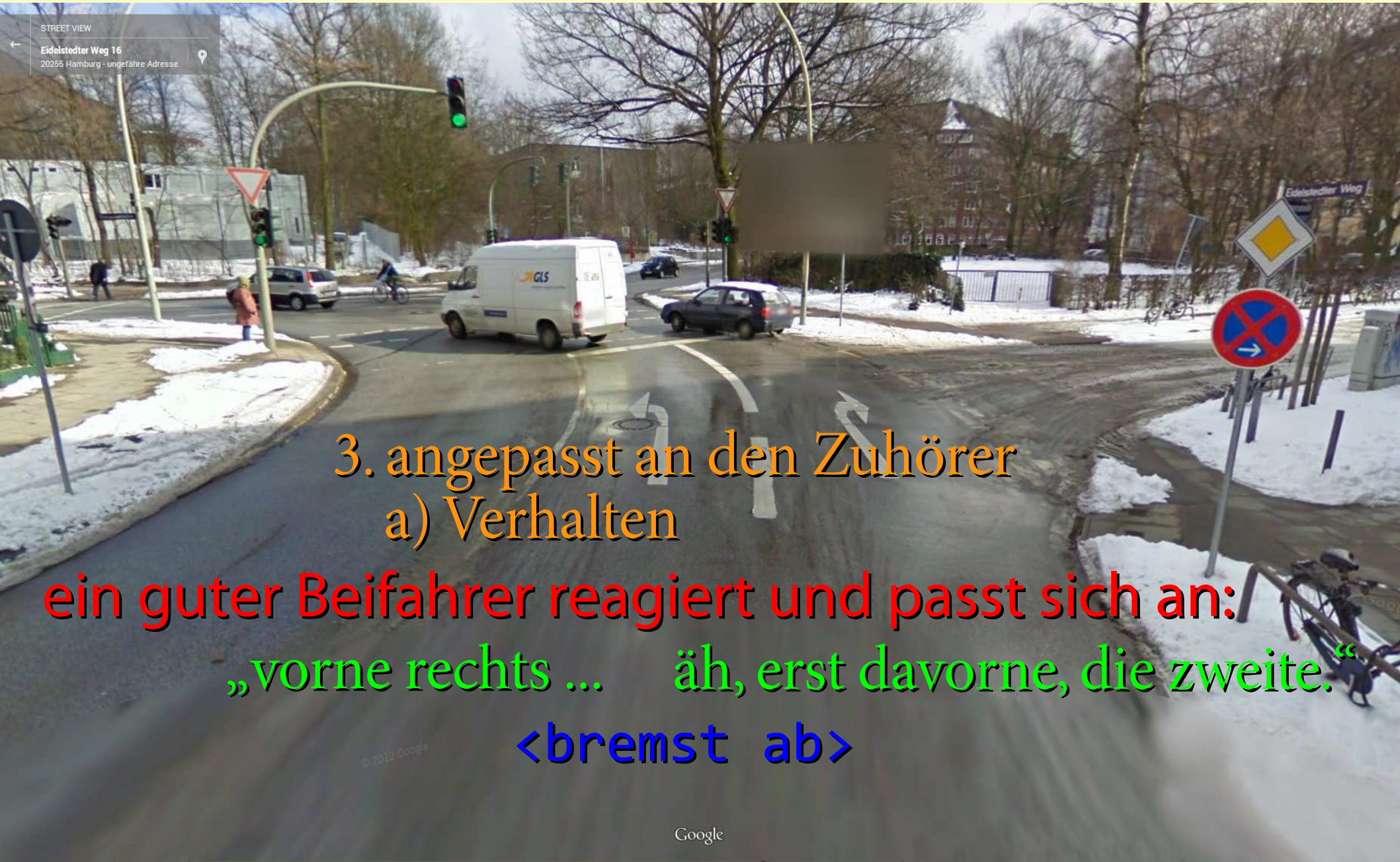
„vorne rechts ...

Menschen sprechen *responsiv*.



3. angepasst an den Zuhörer
a) Verhalten

ein guter Beifahrer reagiert und passt sich an:

„vorne rechts ... äh, erst davorne, die zweite.“

<bremst ab>

Menschen sprechen *responsiv*.

3. angepasst an den Zuhörer
b) sprachliche Äußerungen

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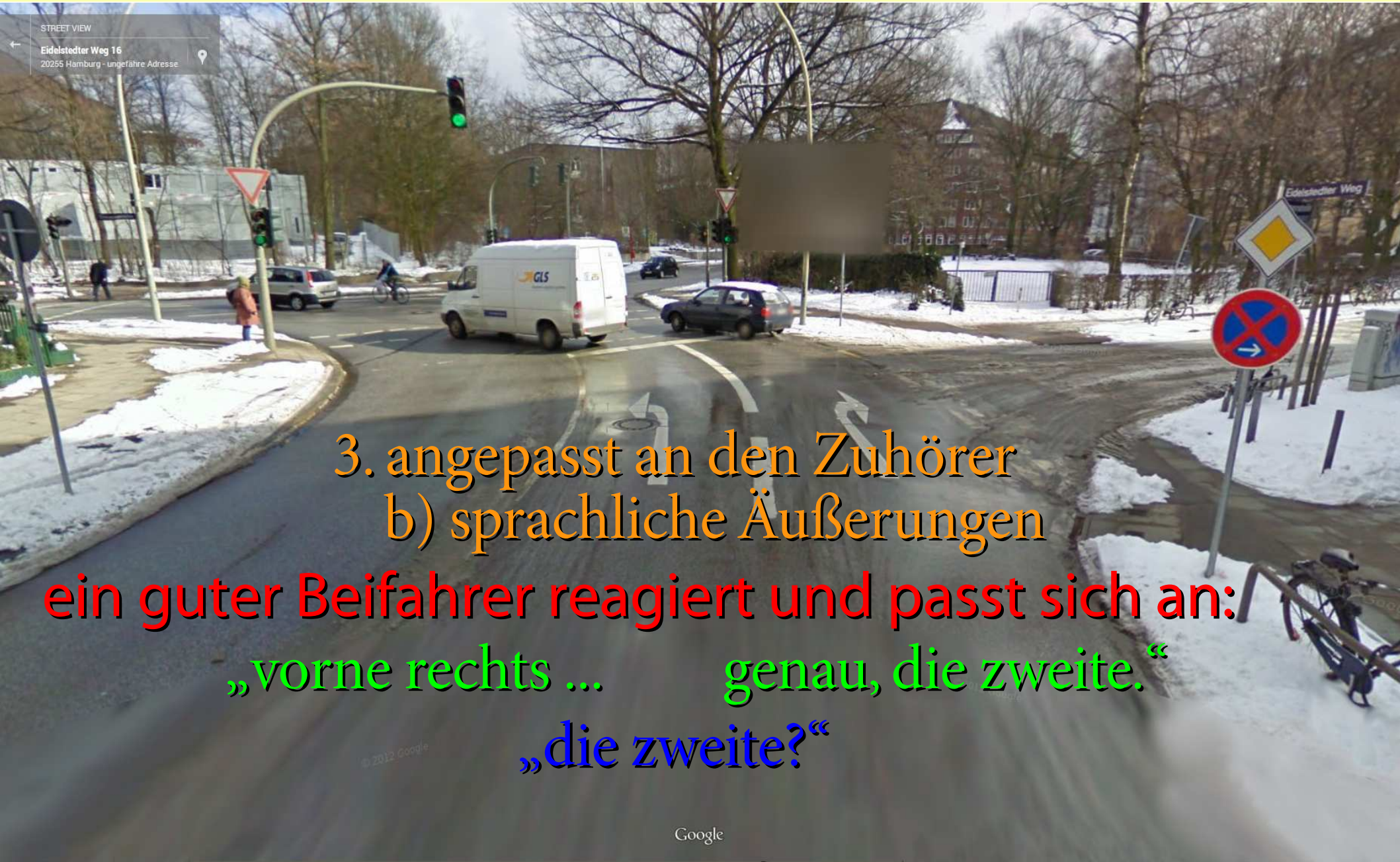

3. angepasst an den Zuhörer
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ein guter Beifahrer reagiert und passt sich an:

„vorne rechts ... genau, die zweite.“

„die zweite?“

Zwischenfazit zur Sprachinteraktion

* bzw. nur sehr eingeschränkt (Baumann 2013 Diss, Baumann&Schlangen 2013, ...)

Zwischenfazit zur Sprachinteraktion

1. Sprache entwickelt sich über die Zeit
2. die Welt ändert sich, während wir sprechen
3. wir ändern uns, während mit uns gesprochen wird

   → Fähigkeit während des Sprechens umzuplanen

   → Fähigkeit während des Zuhörens zu planen & agieren

- Lösung: schritthaltende (inkrementelle) Verarbeitung ermöglicht Responsivität in einer veränderlichen Welt

➔ Computersysteme sind dazu bisher nicht* fähig

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weitere Szenarien

- maschinelles Simultandolmetschen

  v.a. internes Umplanen (Baumann et al., 2014 IWSLT)
- Dialoginteraktion Mensch ↔ Roboter

  v.a. externe Ereignisse (Baumann&Lindner, 2015 ICSR)
- Interaktion mit konversationalen Dialogsystemen
  - v.a. Anpassung an Nutzerfeedback
    (Buschmeier et al., 2012, SigDial; Baumann et al., 2013 ESSV)

➔ praktisch jegliche Sprach*interaktion* profitiert von responsivem Verhalten

vorherrschende Form der Mensch-Maschine-Sprachinteraktion

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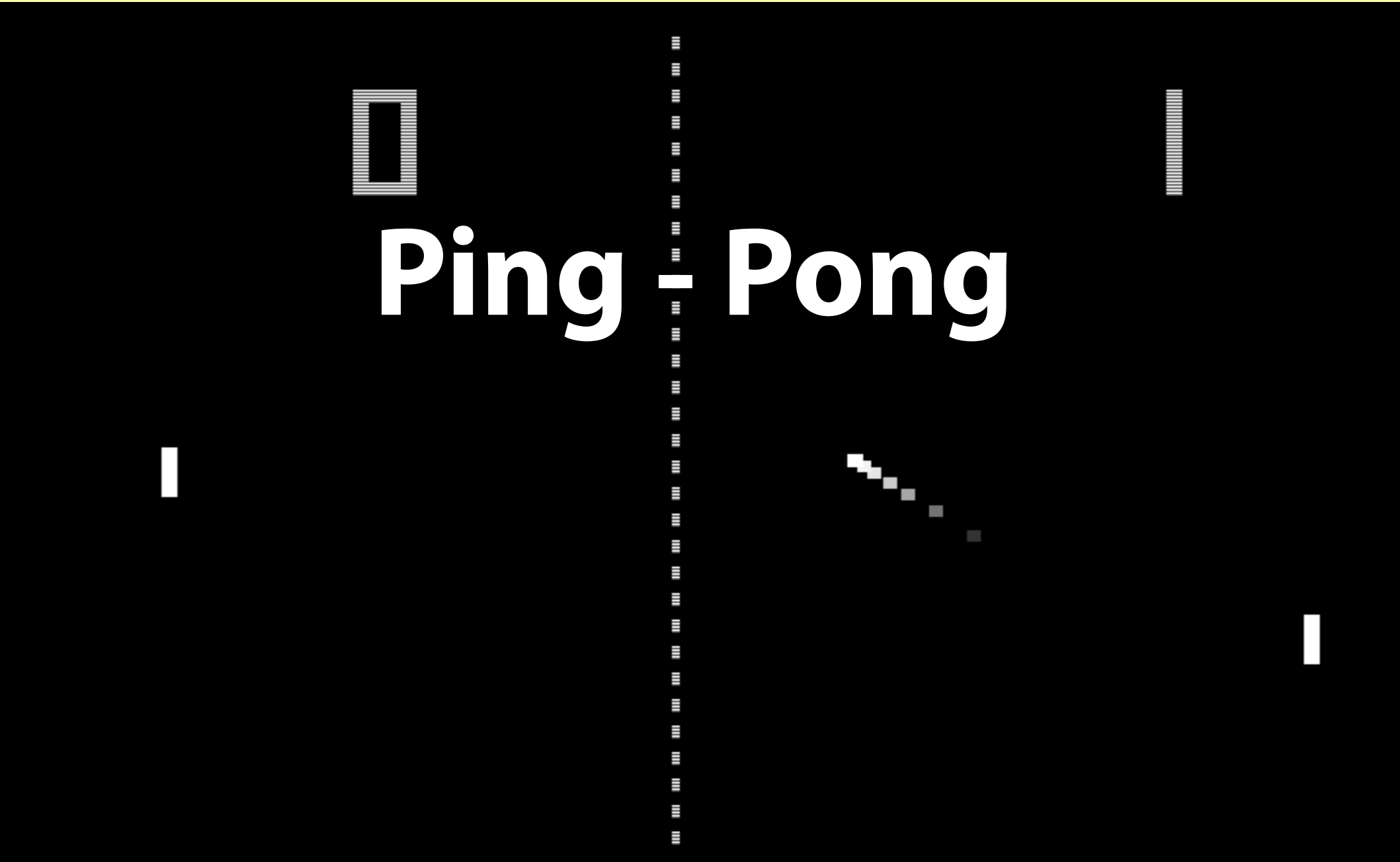


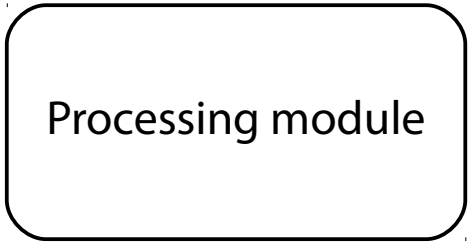
schritthaltende / inkrementelle Verarbeitung: Definition

eine inkrementelle Verarbeitungskomponente

- verarbeitet Eingaben Stück-für-Stück
- generiert (vorläufige) Ausgaben bevor die Eingabeverarbeitung abgeschlossen ist

Incremental vs. Non-incremental Processing

- herkömmliche Verarbeitung:



- Verarbeitung beginnt mit Abschluss der Eingabe → Delay!
  - modulares System: Delays summieren sich

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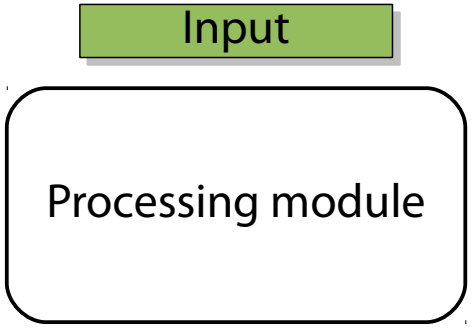

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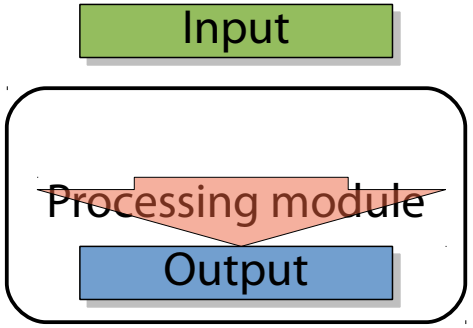

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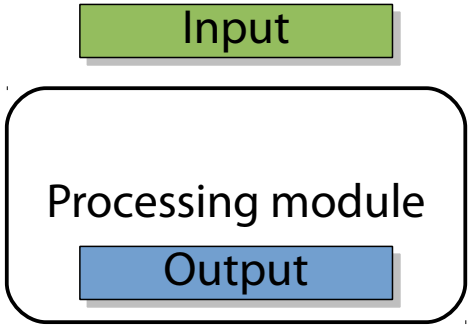

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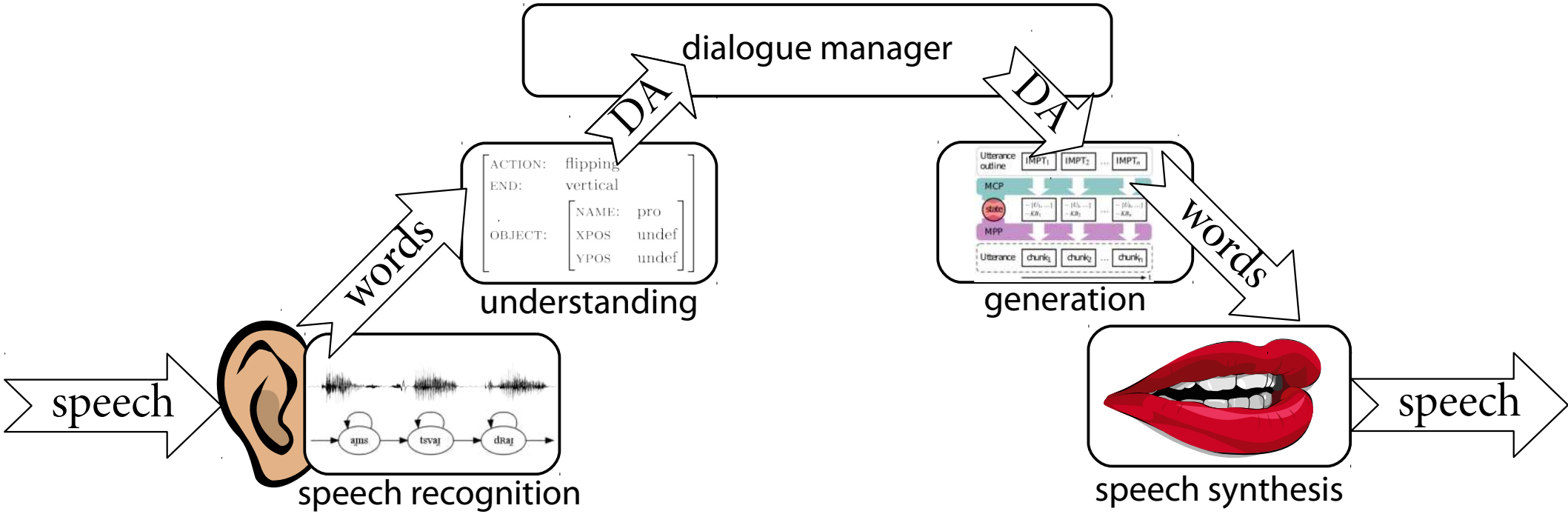
Paradigma: Modulare Verarbeitung

- Verarbeitung gesprochener Sprache ist komplex
  → Teile-und-hersche durch spezialisierte Module
- Pipeline-Verarbeitung, ein Modul nach dem anderen



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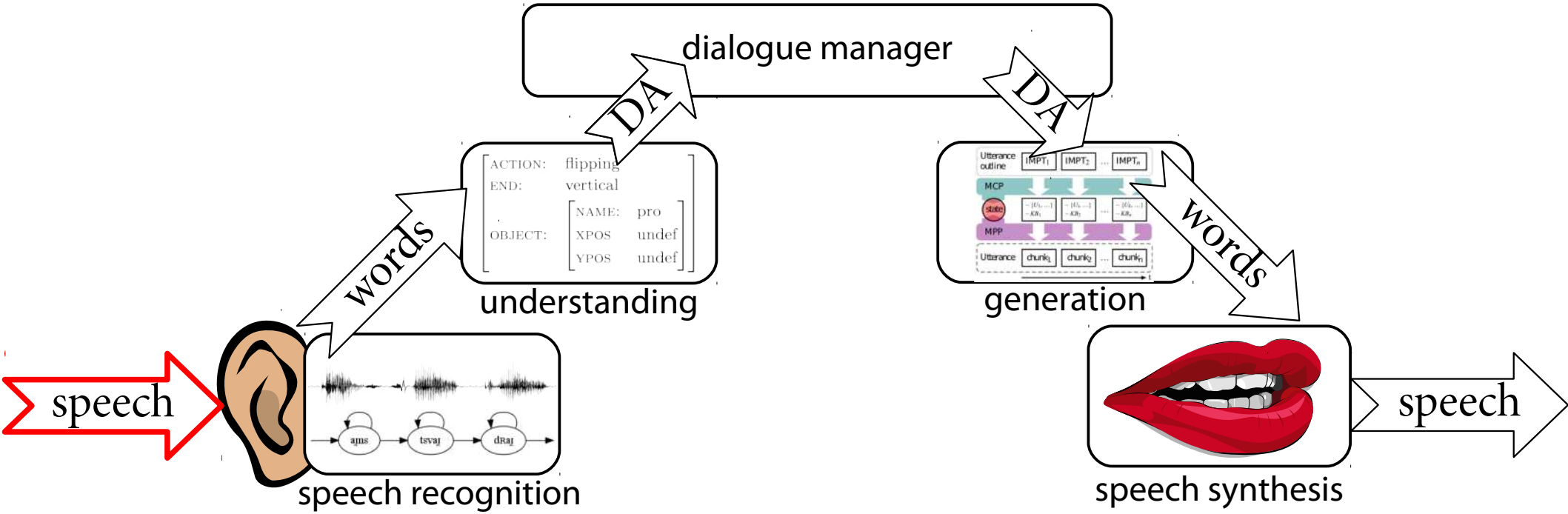

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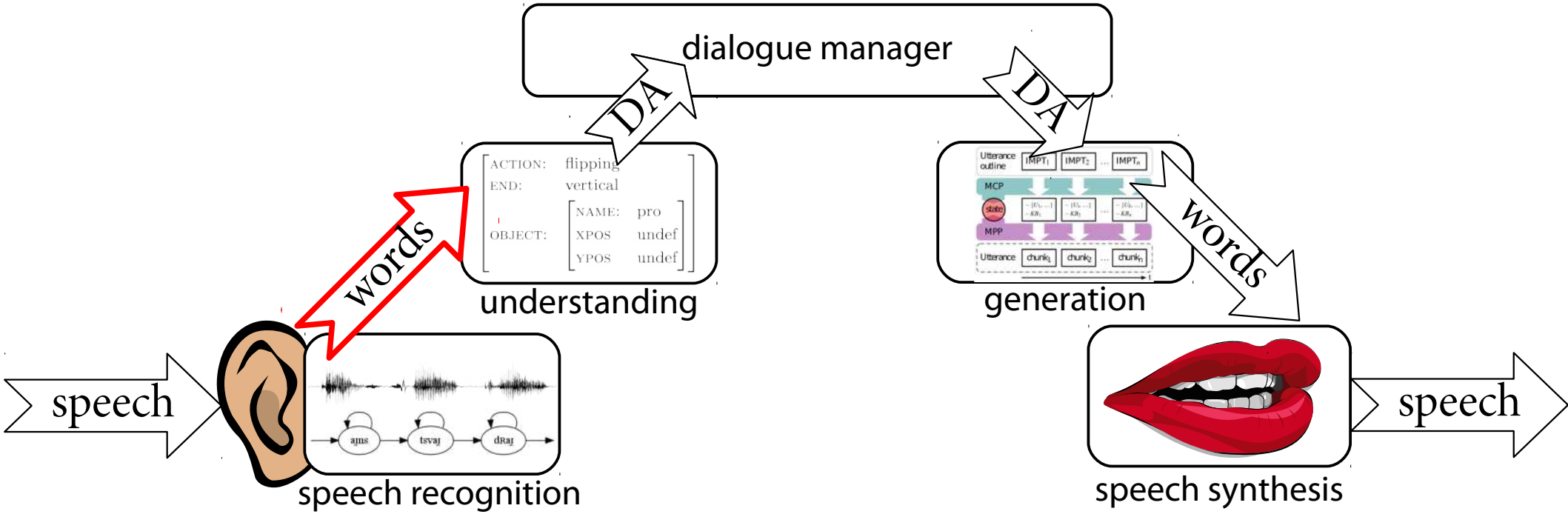

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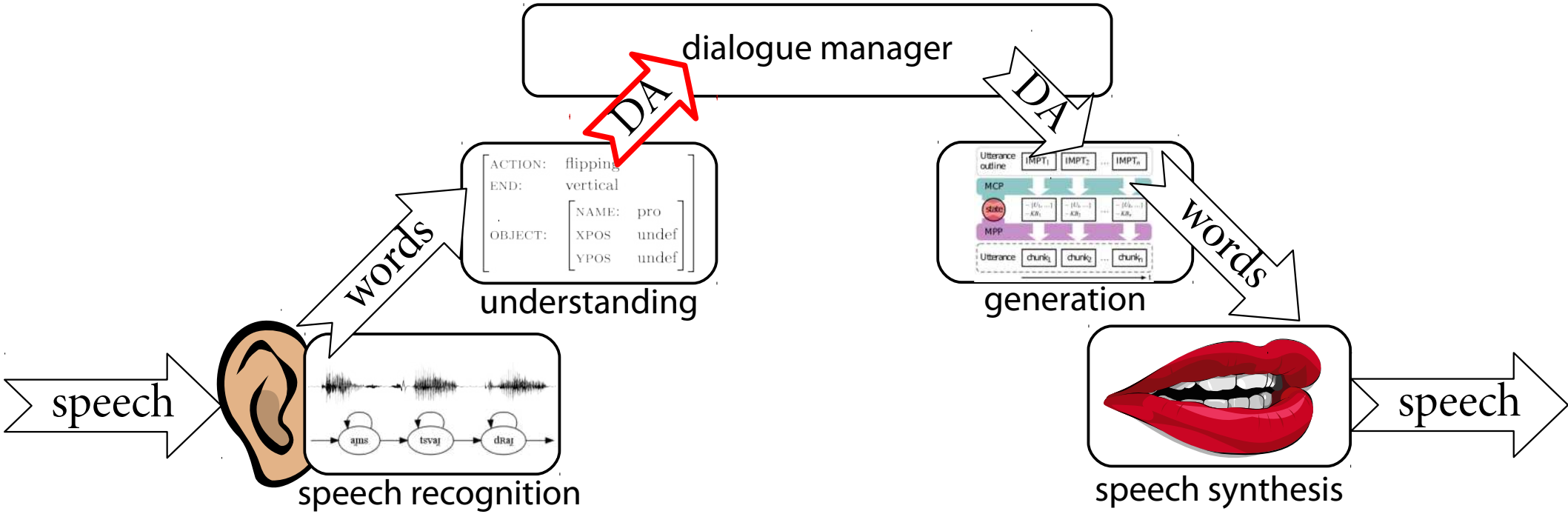

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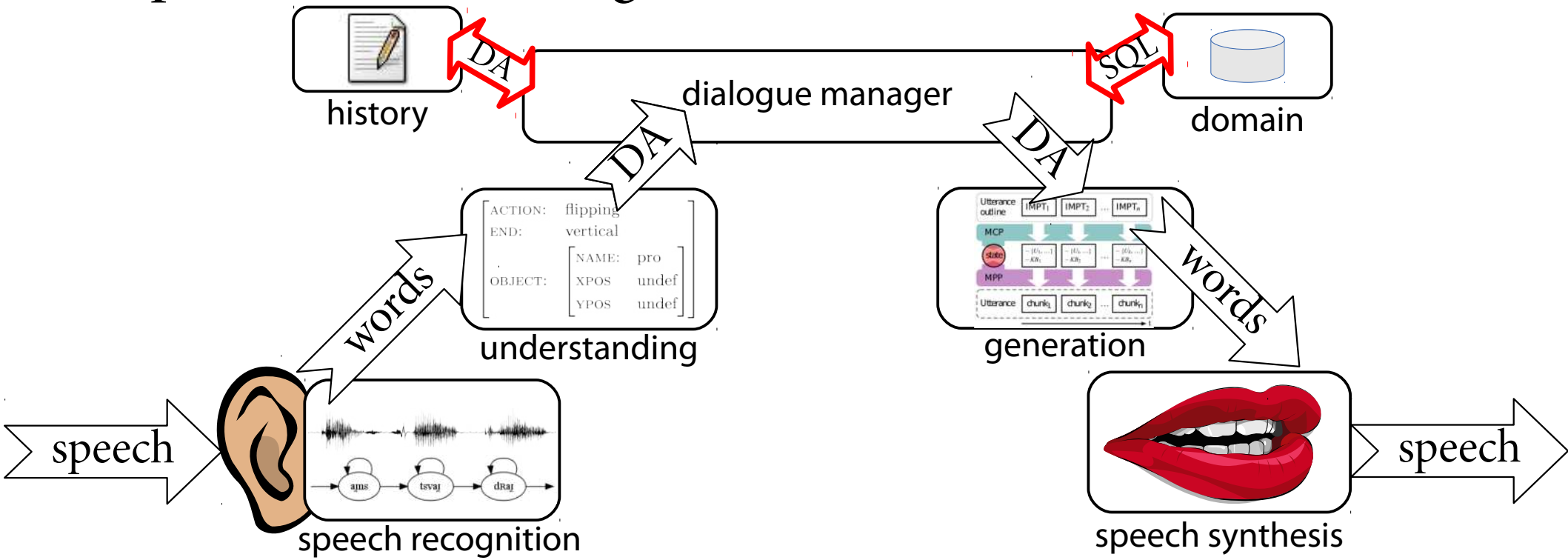

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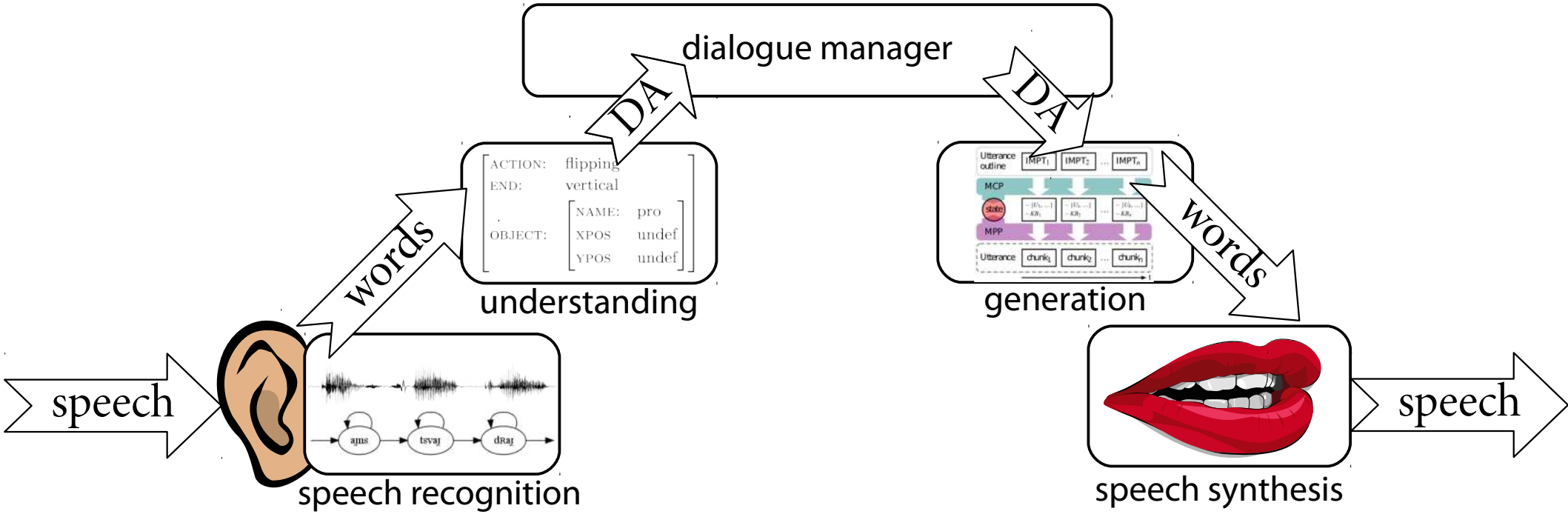

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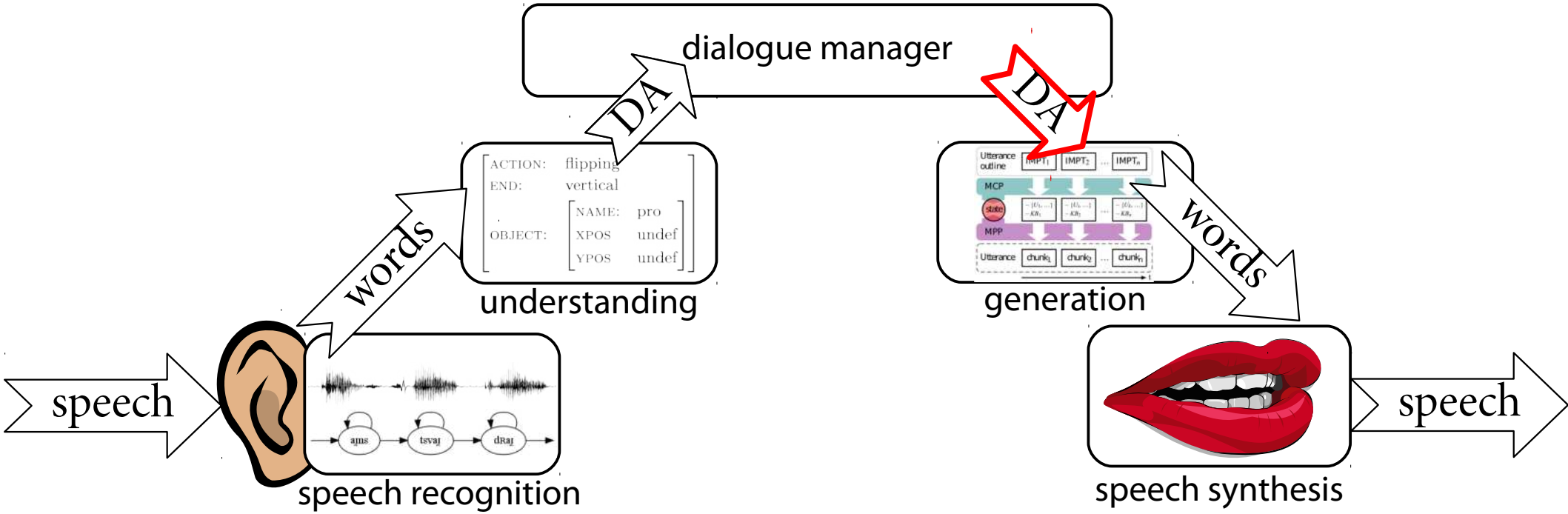

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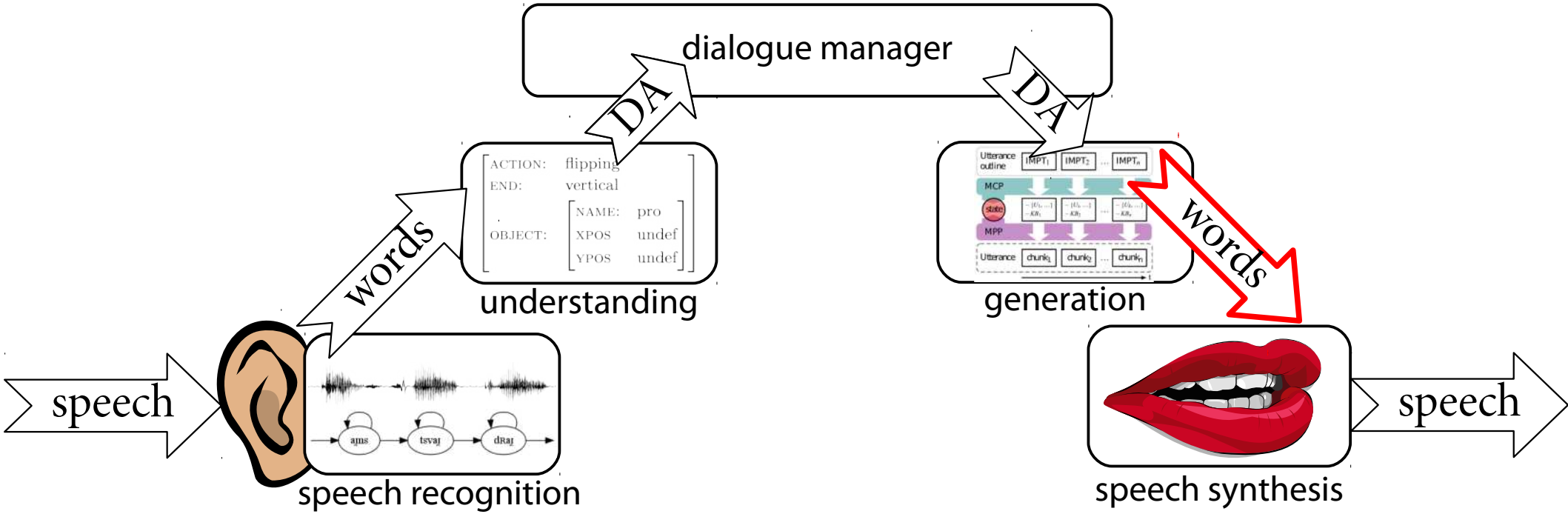

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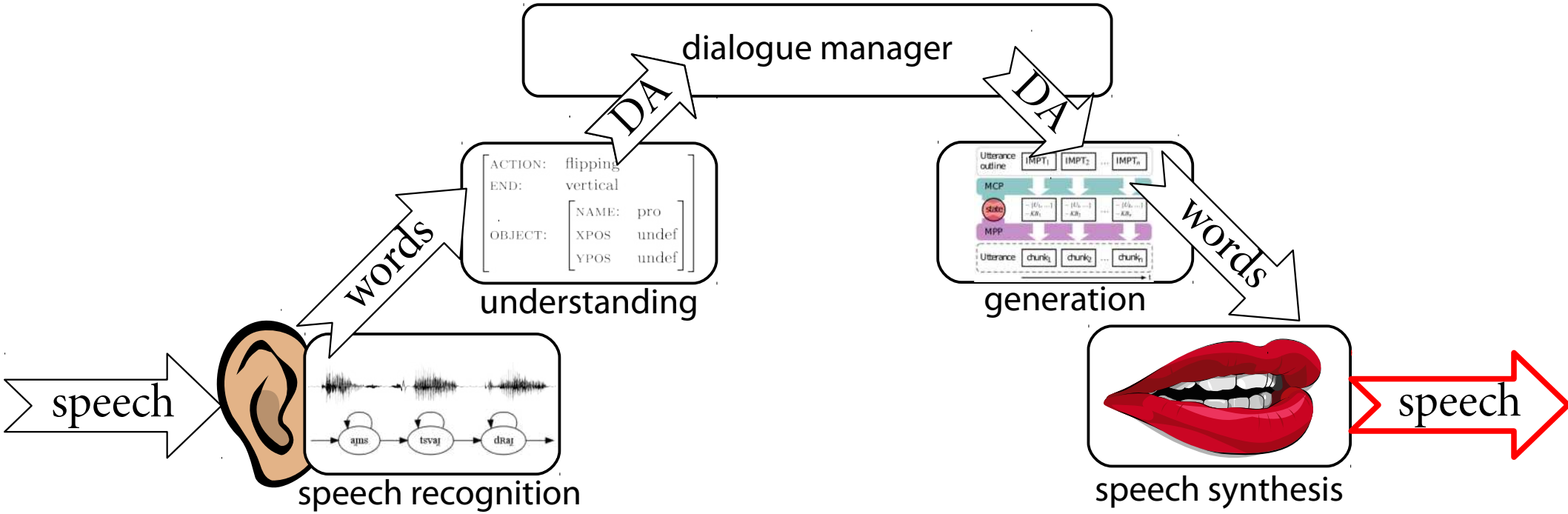

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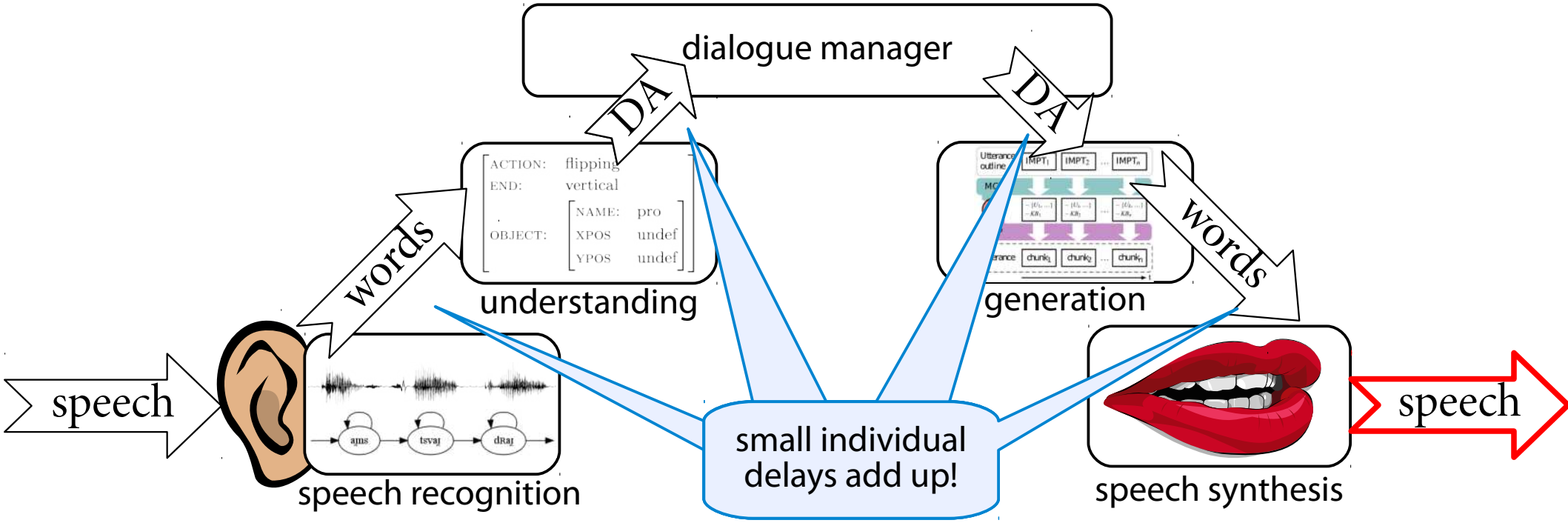

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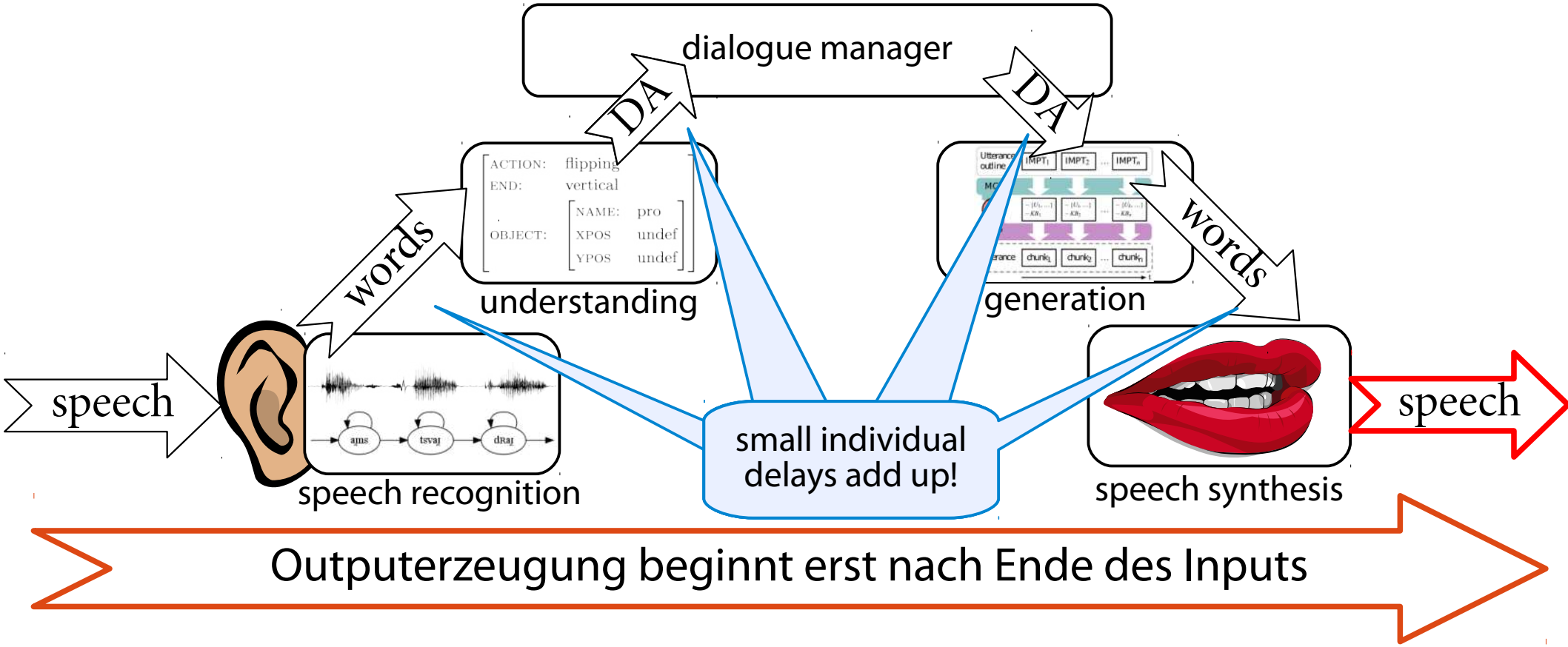

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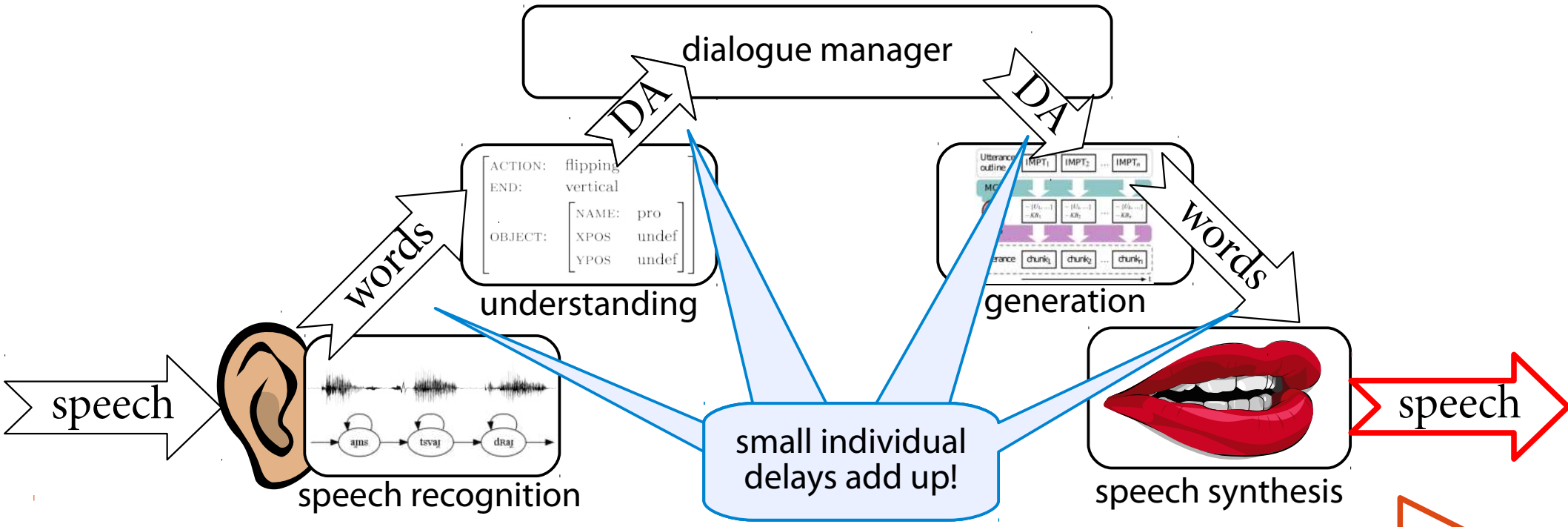
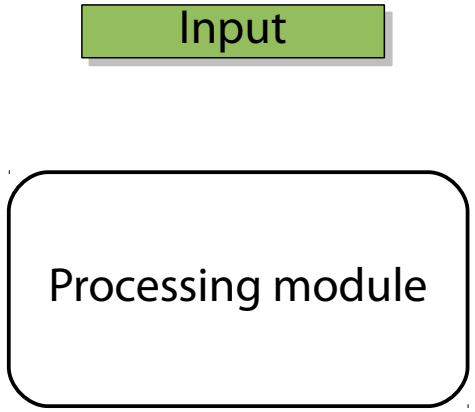


Outputerzeugung beginnt erst nach Ende des Inputs

keine Aktionen vor Ende der Inputverarbeitung

Incremental Processing



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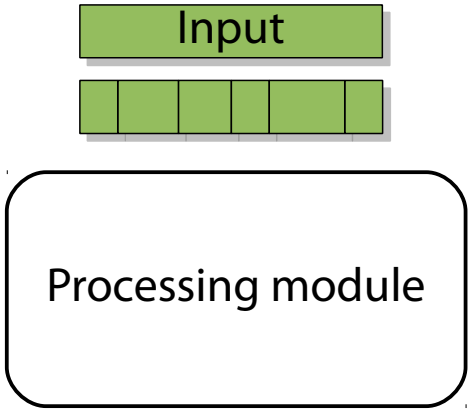

- Eingabe besteht aus minimalen Einheiten die stück-für-stück verarbeitet werden (Sprachaudio, Wörter, Gedanken, …)
- Ausgaben werden schon für Teileingaben erzeugt
- Eingabeeinheiten können zu größeren Ausgabeeinheiten zusammengefasst werden

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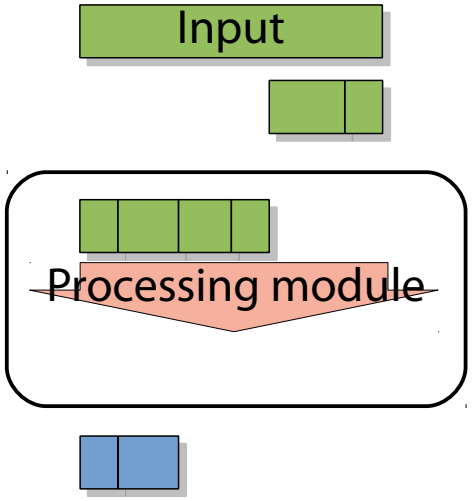

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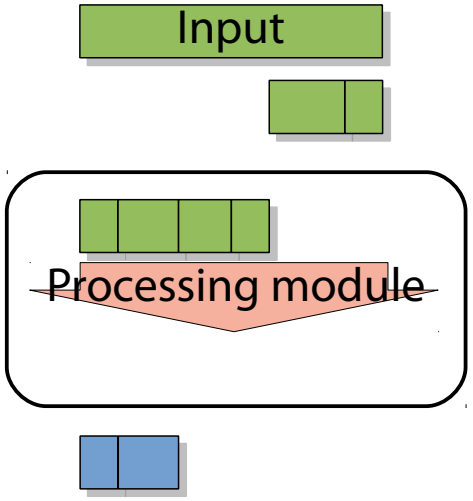

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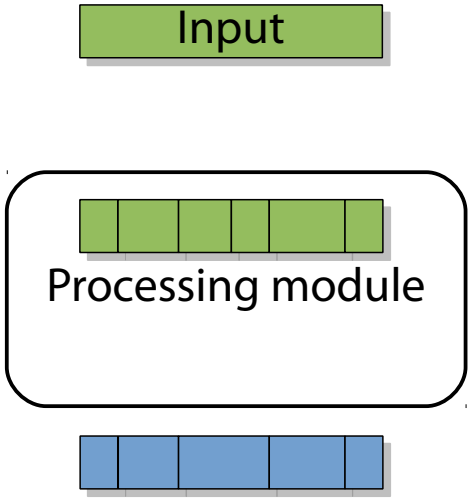

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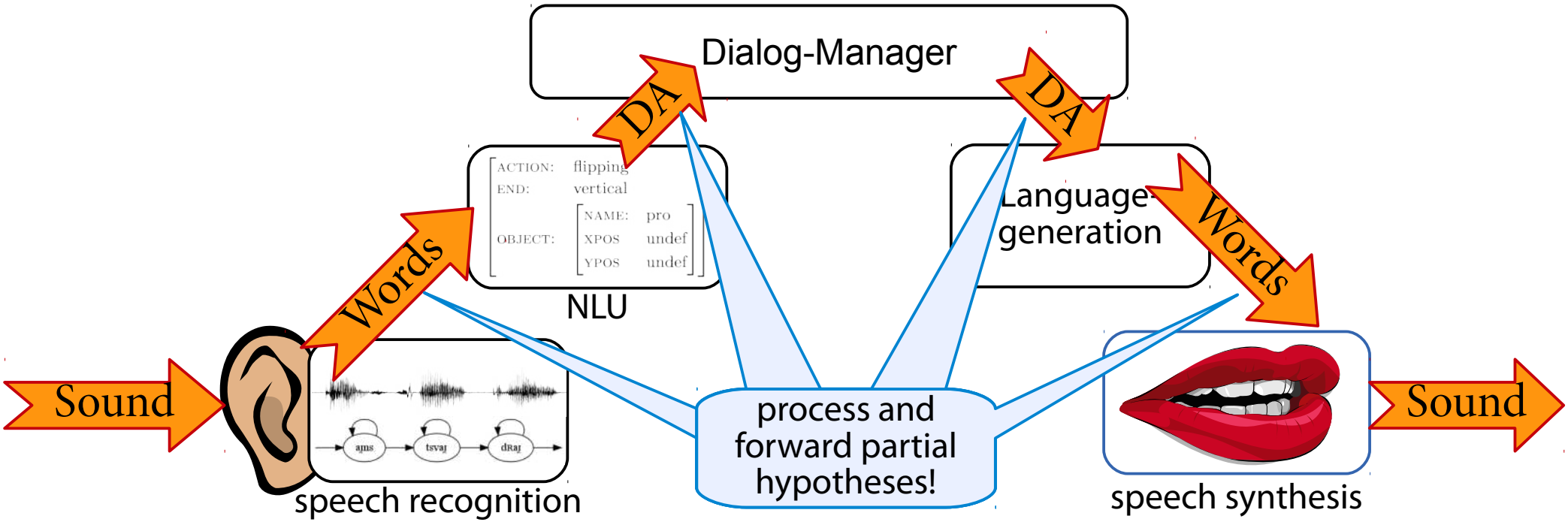

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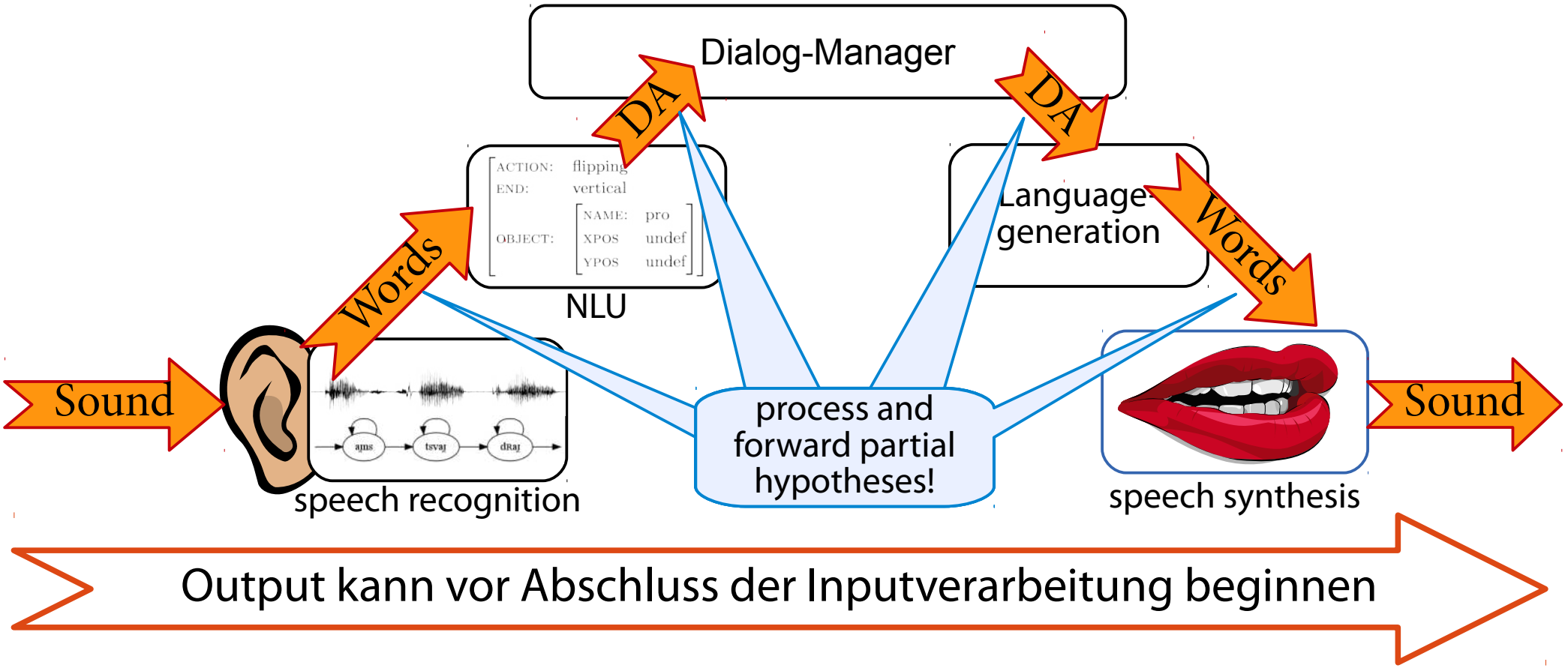

Herausforderung Inkrementalität

four

[f O 6]

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- Hypothesen basieren nur auf dem *was bereits bekannt ist*
  - mehr Kontext kann Ergebnisse beeinflussen
- example: speech recognition
  - input: [f O 6] → this sounds like “four”!
  - addition of [t i:] → together, this sounds like “fourty”!
  - what happens if [n] is next?

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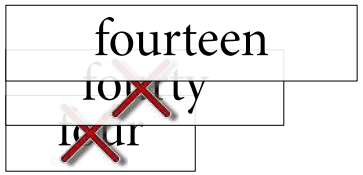

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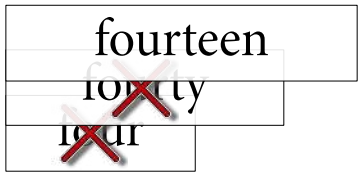

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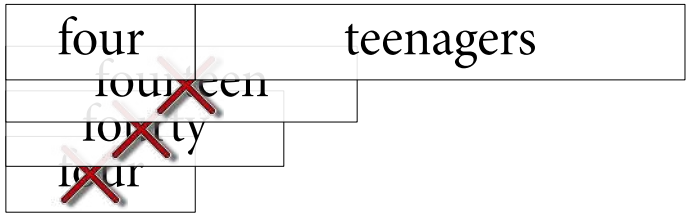


[f O 6 t i: n EI dZ 6 z]

Herausforderung Inkrementalität

Baumann, Atterer & Schlangen (2009), McGraw & Gruenstein (2012)

Herausforderung Inkrementalität

- Hypothesen basieren nur auf dem *was bereits bekannt ist*
  - mehr Kontext kann Ergebnisse beeinflussen
- Notwendigkeit, später Änderungen zu ermöglichen
- lohnt es sich trotzdem noch?

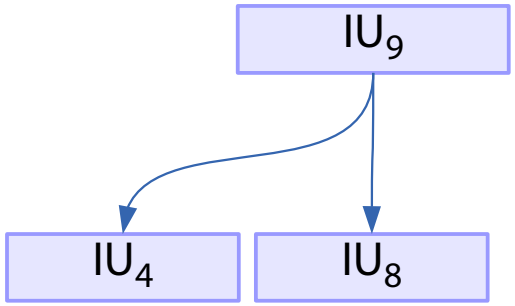
Baumann, Atterer & Schlangen (2009), McGraw & Gruenstein (2012)

Architektur-Grundlage

Incremental Unit model (Schlangen & Skantze 2009, Baumann 2013)

- atomar = minimale Menge an Information auf der gegebenen Abstraktionsebene

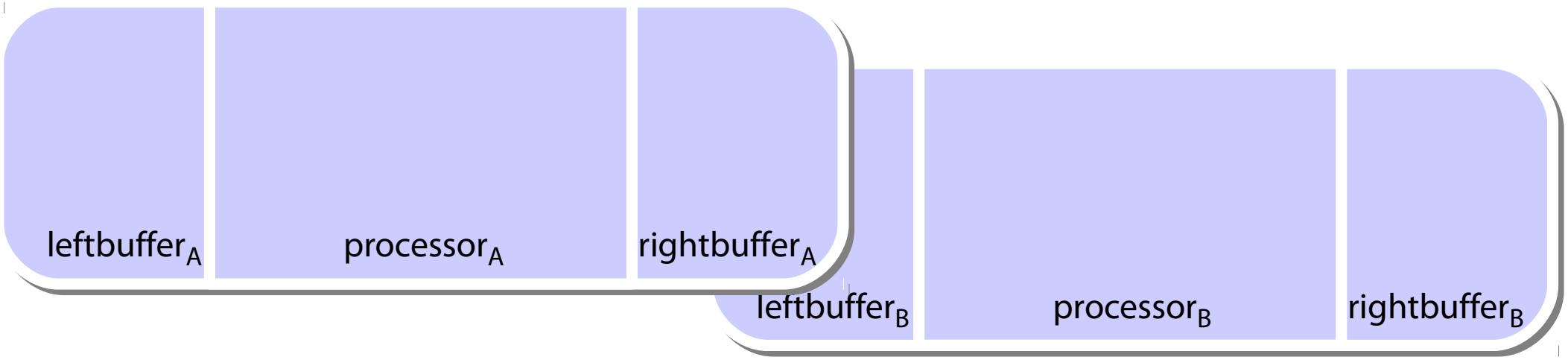
- Verknüpfung mit zugehörigen Einheiten: Gesamtnetz aller Einheiten stellt den Informationszustand des Systems dar



- linking erfasst **Dependenzen** zwischen Einheiten
  - allows to drill into genealogy of the input (white-box approach)
    - semantics of "umfahren"? → inspect prosodic realization!
  - allows to track changes to **revise** one's previous output hypothesis

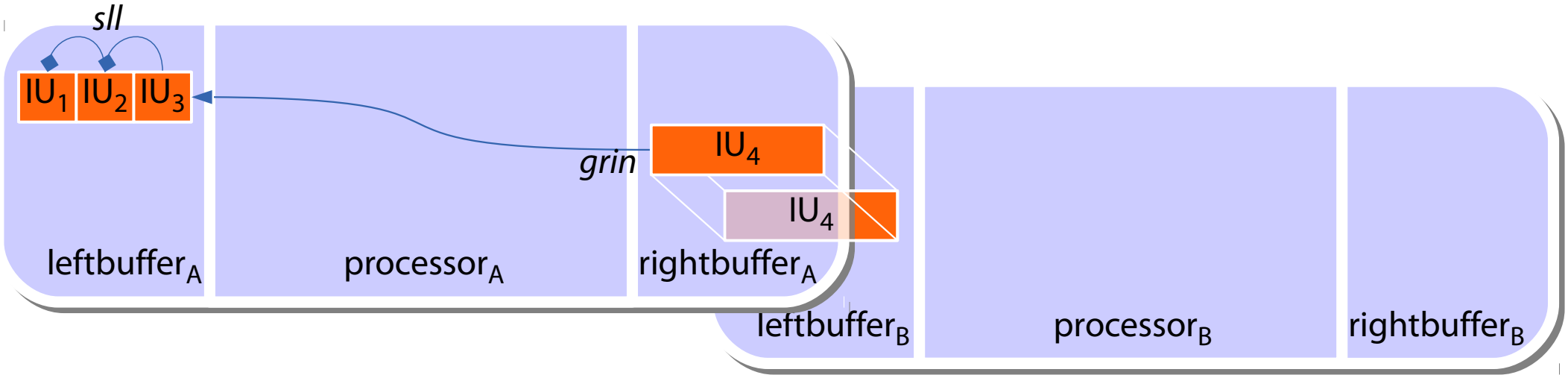
Processing modules

- processing modules are connected via buffers



Processing modules

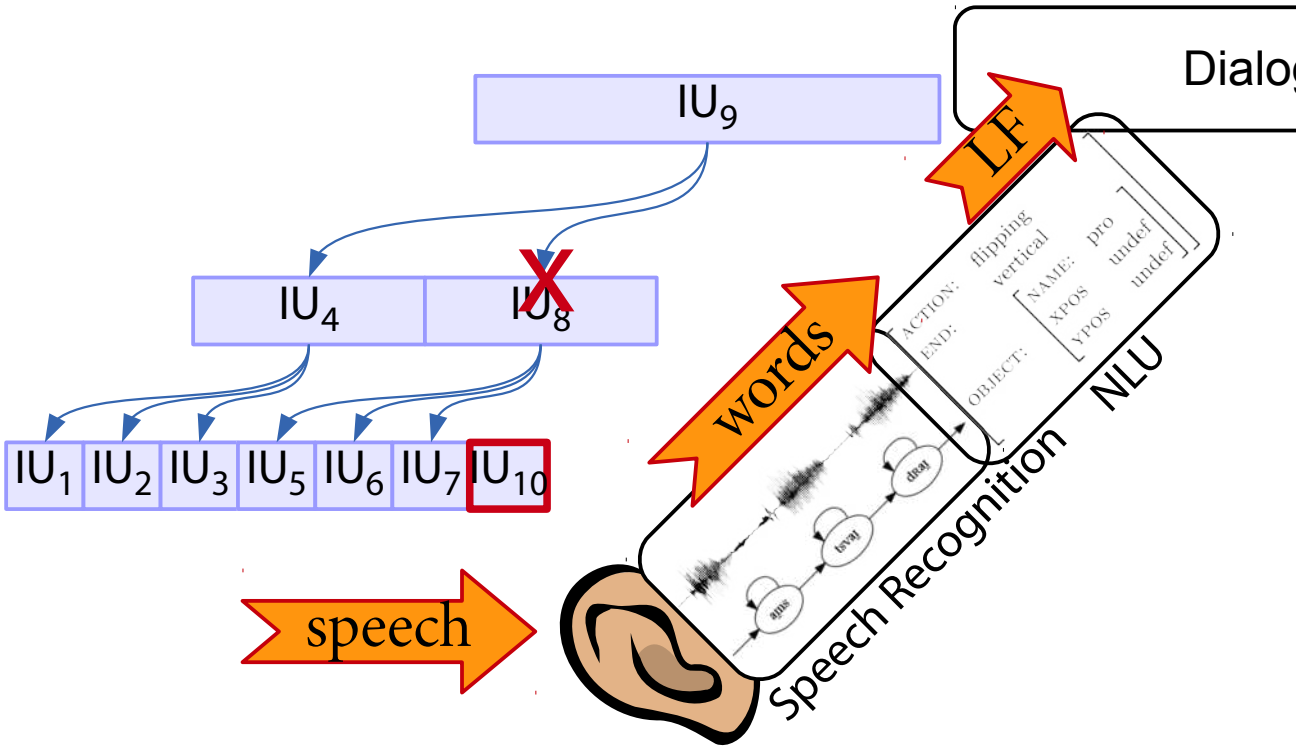
- processing modules are connected via buffers
- buffers contain incremental units (IUs)



- Links between IUs:
  - **grounded-in** links (*grin*) denote ancestry
  - **same-level** links (*sll*) for information of the same type

Incremental Unit Network

- belief changes reflected by changes in the network
  - more audio input arrives
  - word hypothesis is revoked …



Incremental Unit Network

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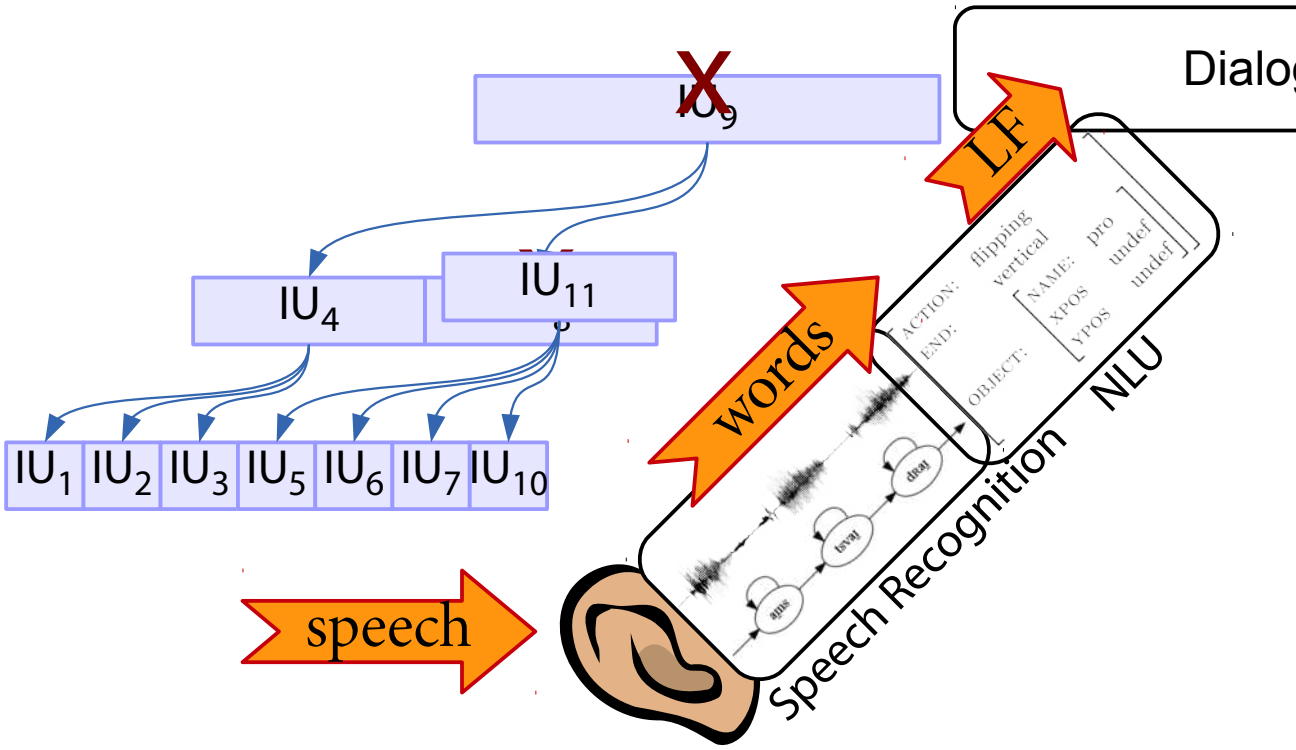
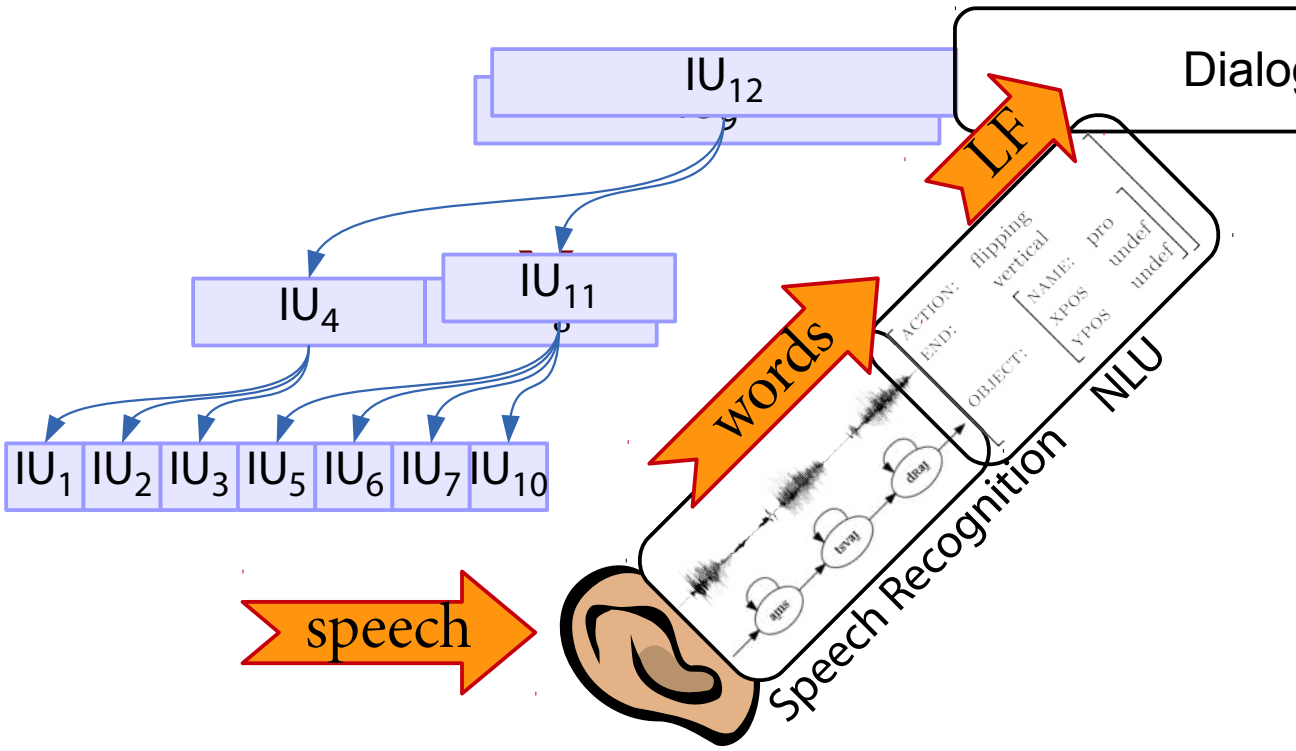
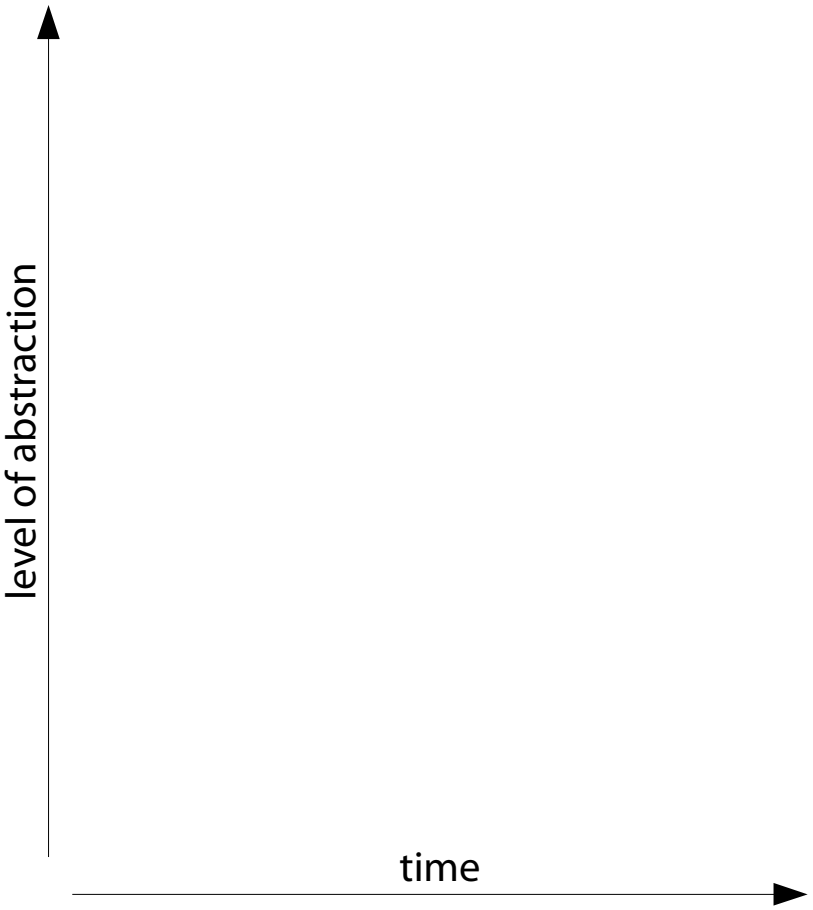


Incremental Unit Network

- belief changes reflected by changes in the network
  - more audio input arrives
  - word hypothesis is revoked and replaced by a different one
  - changes trickle up in the system



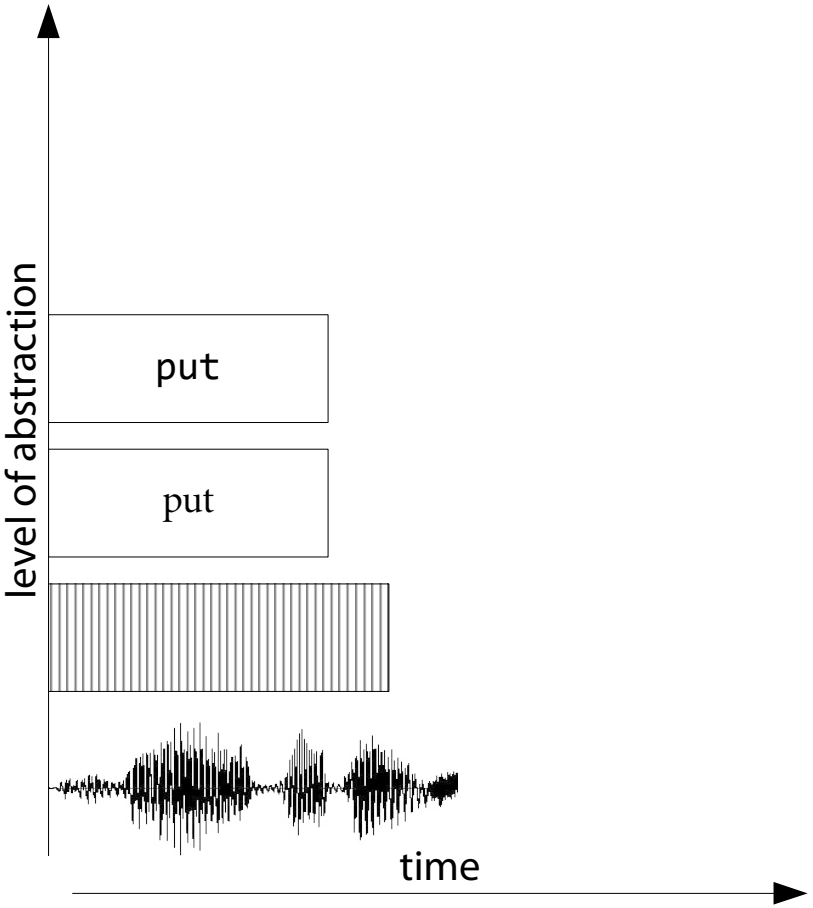
Consuming input incrementally



input side

Baumann (2013)

Consuming input incrementally



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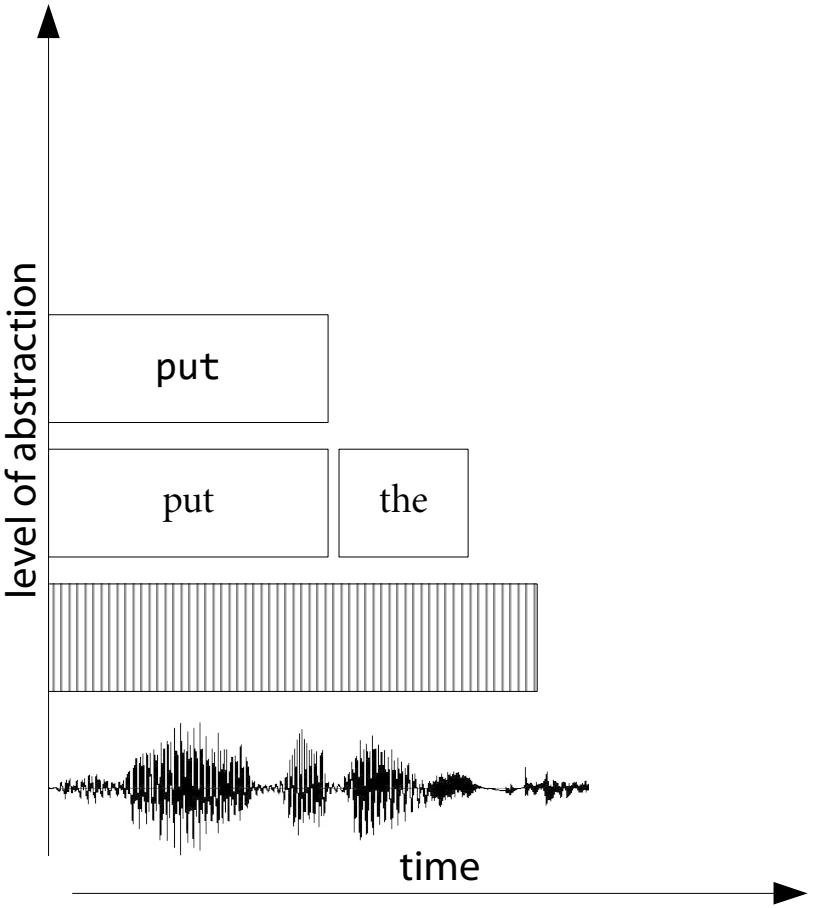

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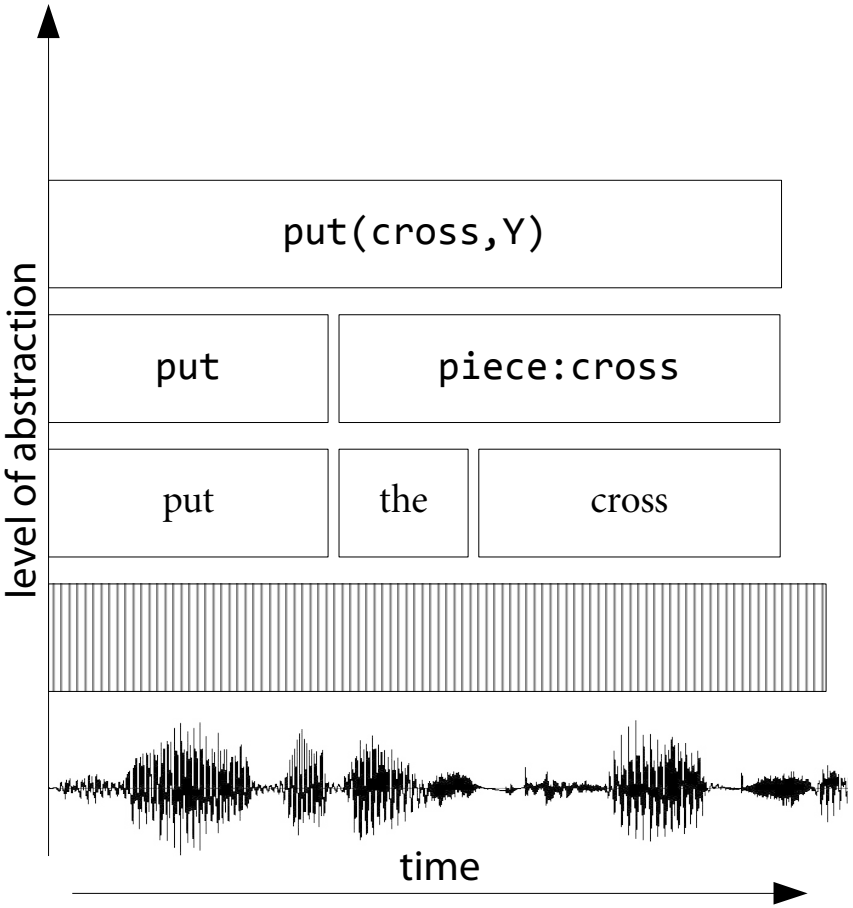

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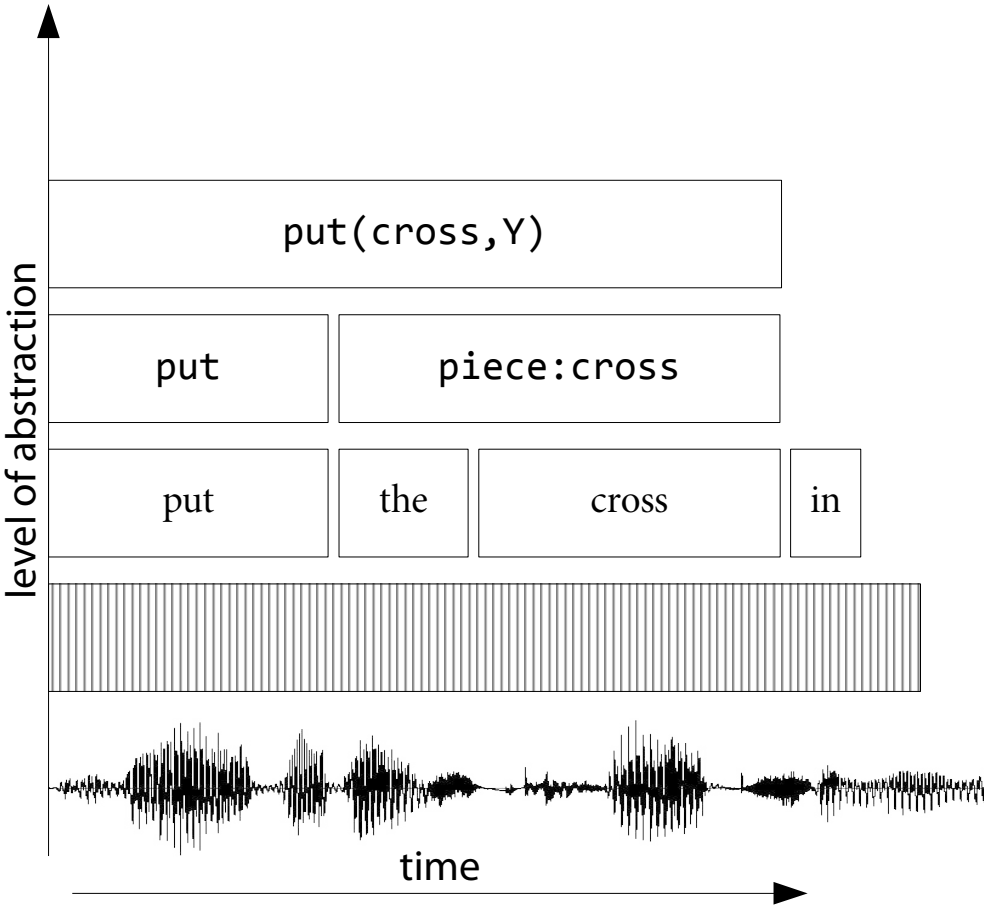

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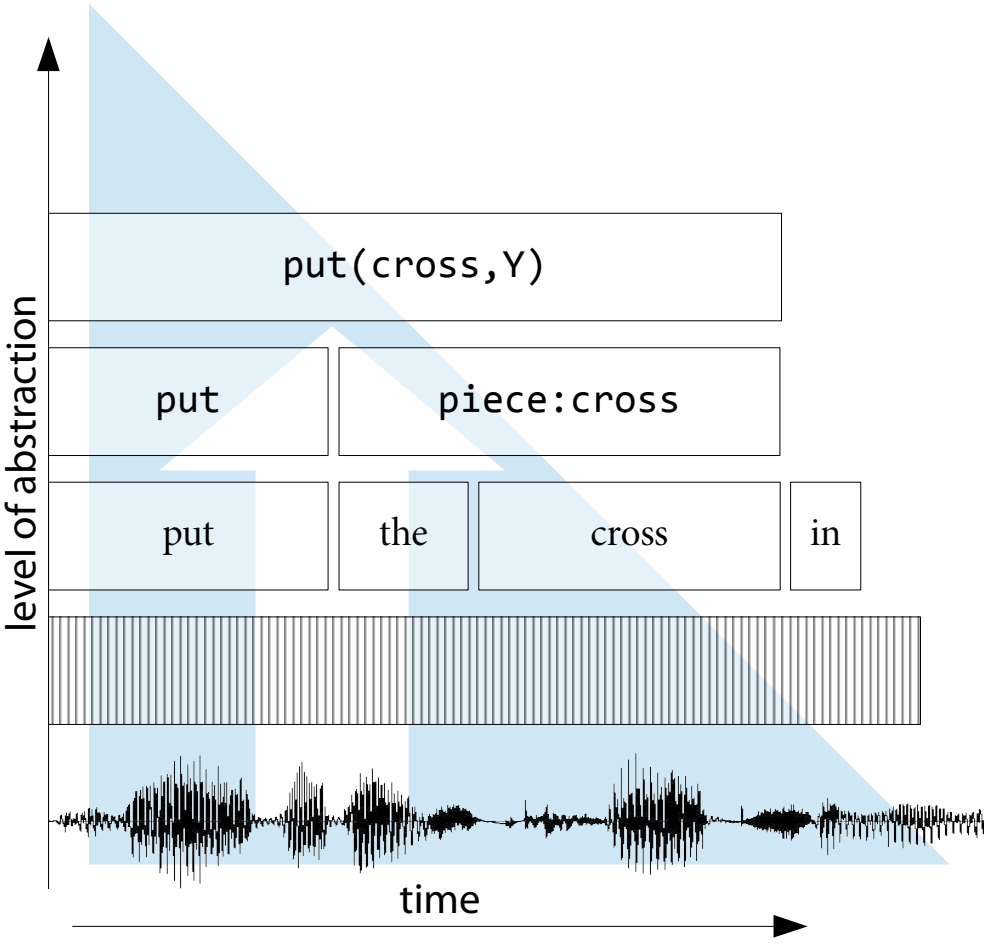
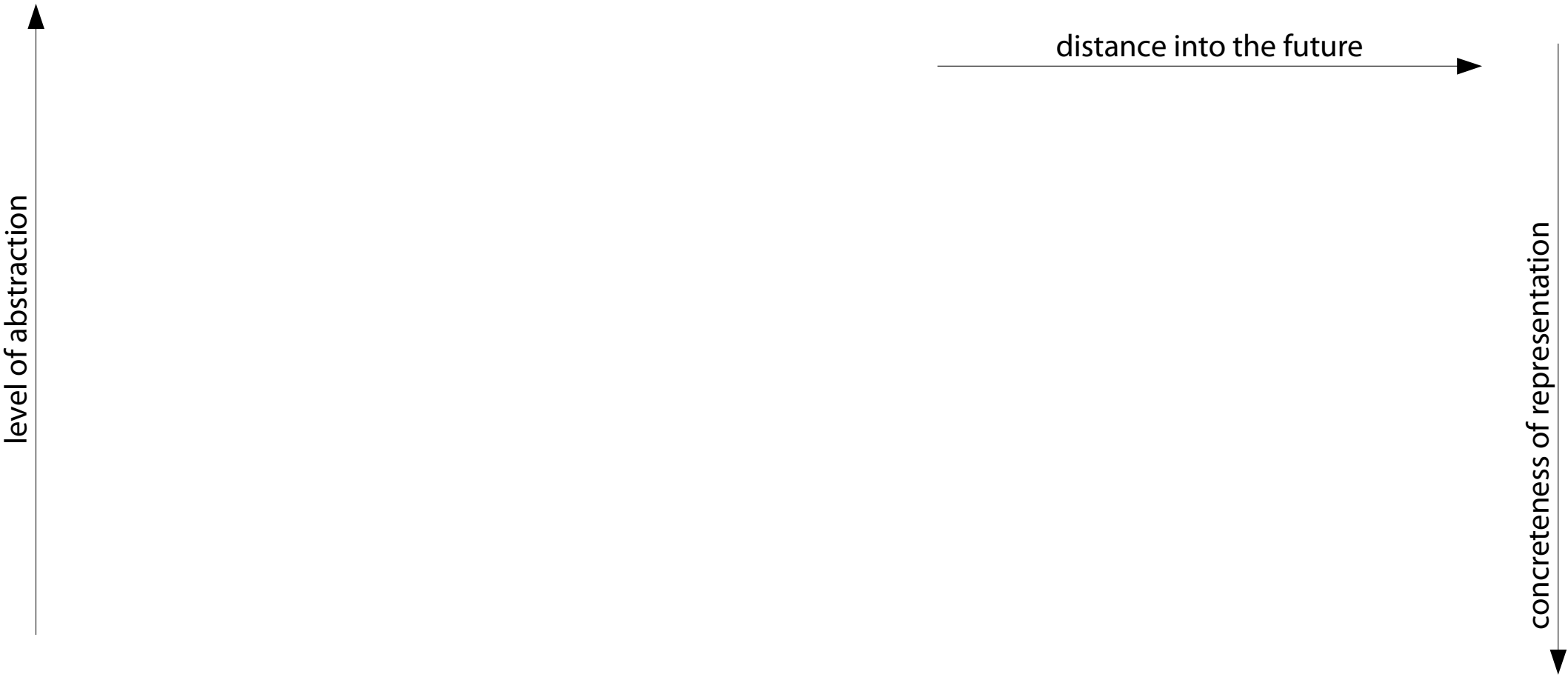


input side

Baumann (2013)

Producing output just-in-time



output side

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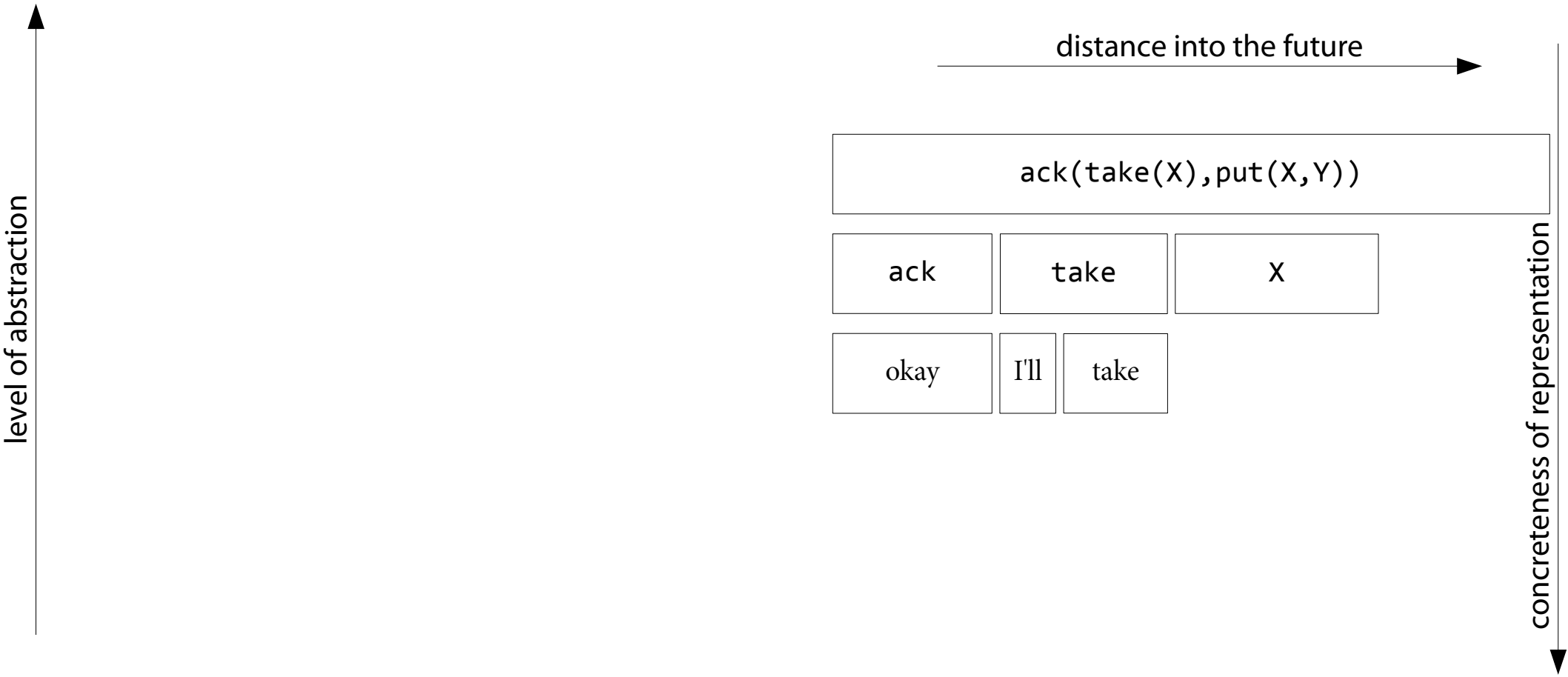

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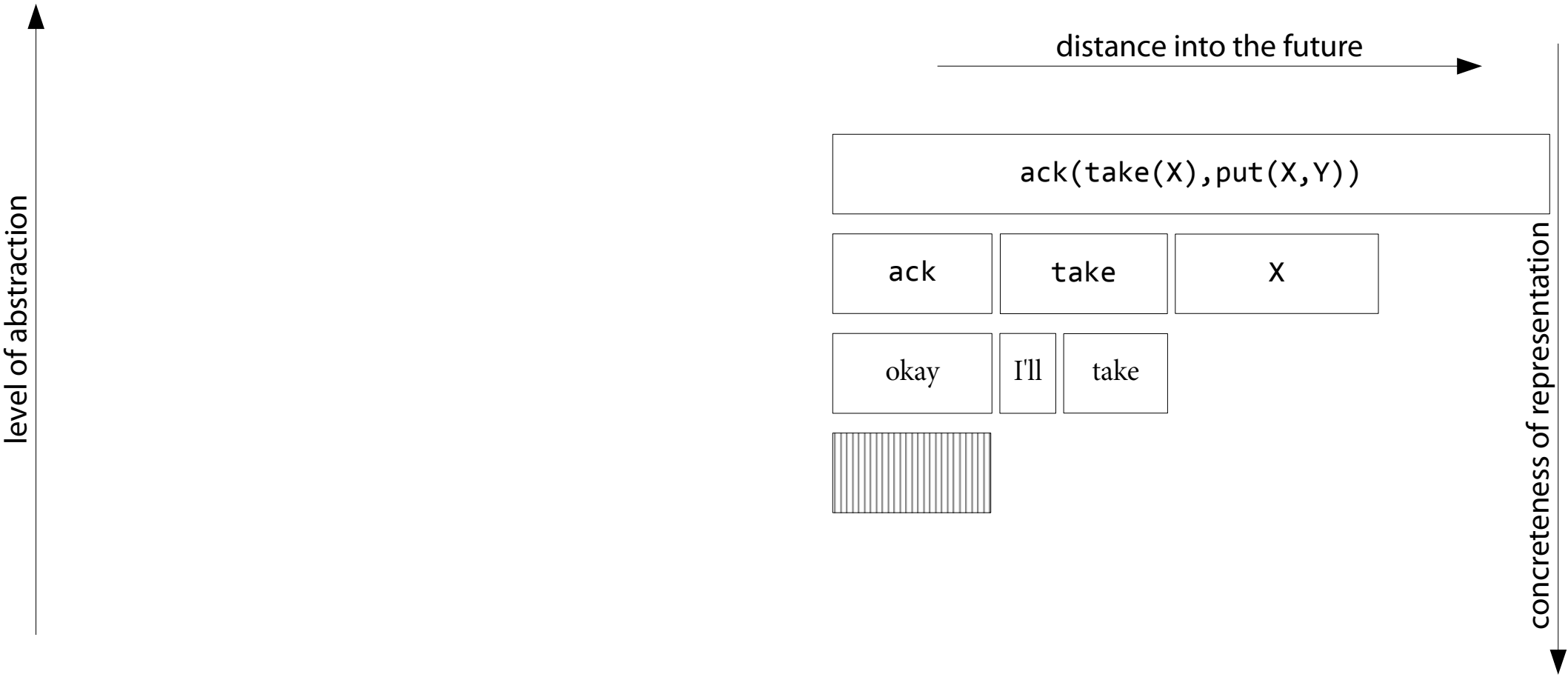

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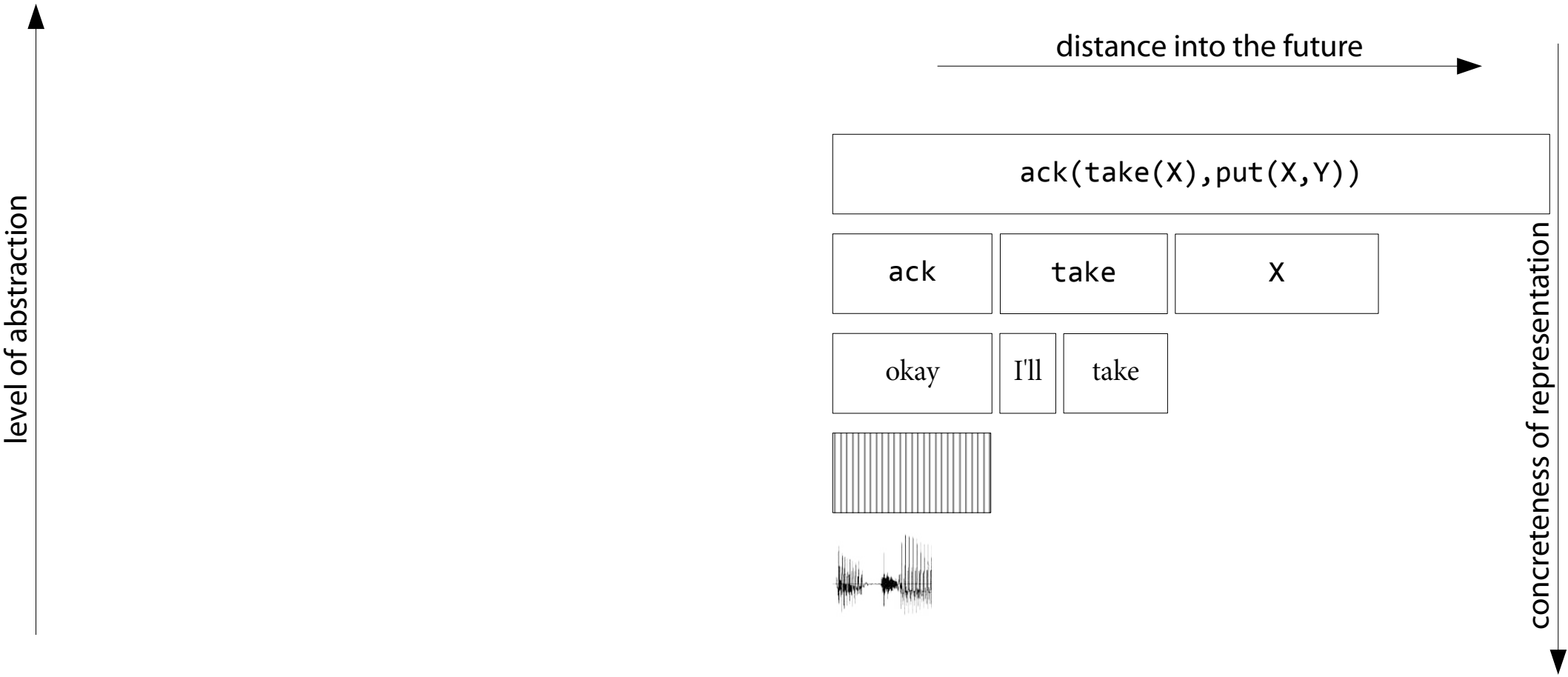

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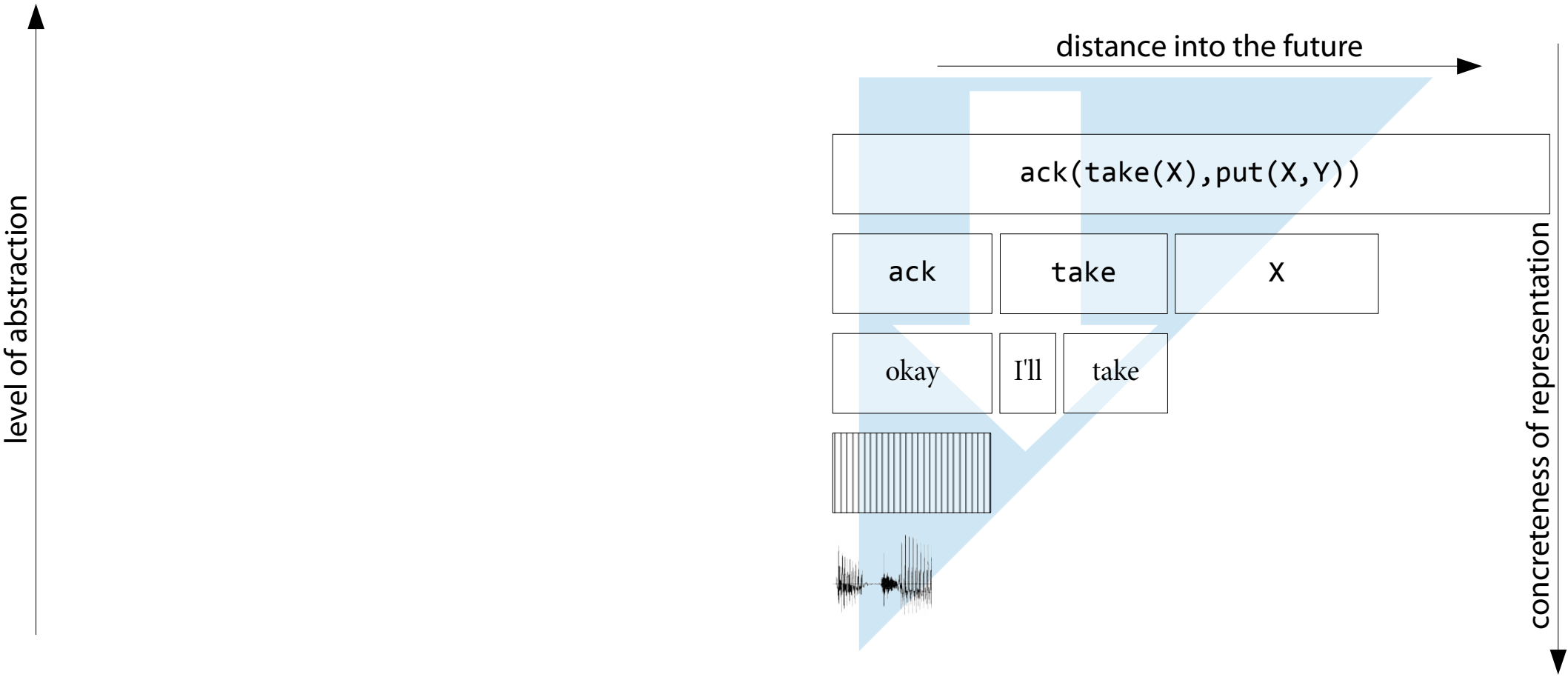
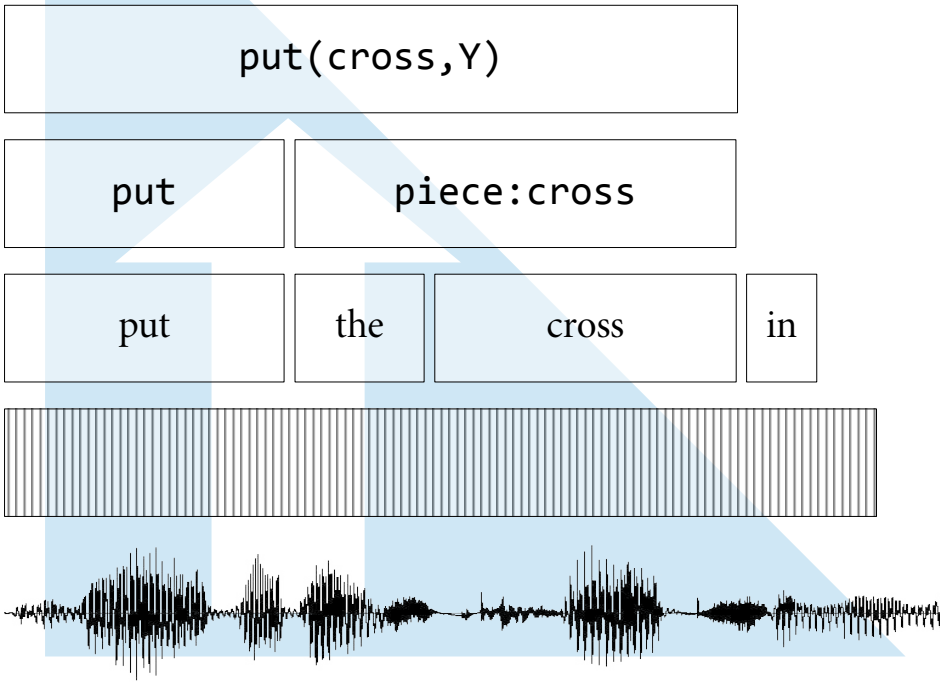
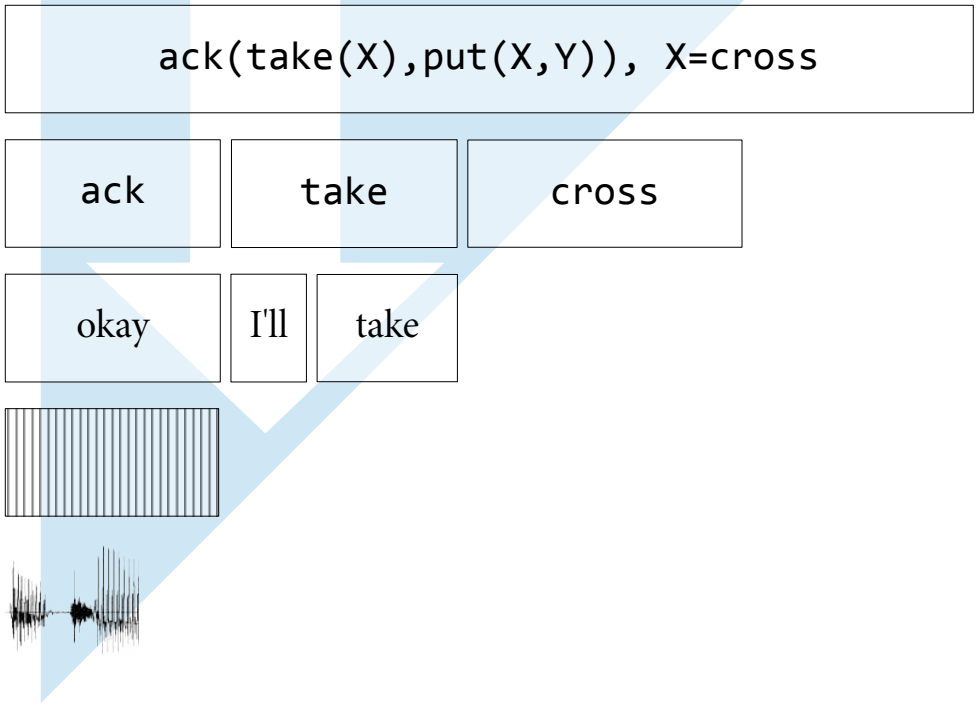


output side

Baumann (2013)

A data model for incremental just-in-time processing





input side

output side

Baumann (2013)

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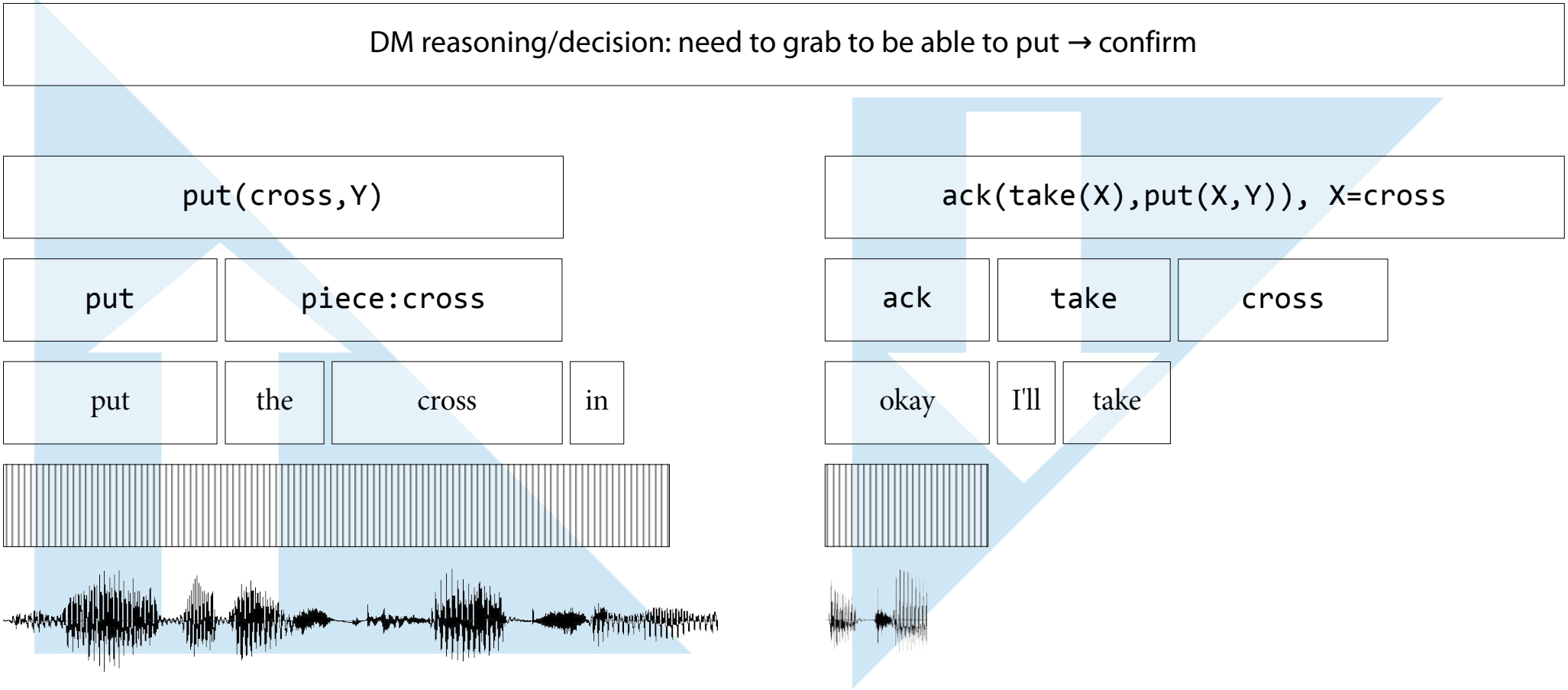


input side

output side

Baumann (2013)

IU Data Model

- Incremental Units (IUs)
  - encapsulate minimal amounts of information at the current level of abstraction (phones, words, ideas, …)
  - linked to other units on the *same level* to form hypotheses
  - linked to units they are based on to track dependencies
  - network of units stores information states
- Updates to the network reflect changes in understanding:
  - add units when new information becomes available
  - *revoke* units if they turned out to be wrong
  - notify about degree of commitment/certainty to a unit

Schlangen & Skantze (2009, 2011)

~~Drei~~ ein paar Beispiele für inkrementelle Verarbeitung

More natural human-computer interaction

- partial incremental (multi-modal) dialogue systems
  - reduced system domains that exploit only one specific aspect
- some example systems
  - subtle feedback to signal understanding, sub-turn interaction
  - the use of affordances in continuous control
  - flexible delivery of spoken output to bind with other modalities
  - flexible spoken output in a noisy domain
  - ability to co-complete / shadow user speech

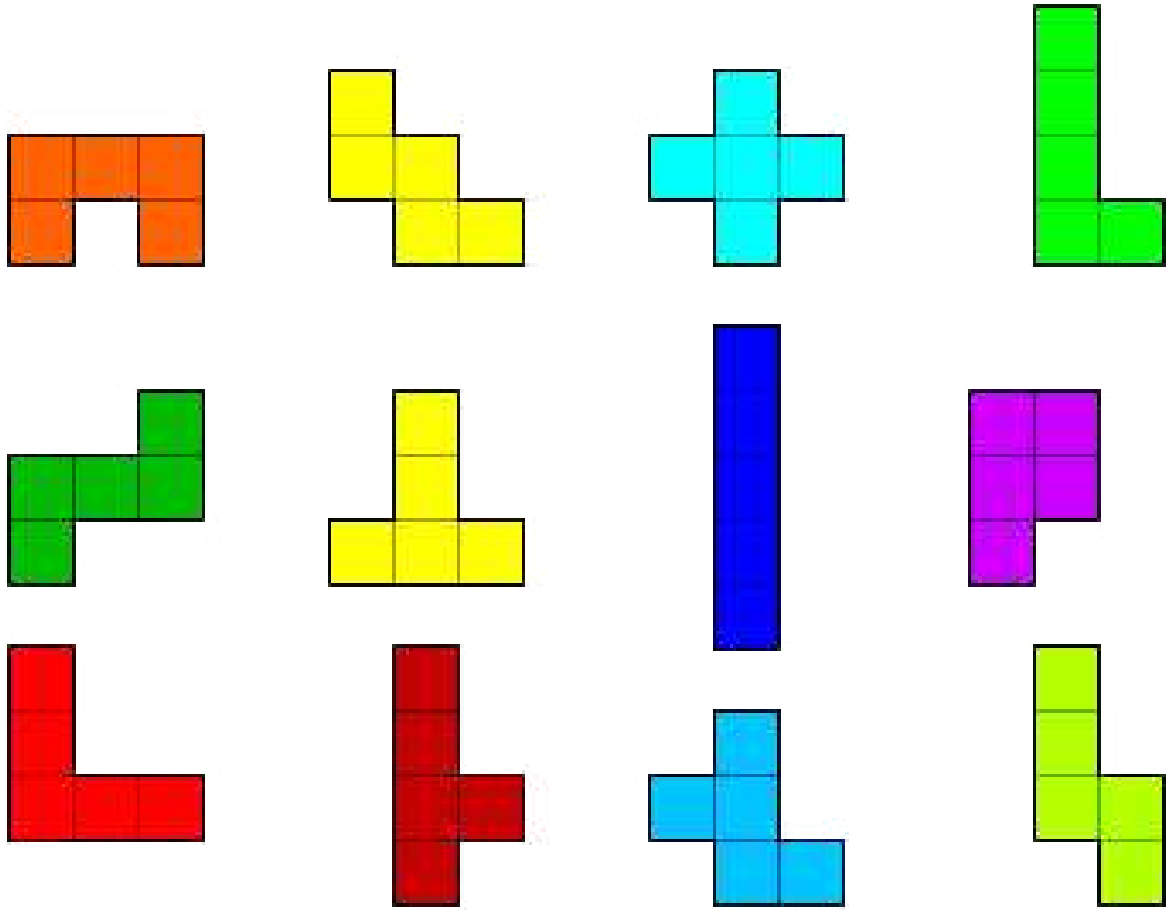
for the „micro-domain principle“ see (Edlund et al, Speech Communication 2008).

Feedback and sub-turn interaction

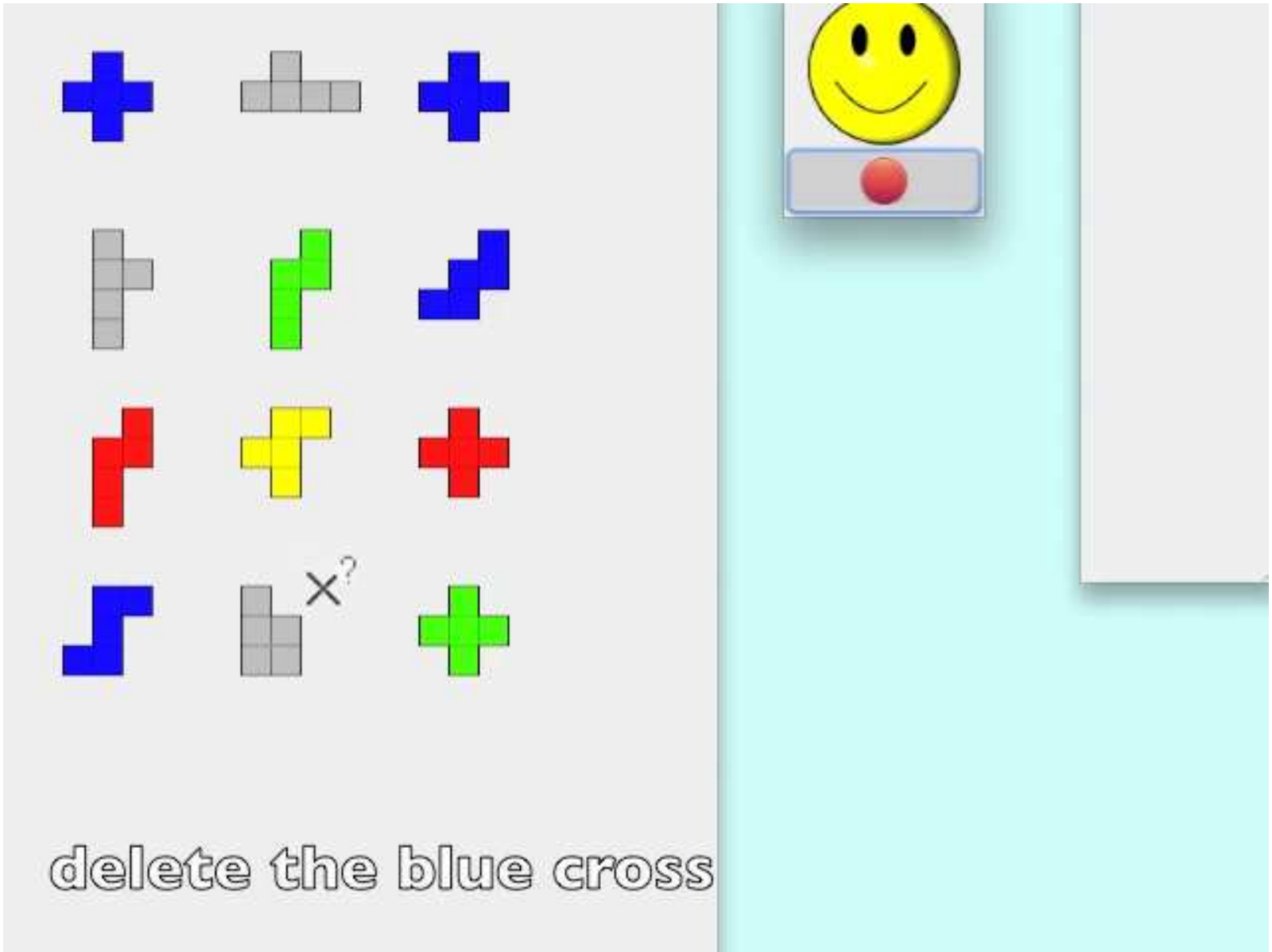
- Humans use feedback to signal state of understanding
  - often within a very tight *feedback loop*
  - incremental processing allows to tighten this feedback loop
  - in the video (to follow): visual feedback during the utterance
- Human reaction time (and type of reaction) depends on pragmatic completeness and prosody
  - crudely modelled using a simple prosodic rule
  - actions are performed as soon as system is certain

A simple task domain

- 12 pentomino pieces
- human is to manipulate pieces:
  - rotate
  - flip
  - delete



Feedback and sub-turn interaction

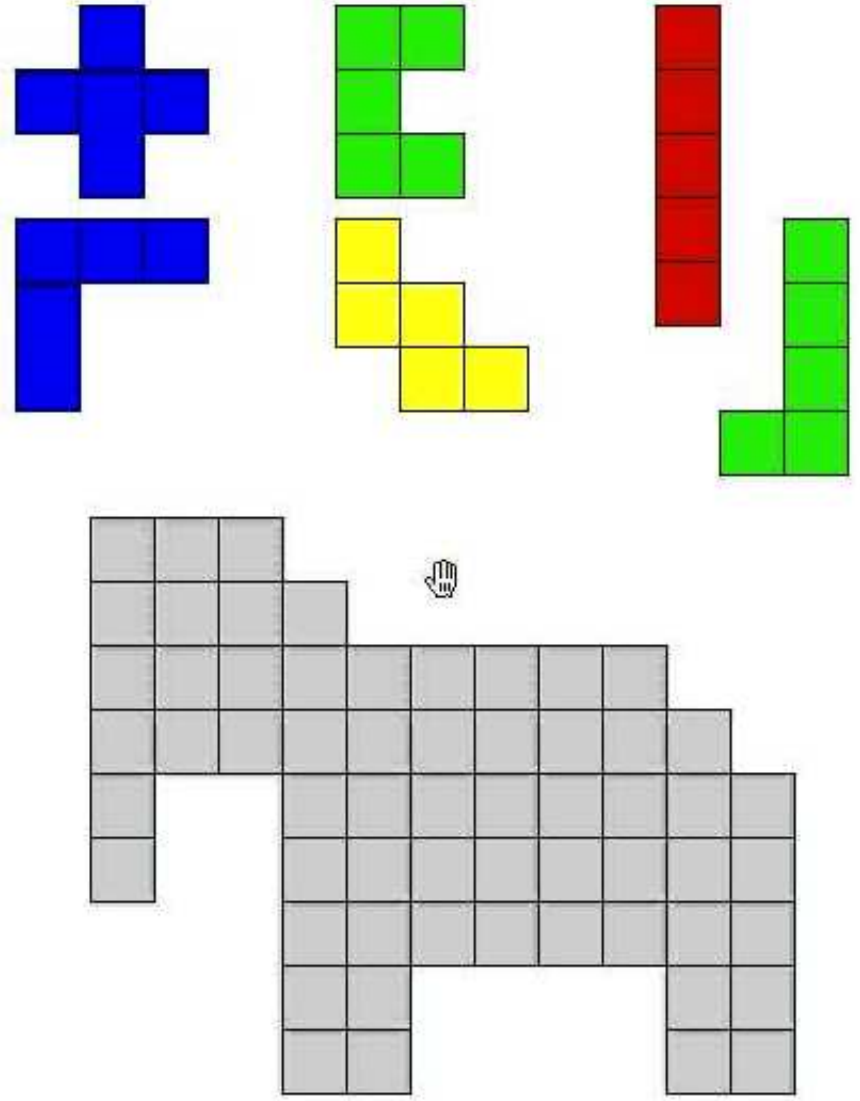


Feedback and sub-turn interaction

- main features:
  - tight visual feedback loop to signal partial understanding
  - fast, sub-turn interaction based on prosodic rules

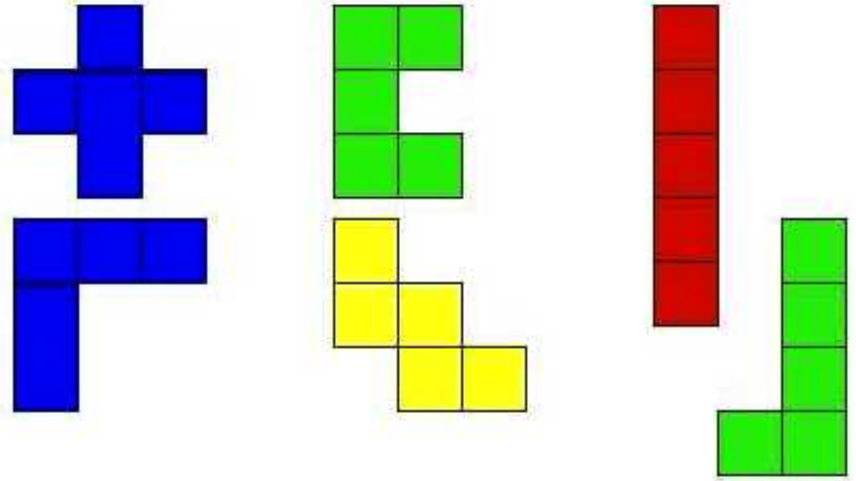
- overhearer study showed significantly better rated interactions over a baseline system
  - despite the differences between the systems being very subtle
  - small difference in behaviour → large difference in impression

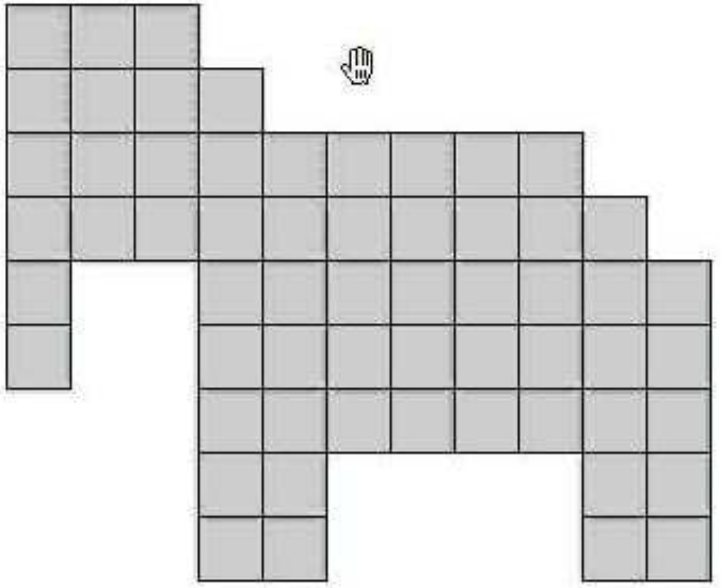
Playing puzzle games



Playing puzzle games

- how to puzzle an elefant?
- game alternates between
  - selecting puzzle piece
  - and placing it on the board





→ main challenge:
referring expressions

→ move complexity into
the interaction loop:
steering instead of naming

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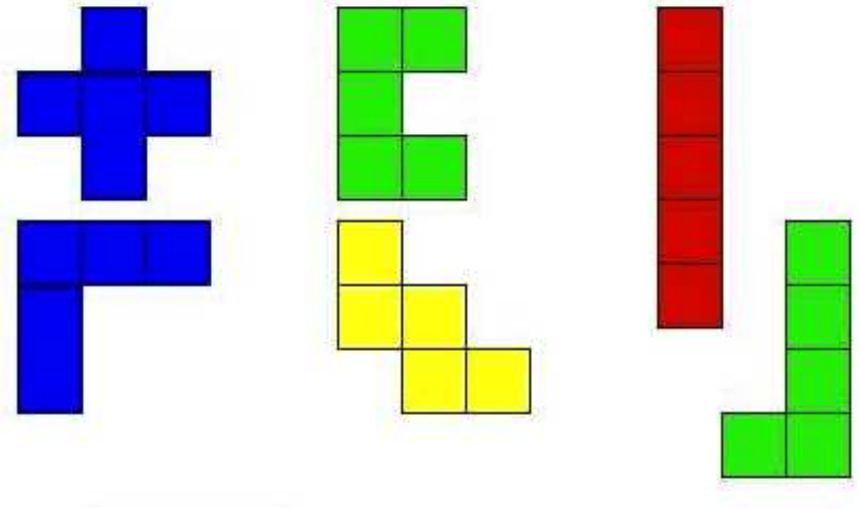

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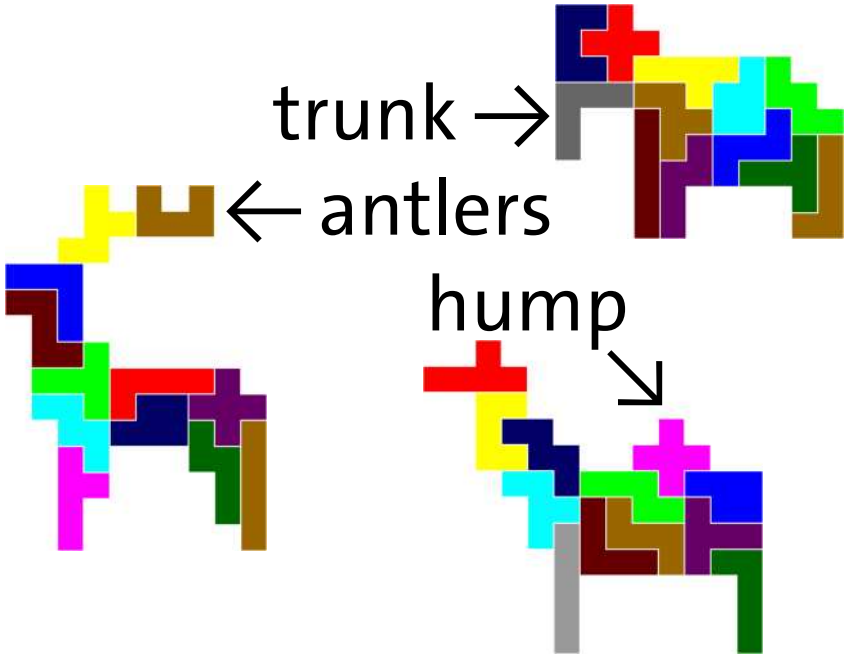

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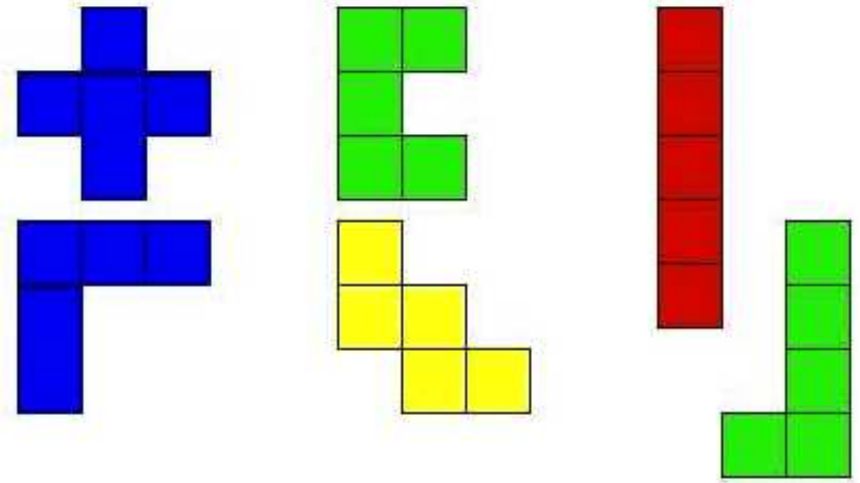

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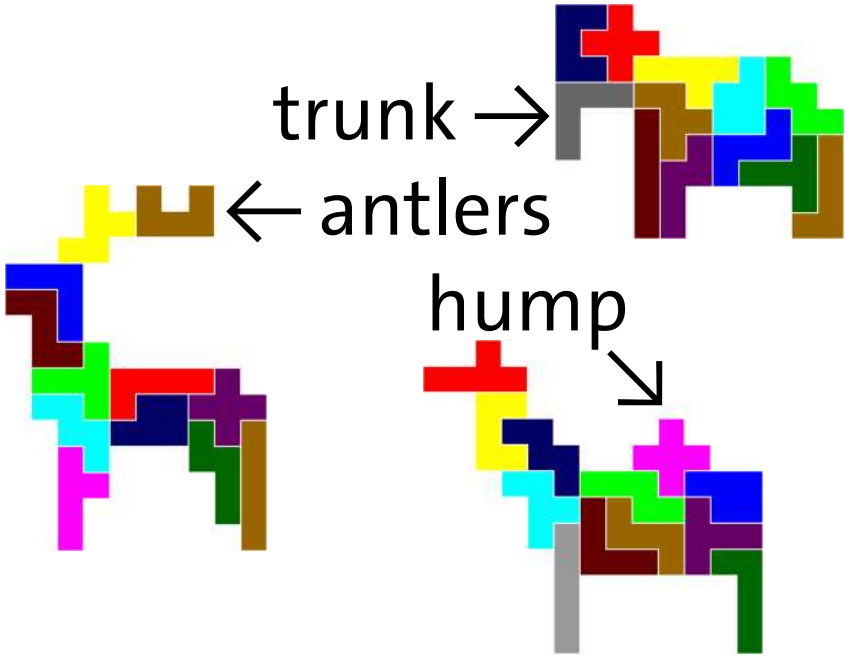


Baumann et al. (2013)

Affordance as a driving principle

Jenkins, Journal of Scientific Psychology, pp. 34-45, Dec. 2008.

Affordance as a driving principle

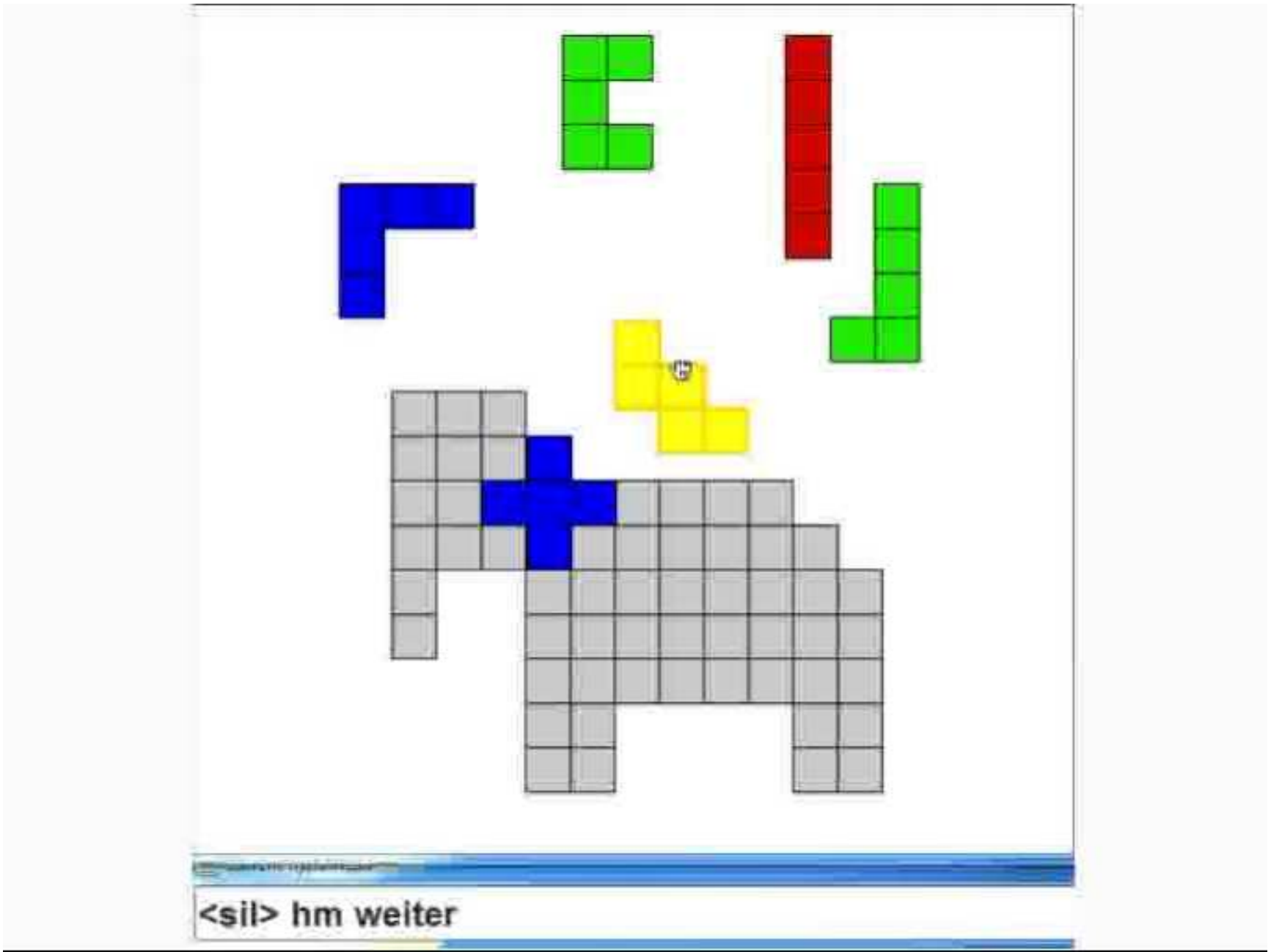
- affordances: conventionalized attribute-meaning pairs that manifest possibilities of interaction
  - doors afford to be opened
  - questions afford to be answered („where should I put the piece?“)
- *motion* manifests the possibility of interacting with the motion itself (*steering*)
  - steering (in 2D) is comparatively easy
  - to keep up the steering metaphor, the system must react to commands without noticeable delay

Jenkins, Journal of Scientific Psychology, pp. 34-45, Dec. 2008.

Example Video

please focus on:
- swiftness of system reactions
- error recovery
(ASR results shown at the bottom)

Steering metaphor in interaction



Experimental Evaluation

Baumann et al. (2013)

Experimental Evaluation

system was tested with/without immediate motion after the positioning question

- all users react to the affordance of motion (i.e., give steering commands)
- significantly faster task completion
- user questionnaire indicates advantage for affordance of motion (rated more transparent and reactive)

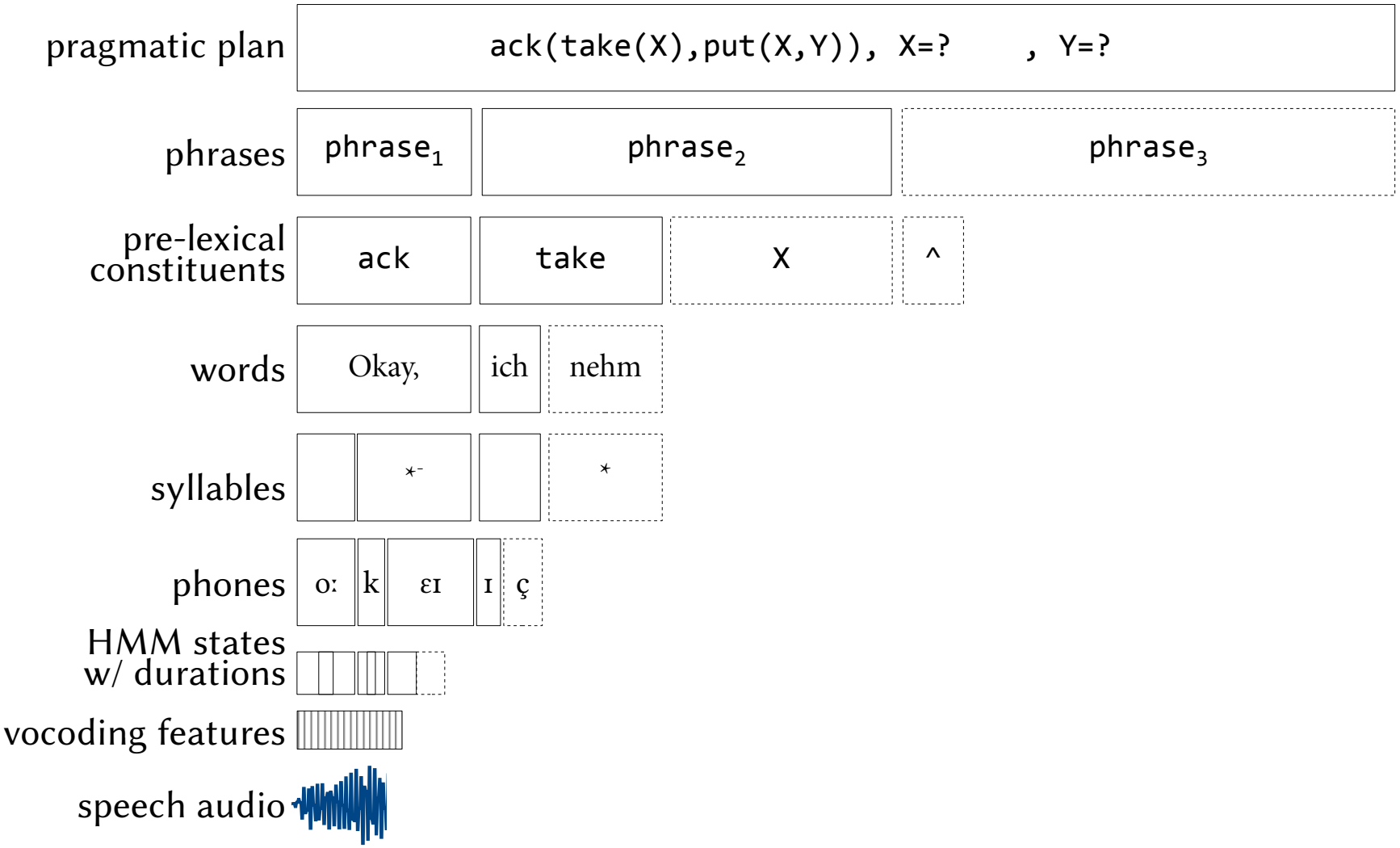
→ **ASR errors inhibit understanding, but not interaction!**

Baumann et al. (2013)

Affordances: Take-away Message

- move complexity where it hurts least / is manageable most easily
  - ask/act often in small steps → incrementally!
- think about what you propose to a user / what affordances are opened up
  - the relative strength of concurrent affordances
    - should the system act, ask, or do both?
    - how about the ordering of these?
  - the *ease of use* of affordances (e.g. steering is easy)

Incremental Speech Generation and Synthesis (HMM-based)



Baumann and Schlangen (2012a,b)
Baumann and Schlangen (2013a,b)
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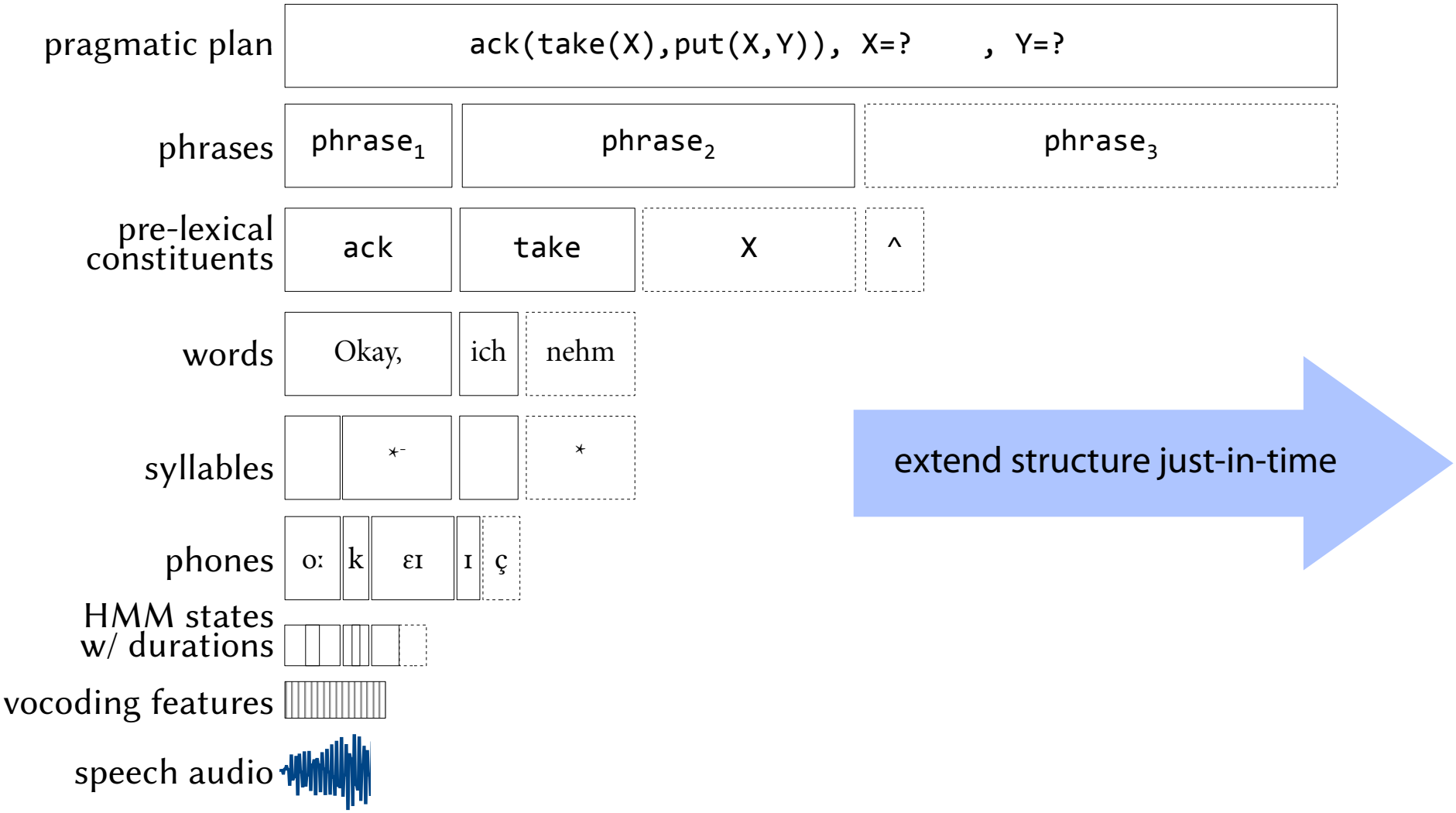

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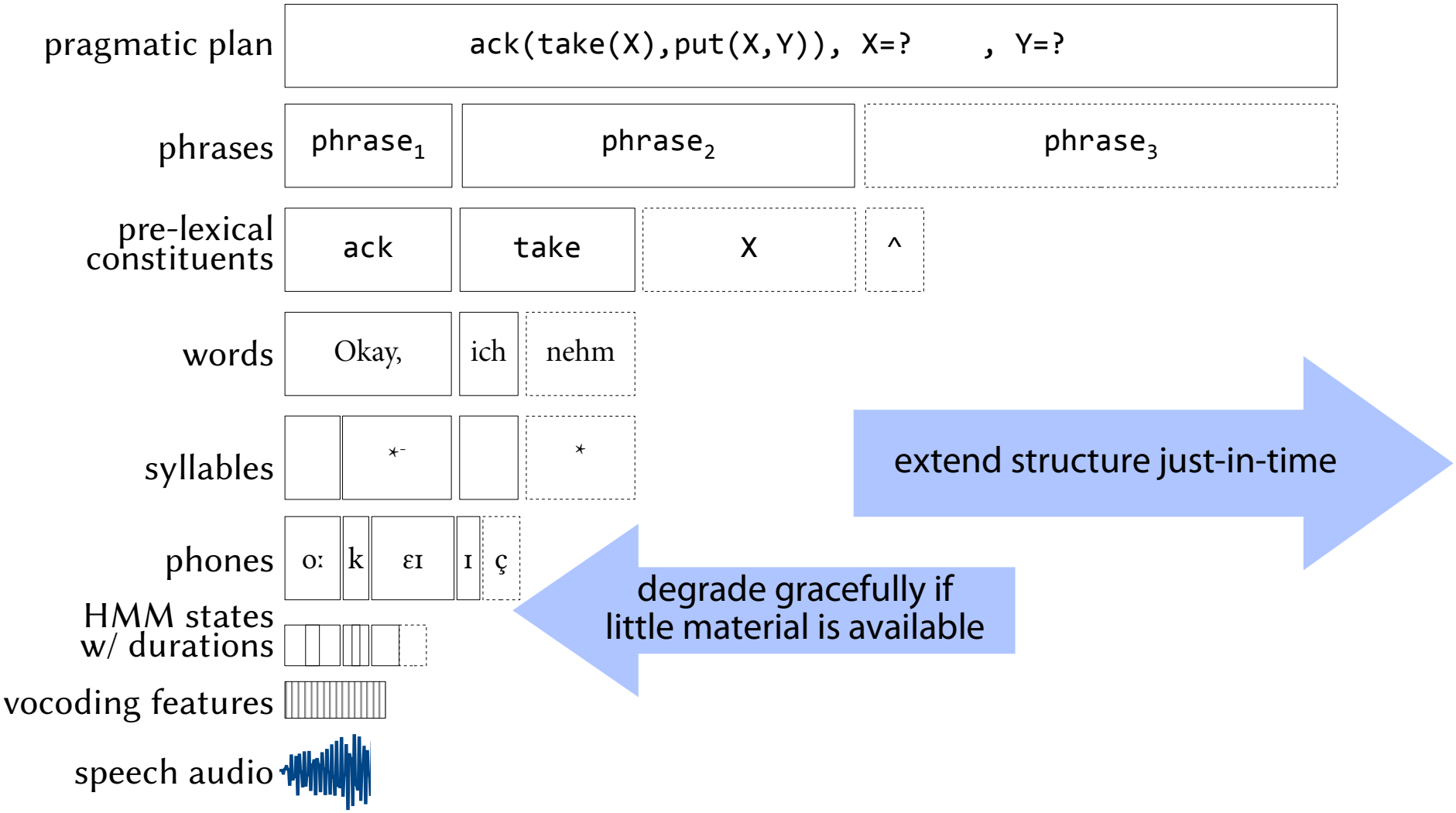

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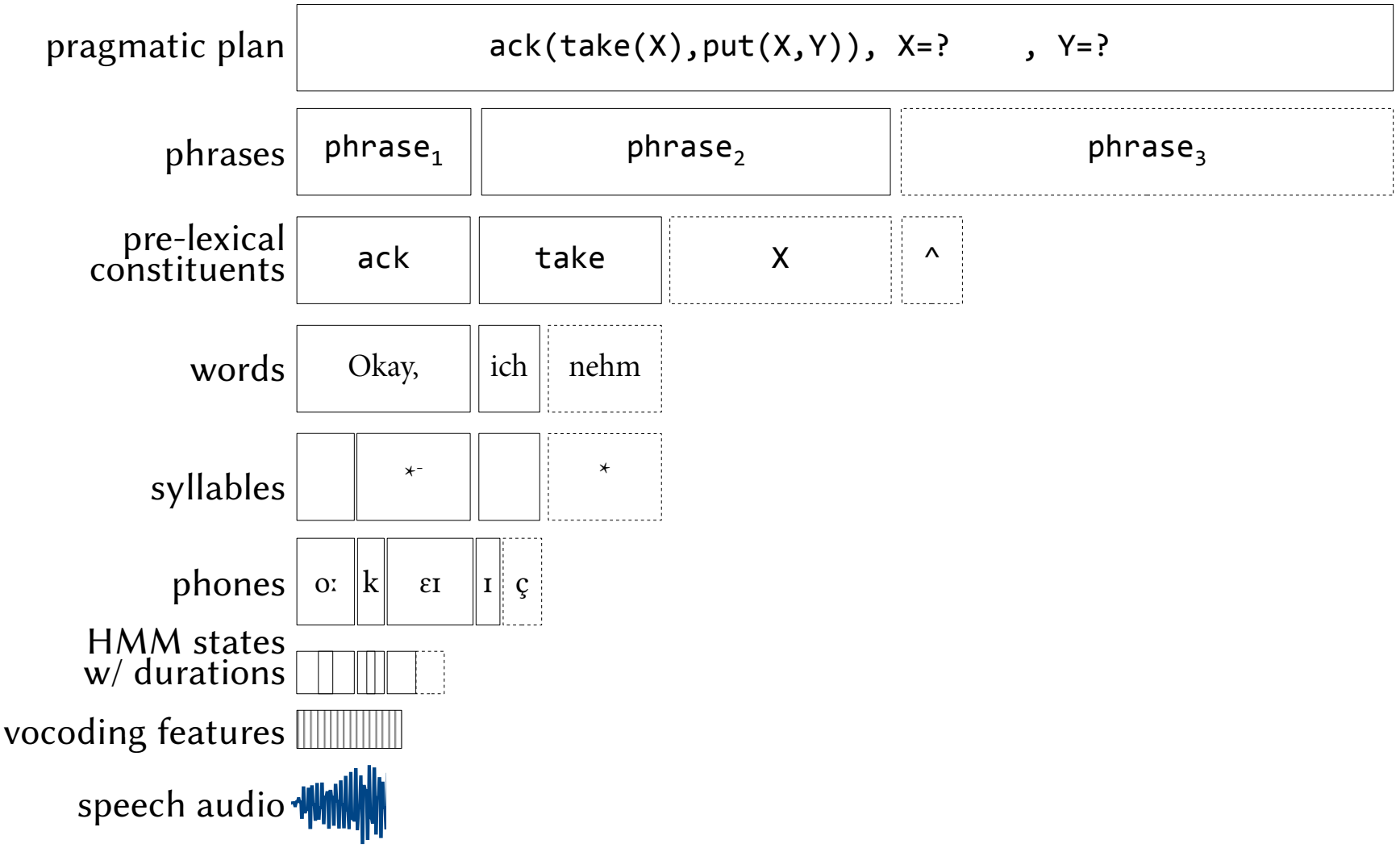

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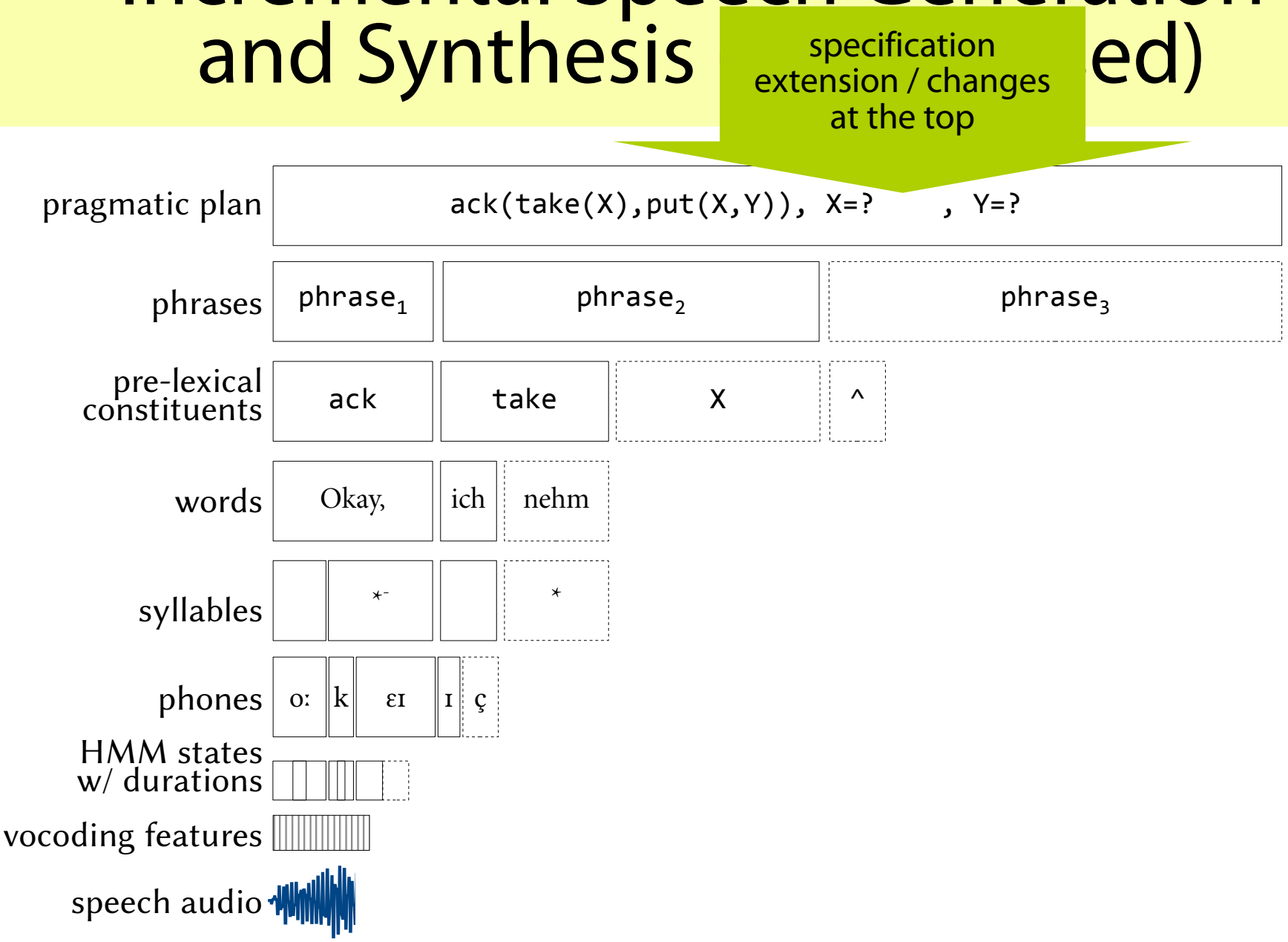

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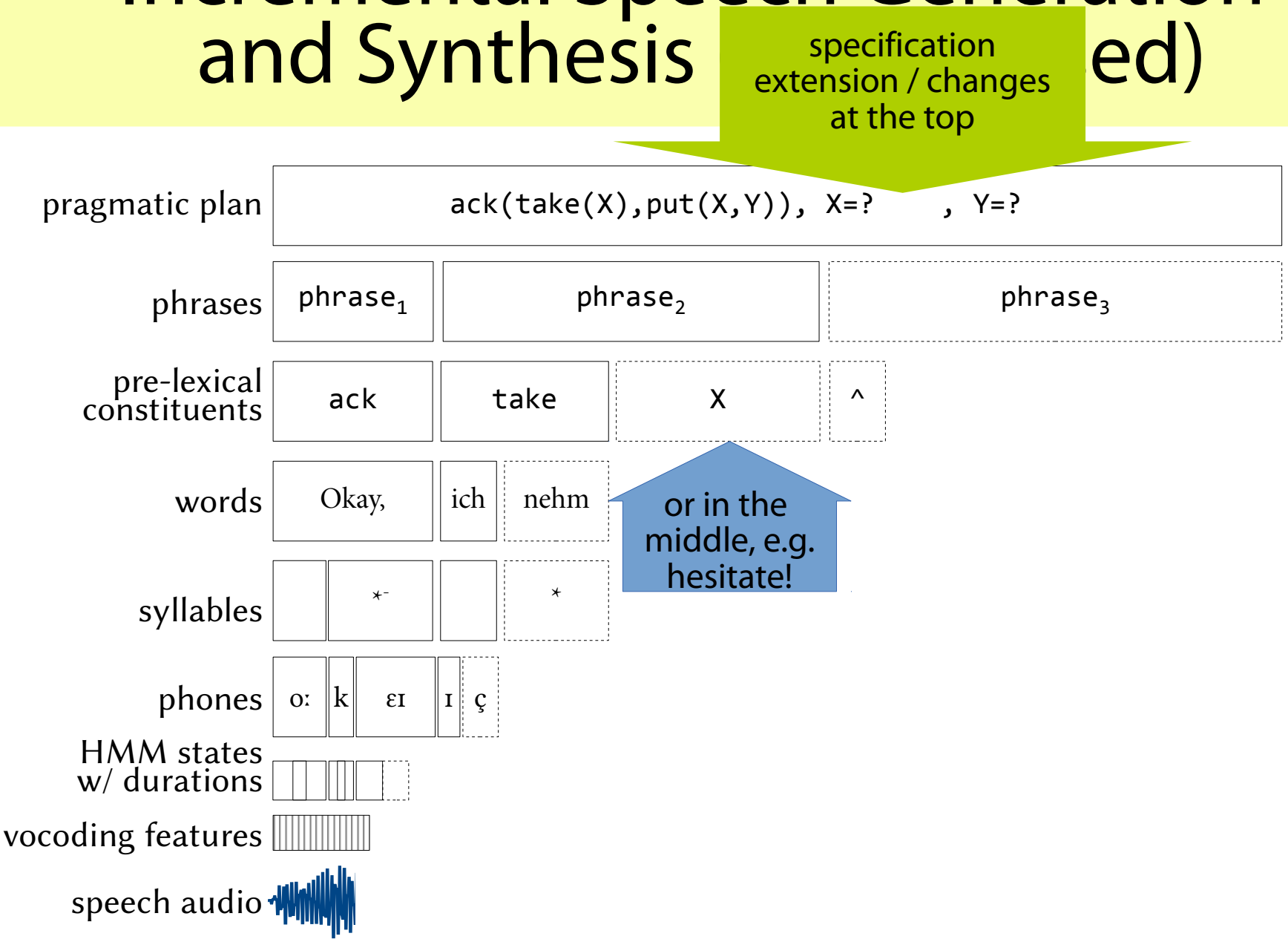

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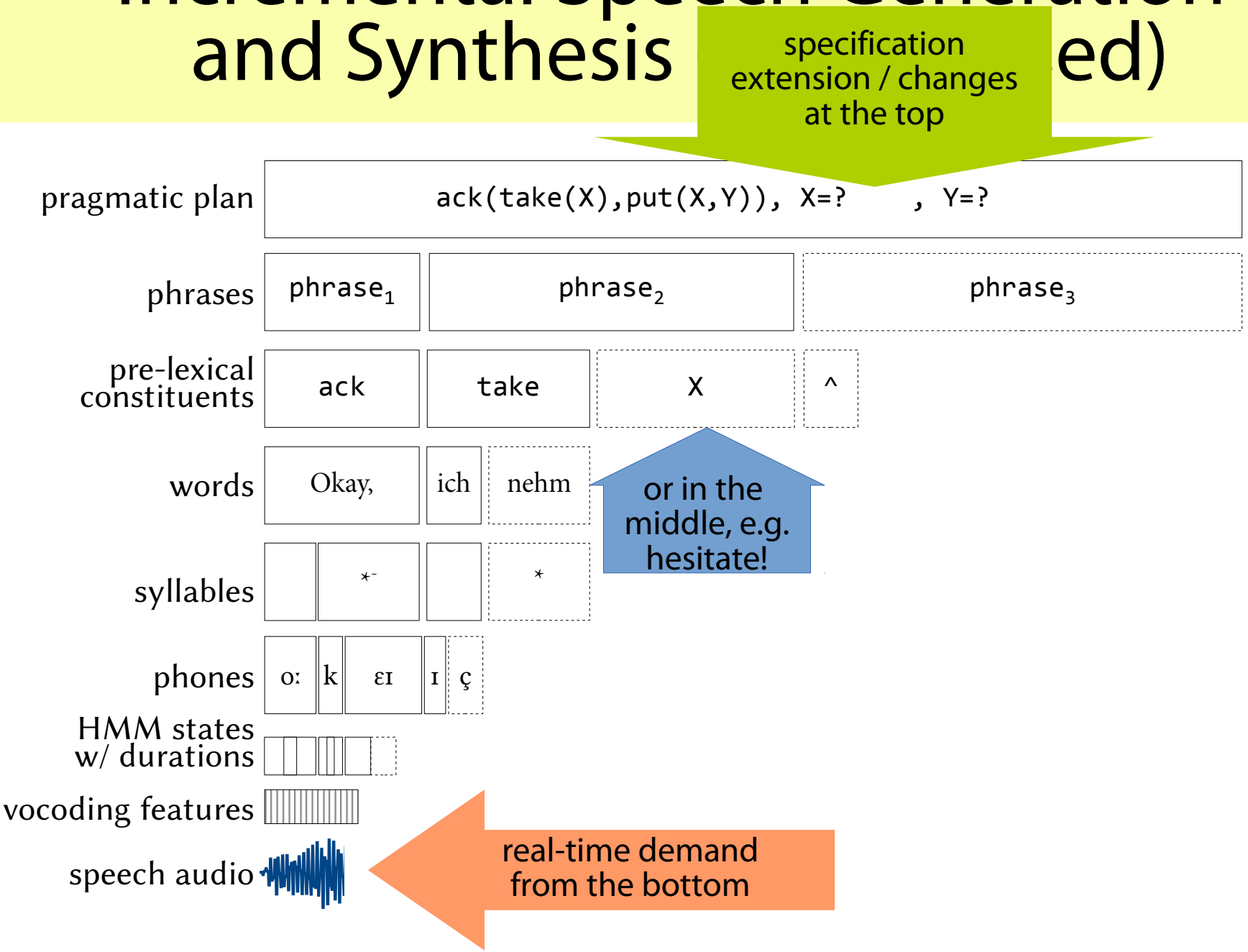

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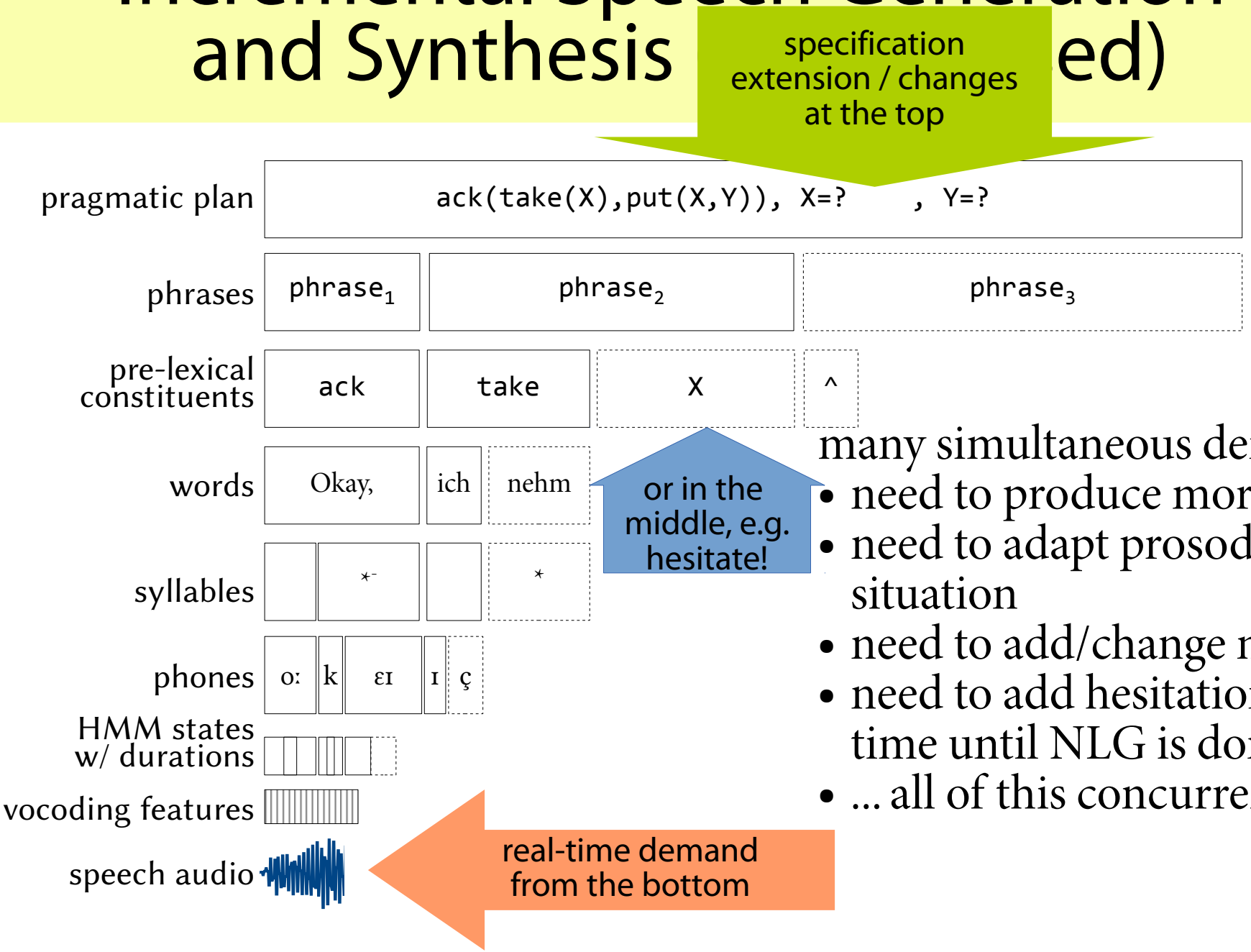

many simultaneous demands:

- need to produce more speech
- need to adapt prosody to situation
- need to add/change material
- need to add hesitation to span time until NLG is done
- ... all of this concurrently

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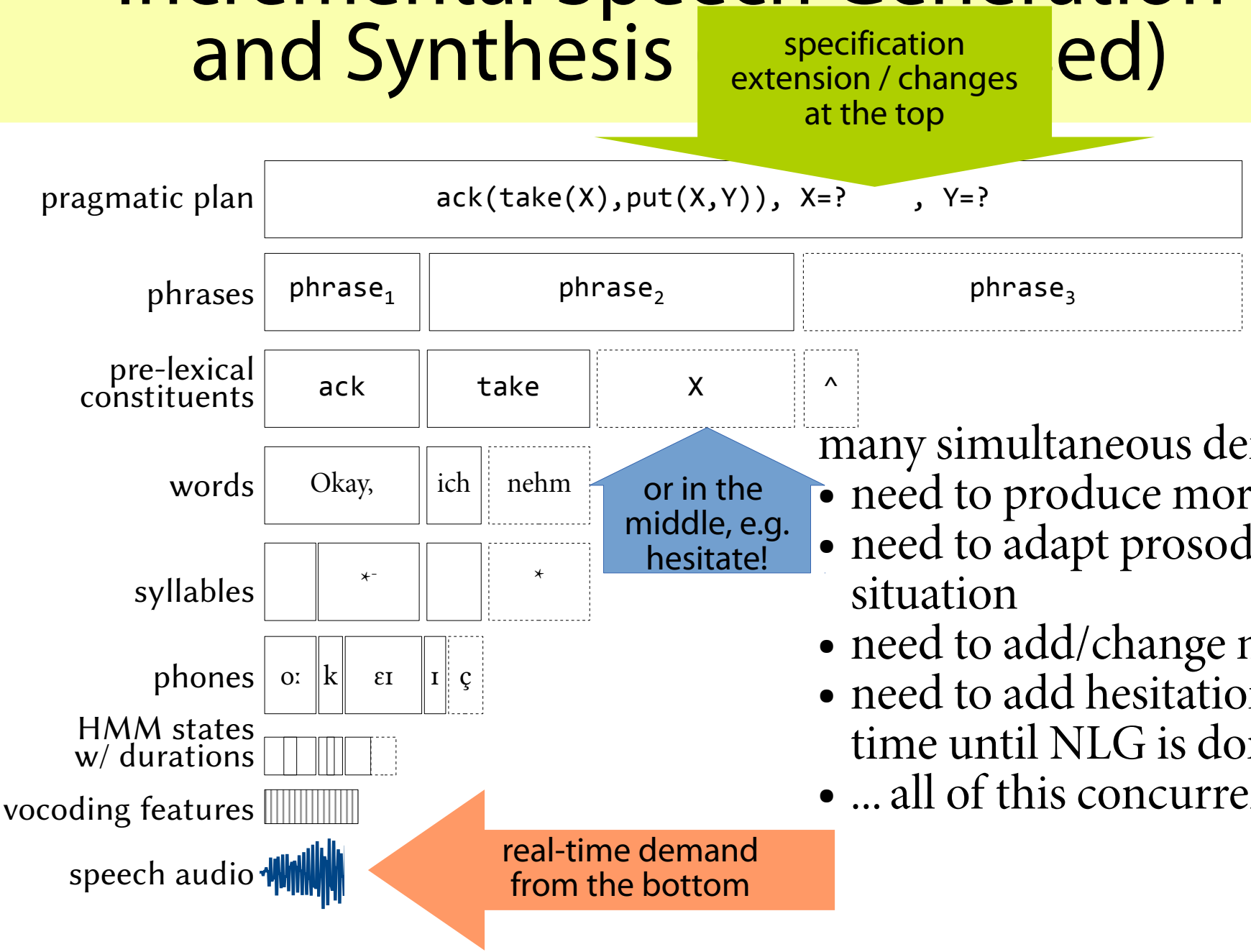

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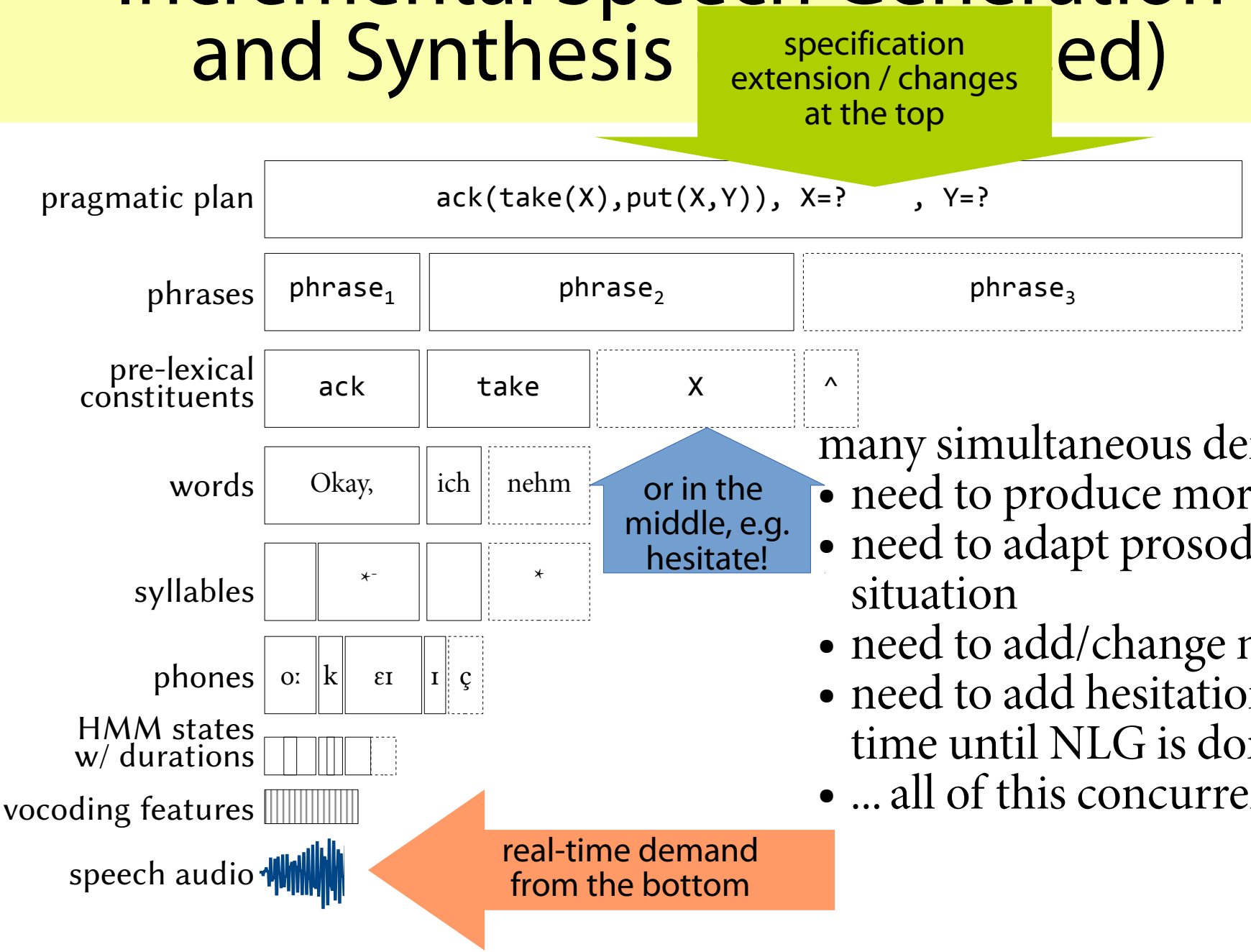

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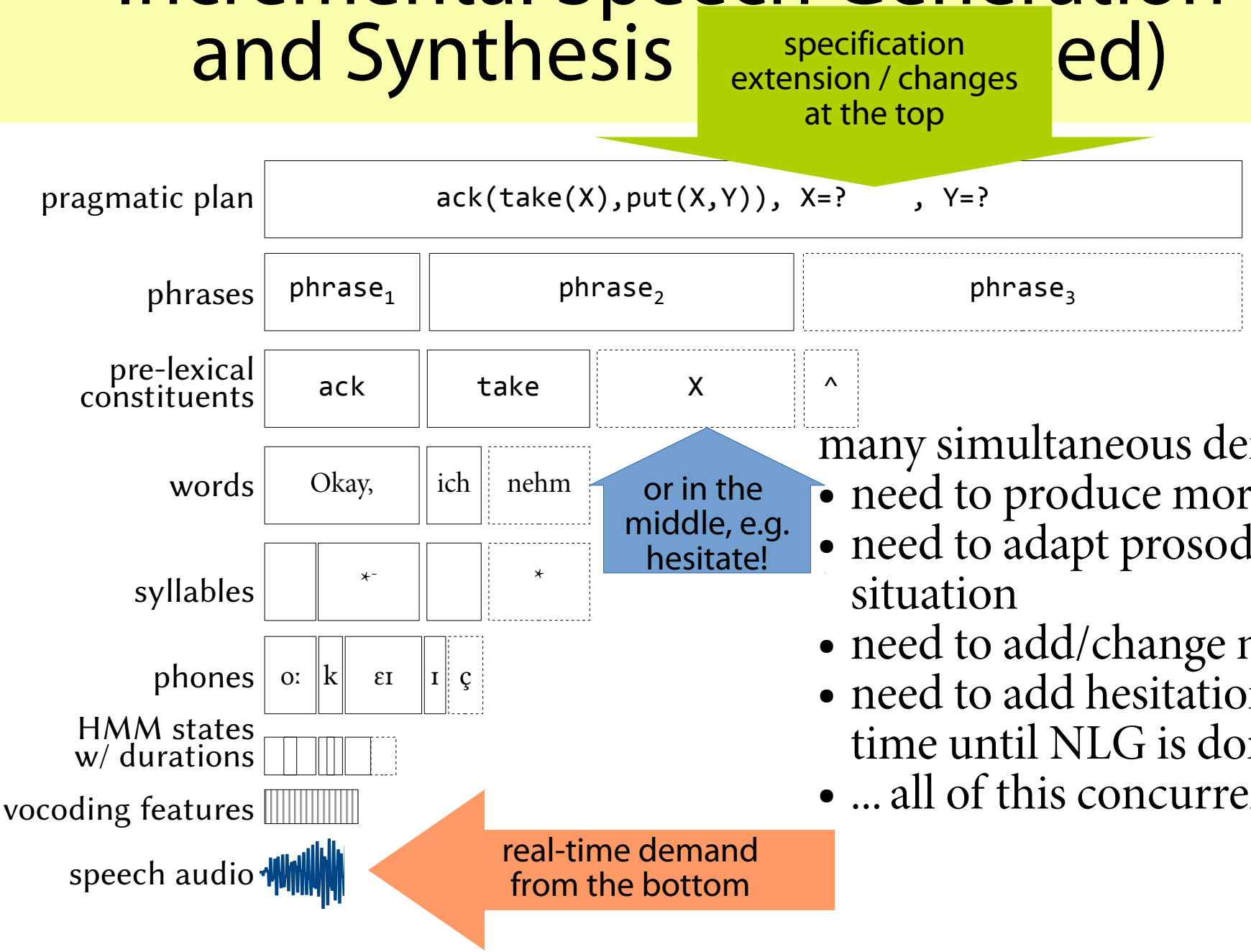

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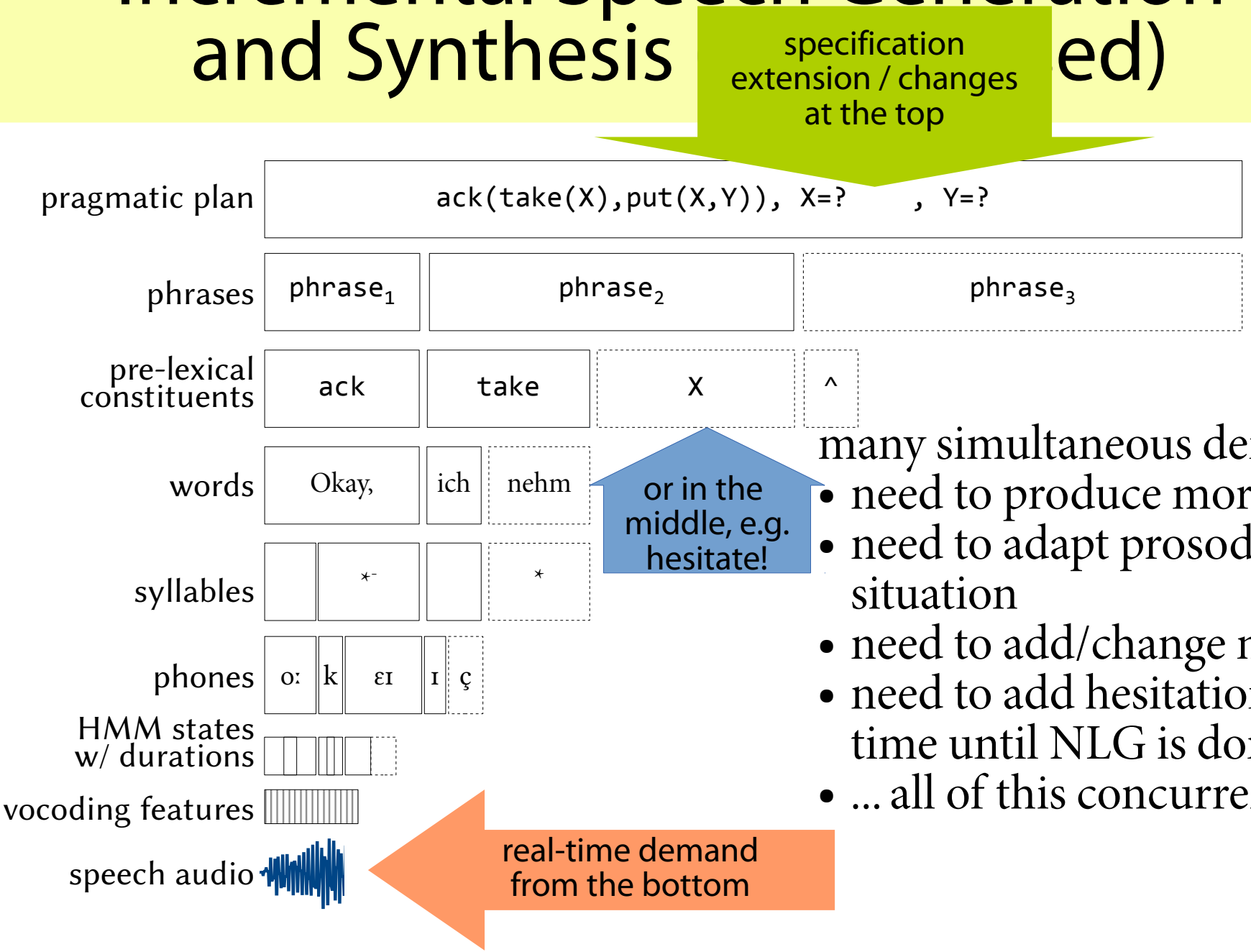

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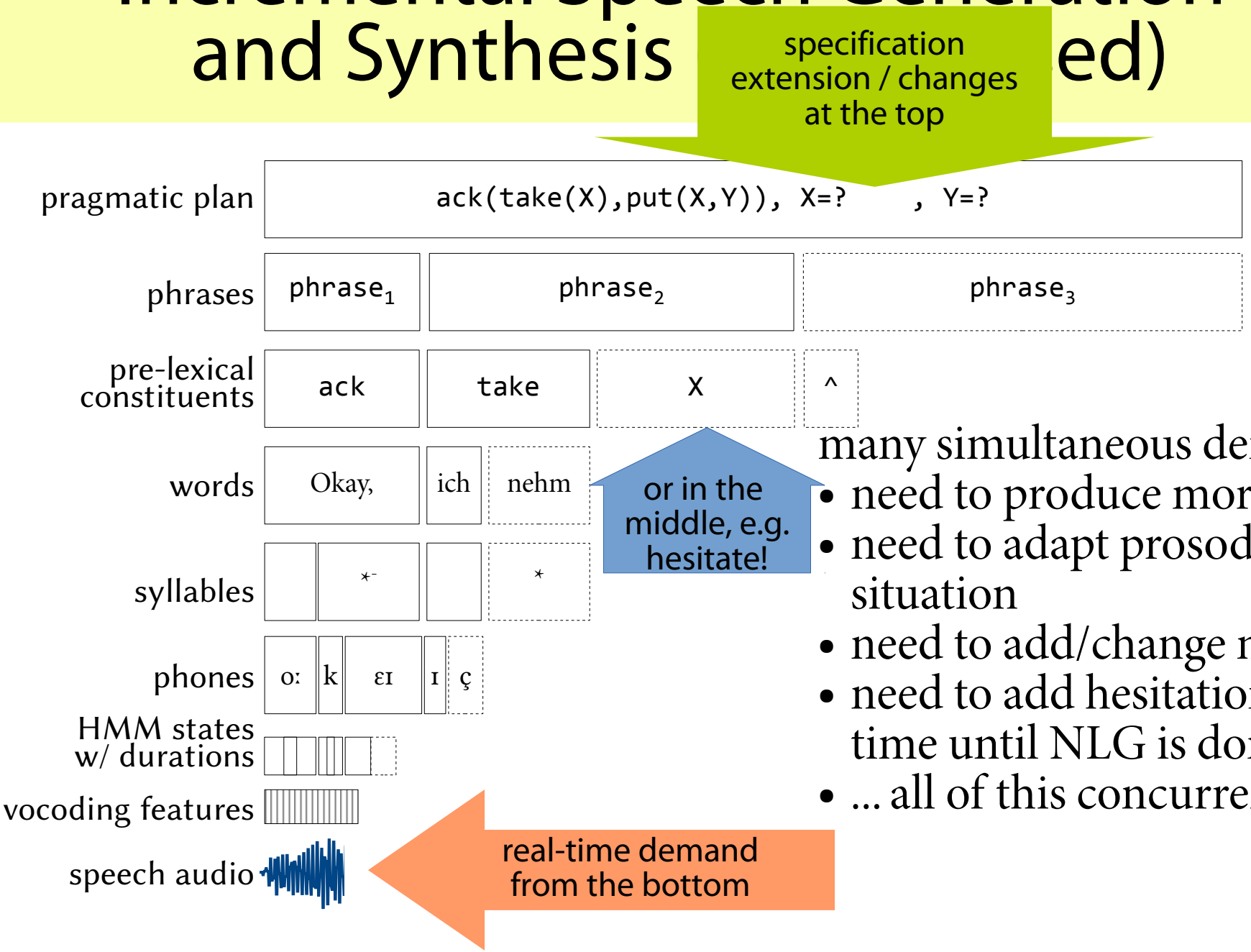

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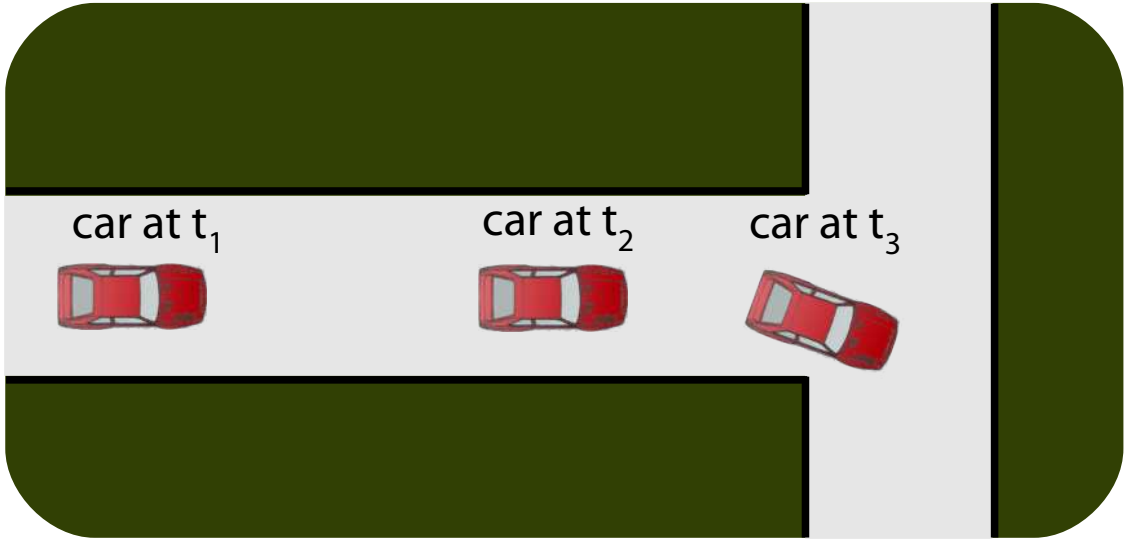
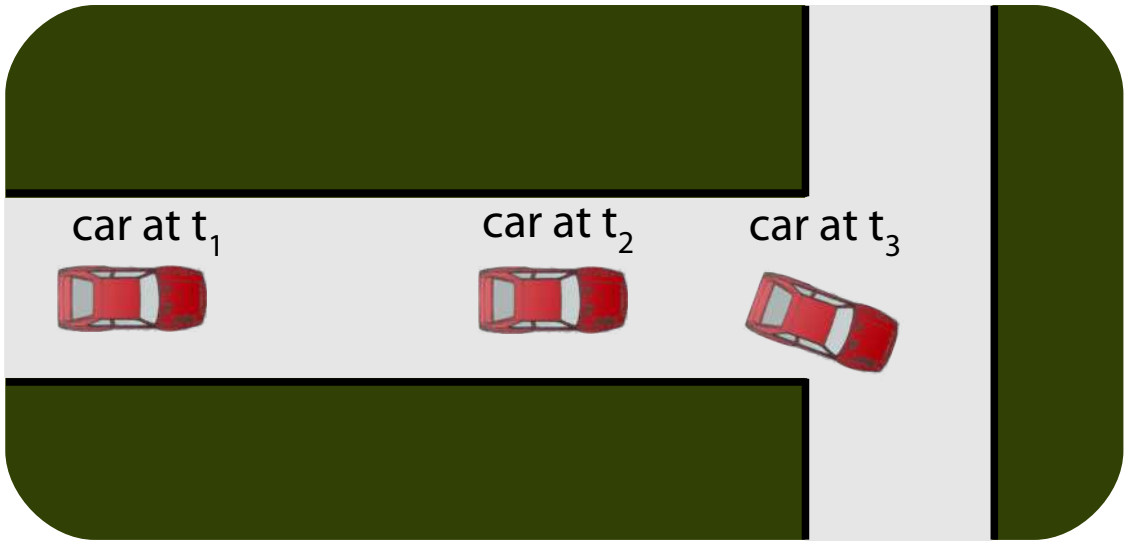
Breaking
NEWS

Acting in Dynamic Environments

- dynamic environment changes quickly
  - rate of notable events is high – too high to generate one descriptive utterance per event
- events need to be combined into complex utterances



Acting Incrementally



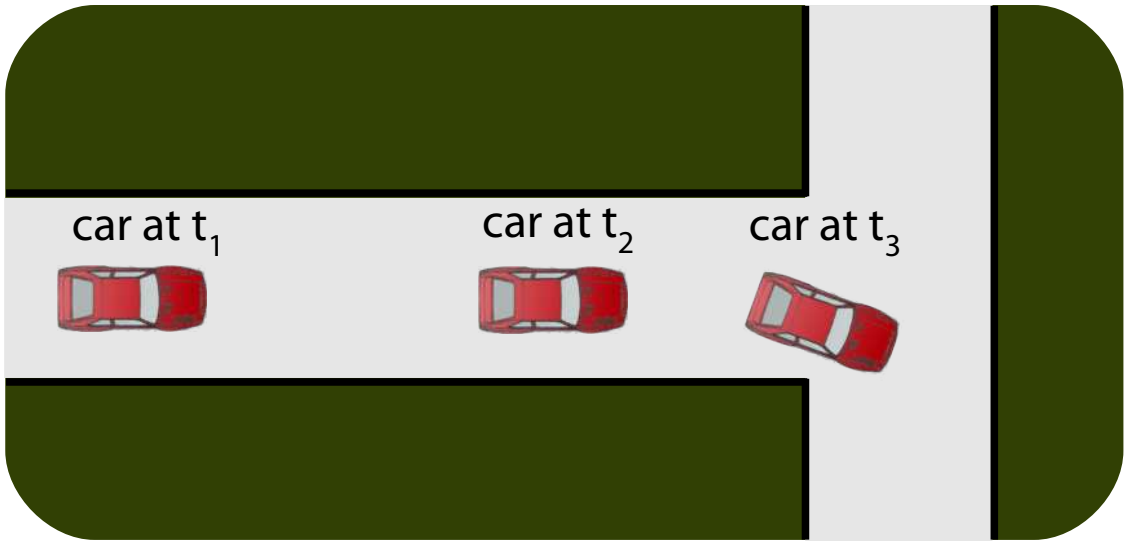
- at t_1: car drives along street
- at t_2: the car is *likely* to turn
- at t_3: car is turning right

"The car drives along X-street.

...X-street, and then turns...

...right into Y-street."

Acting Incrementally



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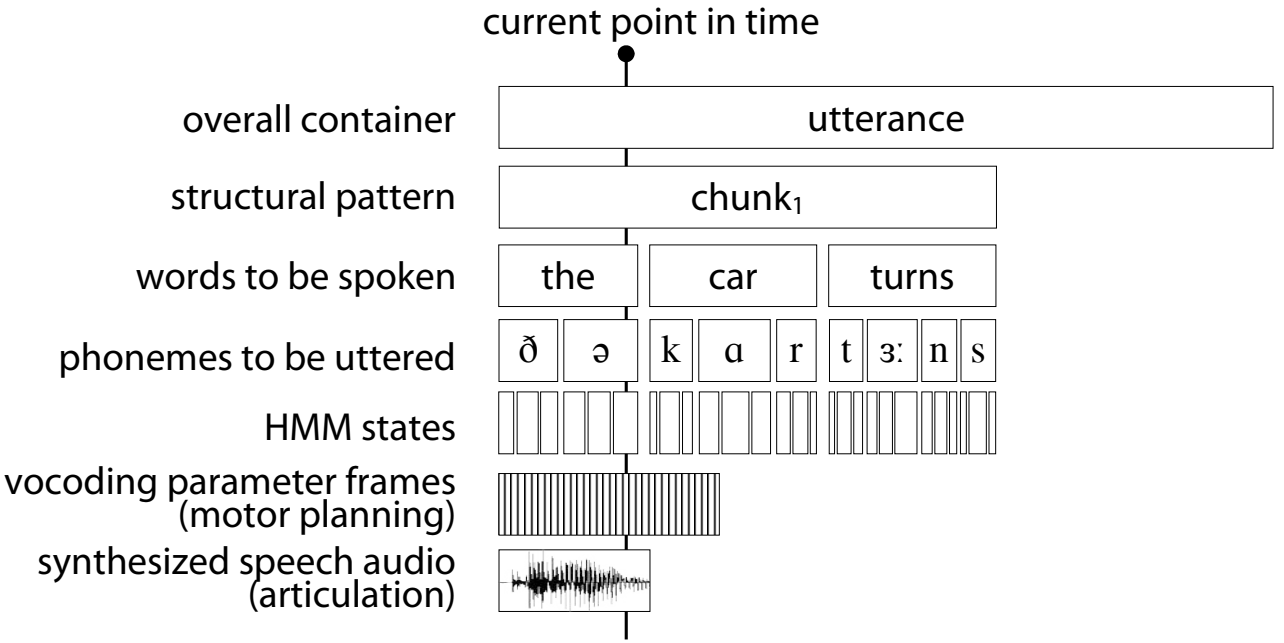
...right into Y-street."

prosody must be adapted!

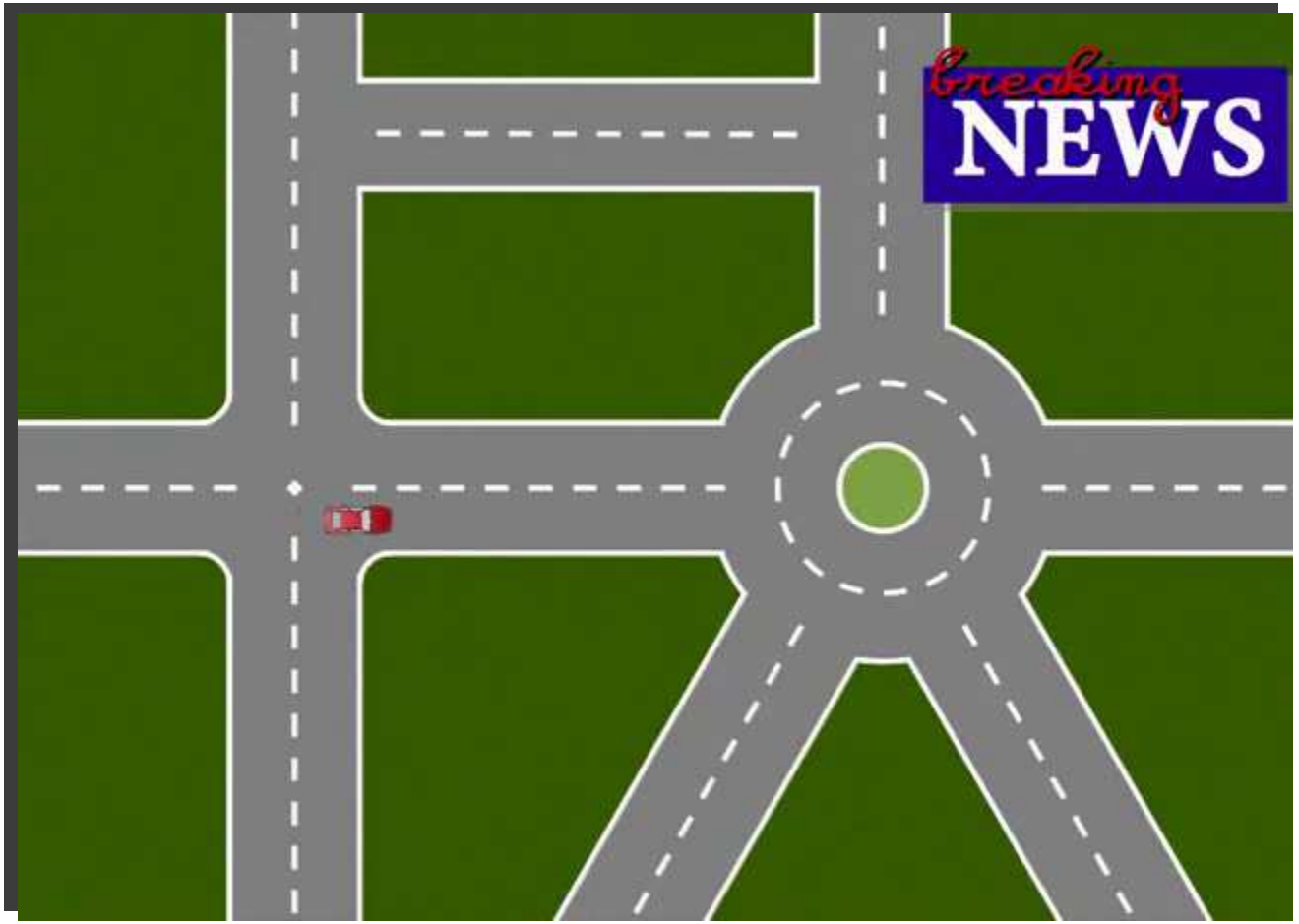
Acting Incrementally: Challenges

- *piece-meal input*: phrases or individual words
  - conventional speech synthesis assumes full utterances
- phrases have to be *connected prosodically*
- processing should occur *just-in-time*



given that incremental speech synthesis
measurable degrades prosodic parameters –
→ does this degradation matter to listeners?

Standard behaviour



Incremental behaviour (taking expectations into account)

Experiment

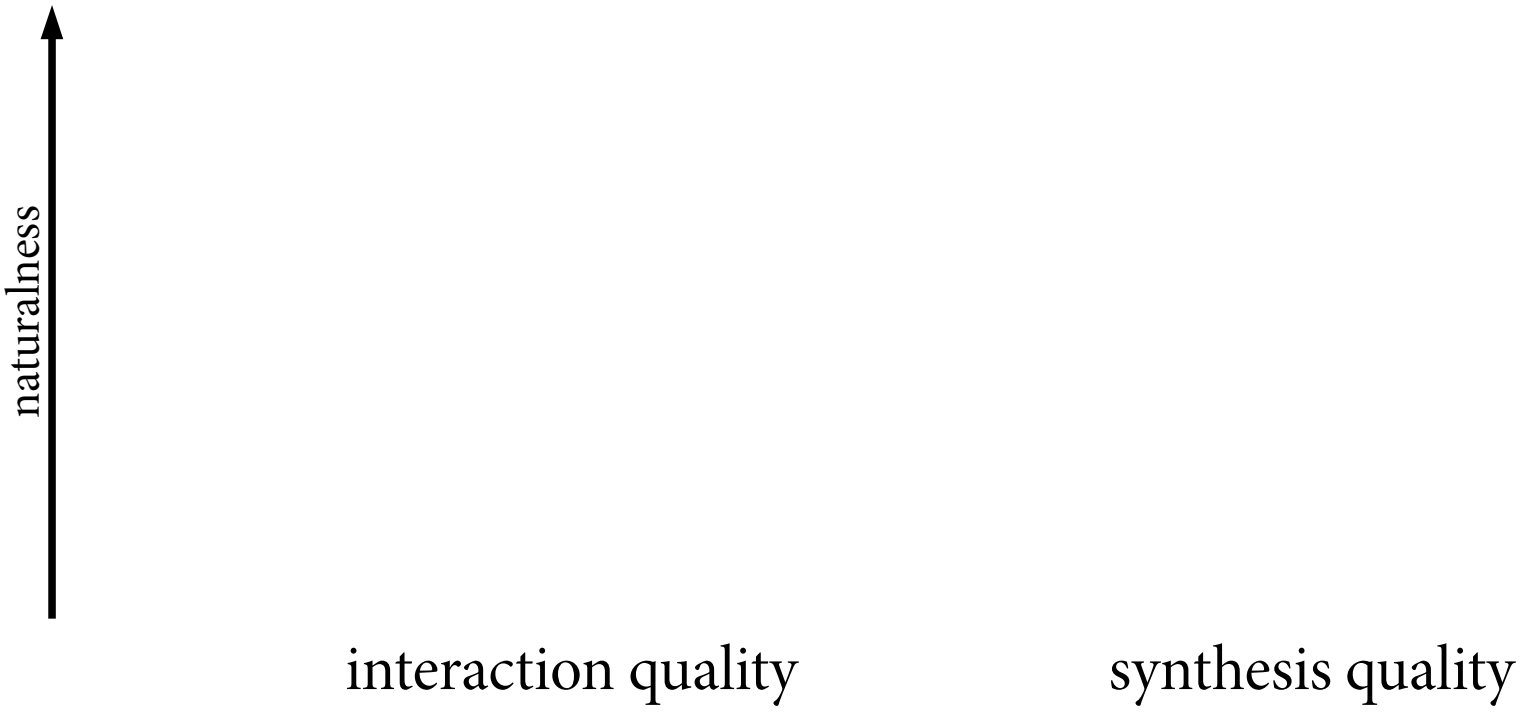
- incremental system vs. baseline system
- 9 settings in the CarChase domain
- 9 subjects were asked to rate (5-point Likert)
  - naturalness of verbalization (to capture interactional adequacy)
  - naturalness of *pronunciation* (to capture synthesis quality)
- results in 81 paired samples

- incremental processing implemented in InproTK, using speech synthesis technology from MaryTTS

InproTK: Baumann&Schlangen, SDCTD 2012; MaryTTS: Schröder&Trouvain, IJST 2003.

Expected results

- we were hoping for a good trade-off:



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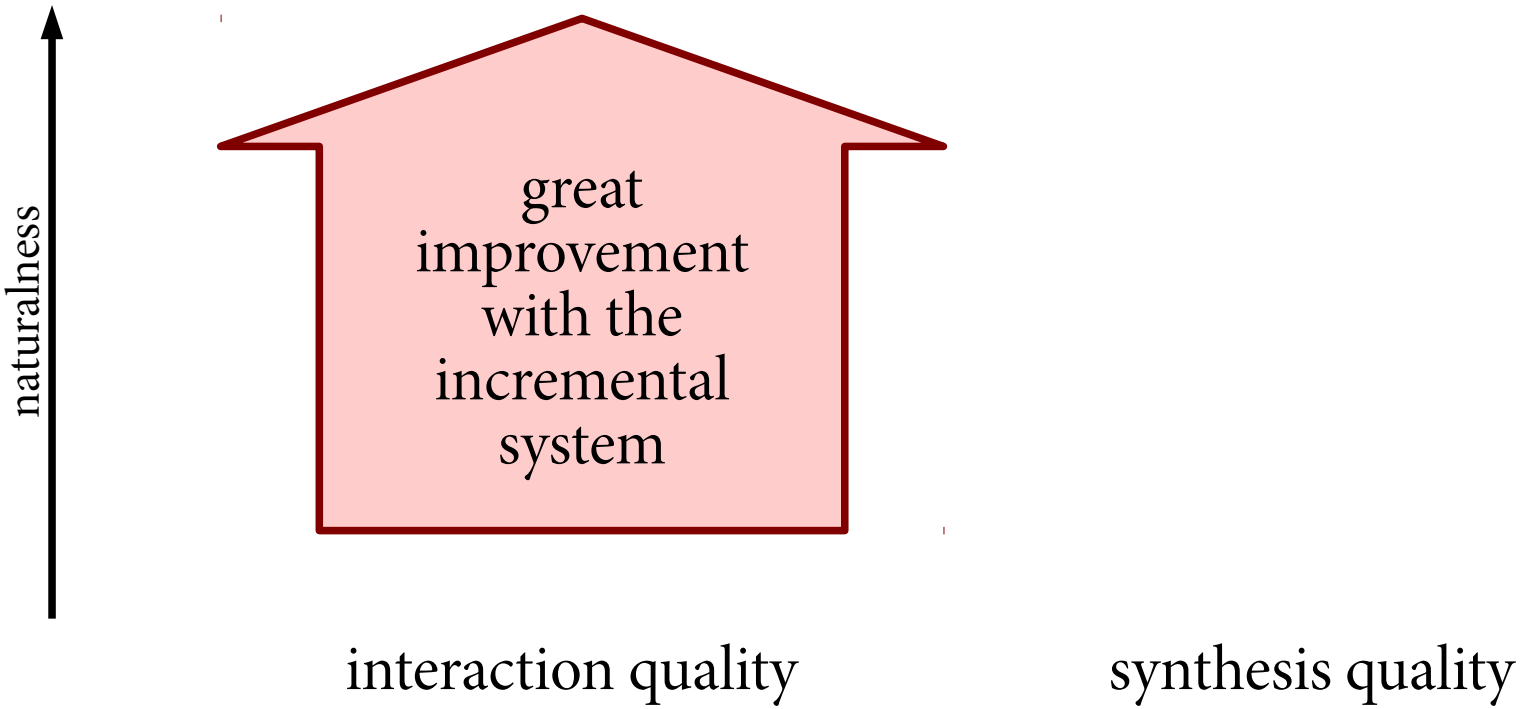

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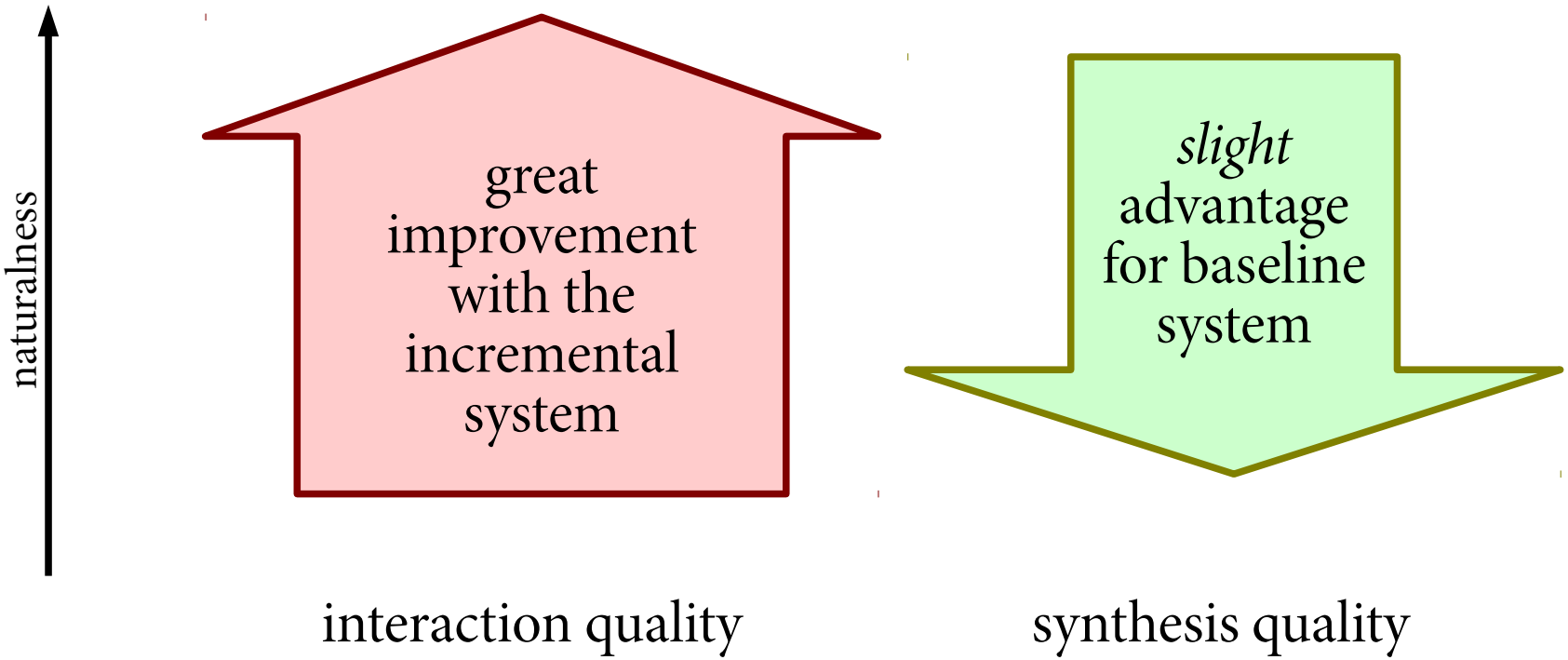

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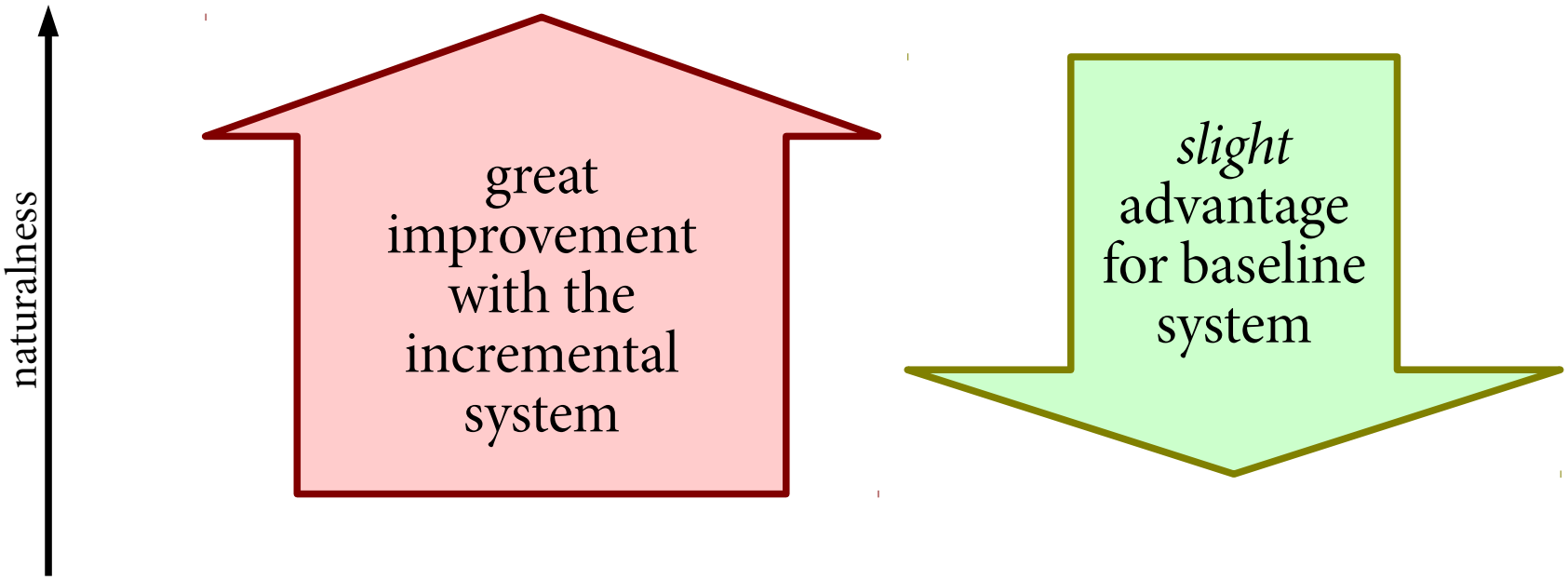
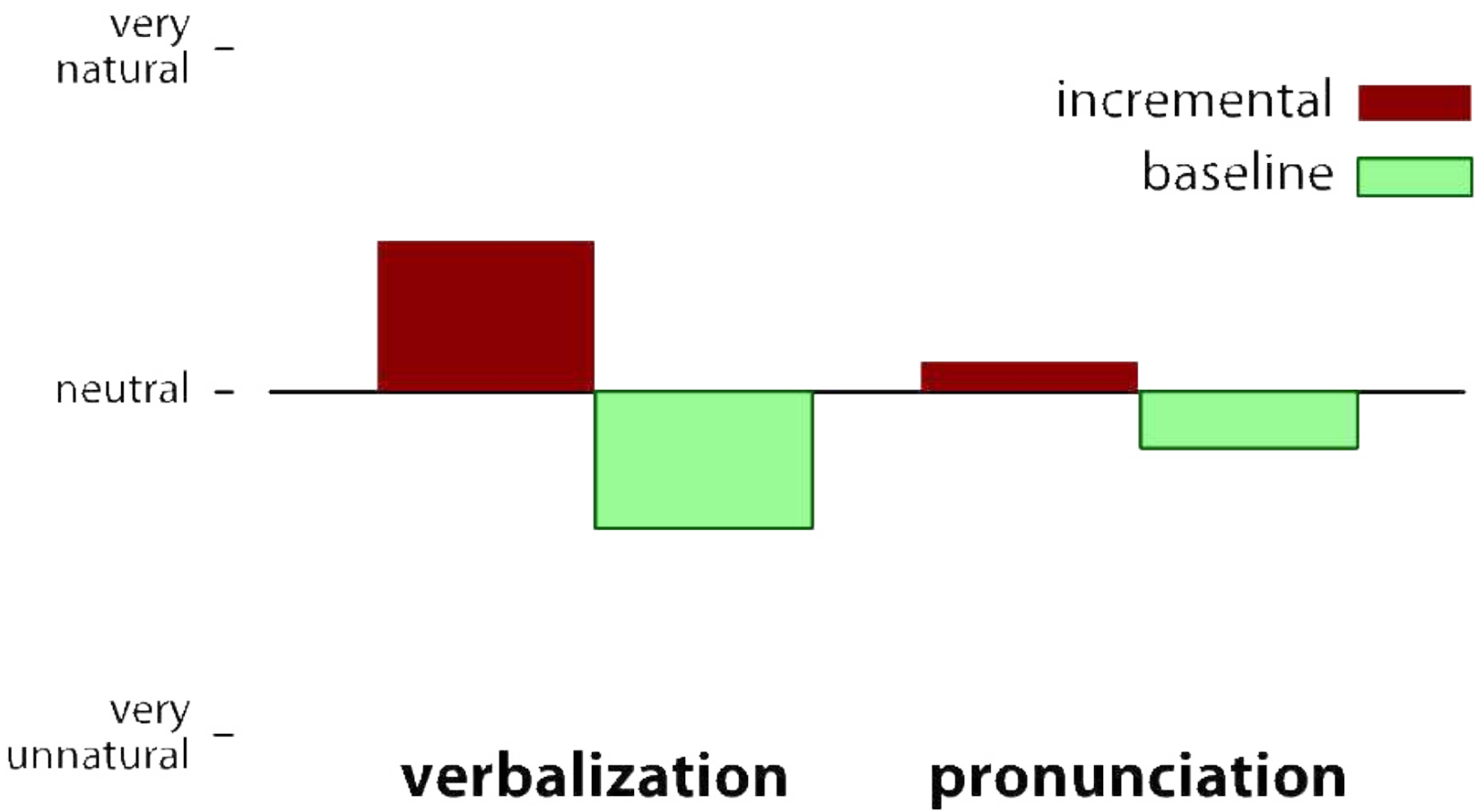
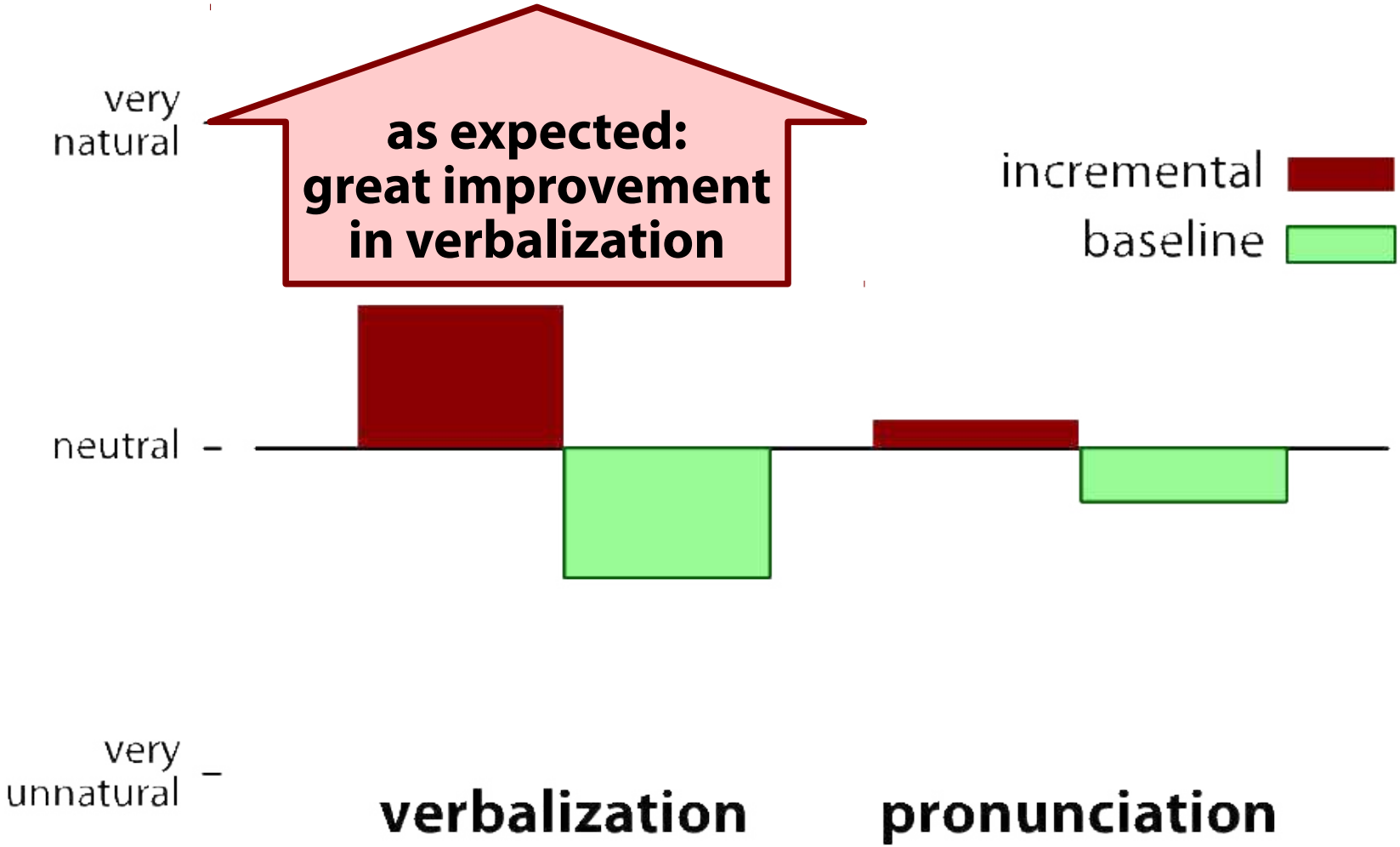


→ write paper: „Trade-off between incrementality of behaviour and speech synthesis quality“

Actual results



Actual results



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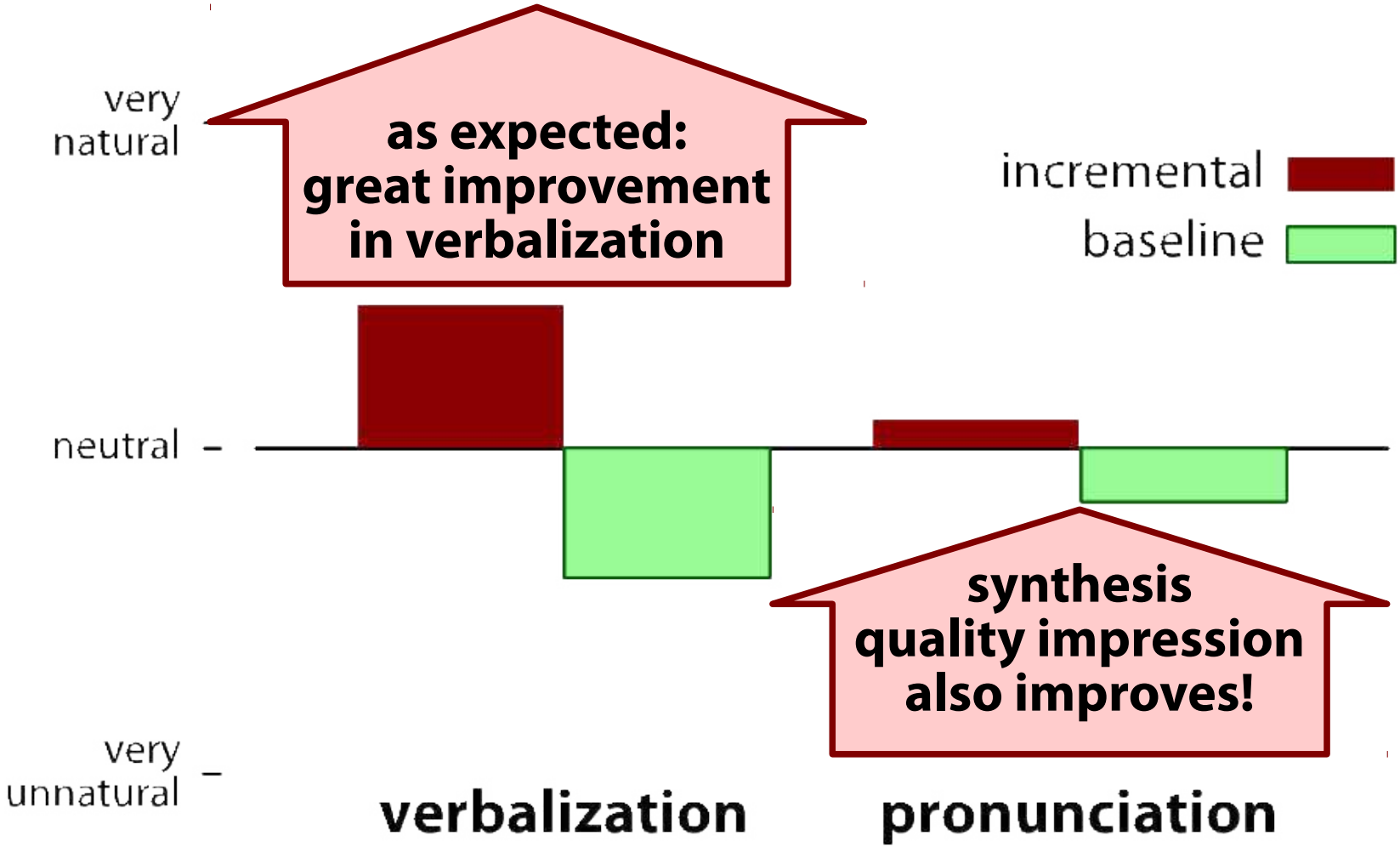


Pronunciation ratings

- Incremental processing cannot have systematically improved synthesis quality
  - incremental synthesis was previously shown to lead to a slight quality degradation (Dutoit et al., 2011)
- but:
  naïve listeners do not distinguish between interaction and synthesis quality (Pearson's r = .537)
- verbalization/wording adequacy seems to outweigh pronunciation/synthesis quality

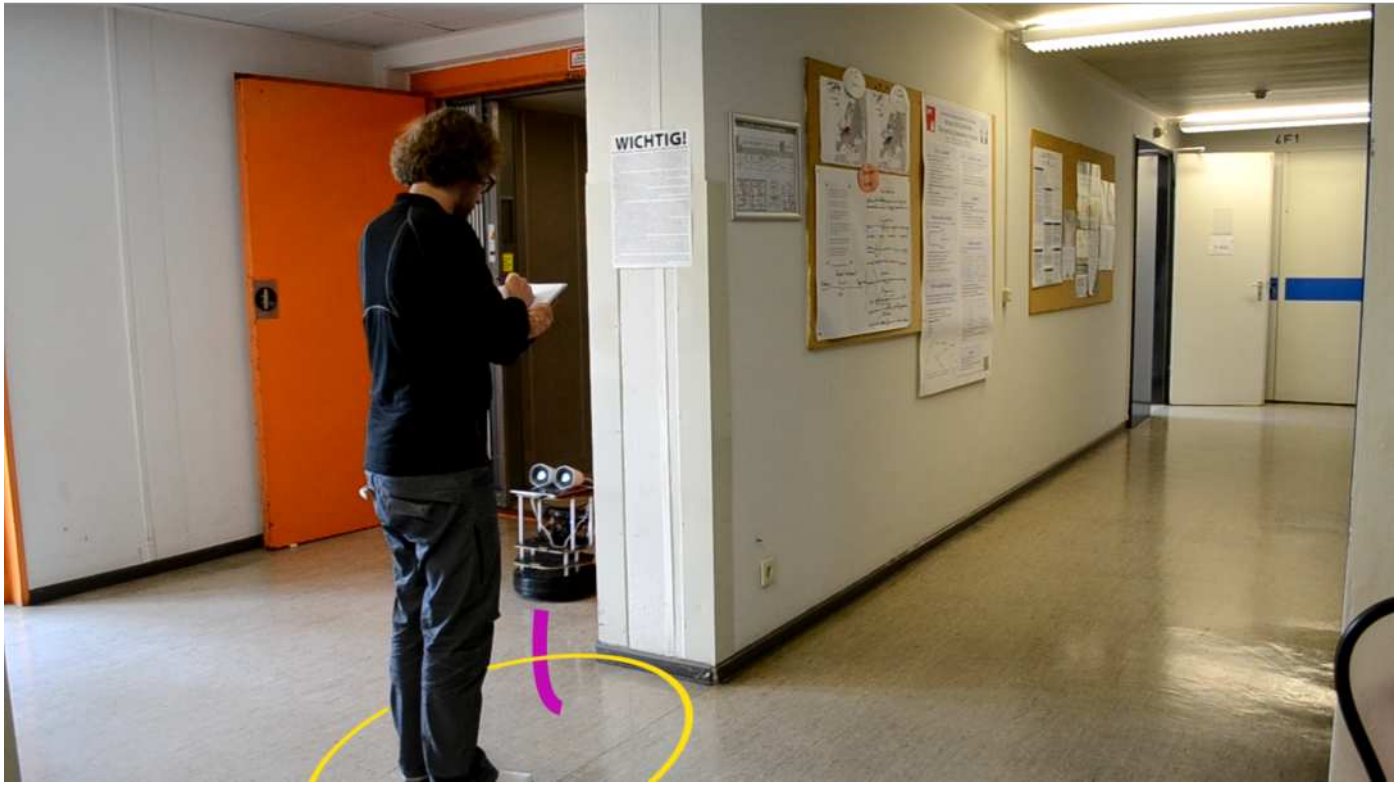
Conclusions: Incremental speech output

- adequate verbalization / wording in a given context
  - may be more important than synthesis quality
  - may even lead to better synthesis quality ratings!
  - despite somewhat reduced quality

➔ you need to find out what really matters for the users of your application!

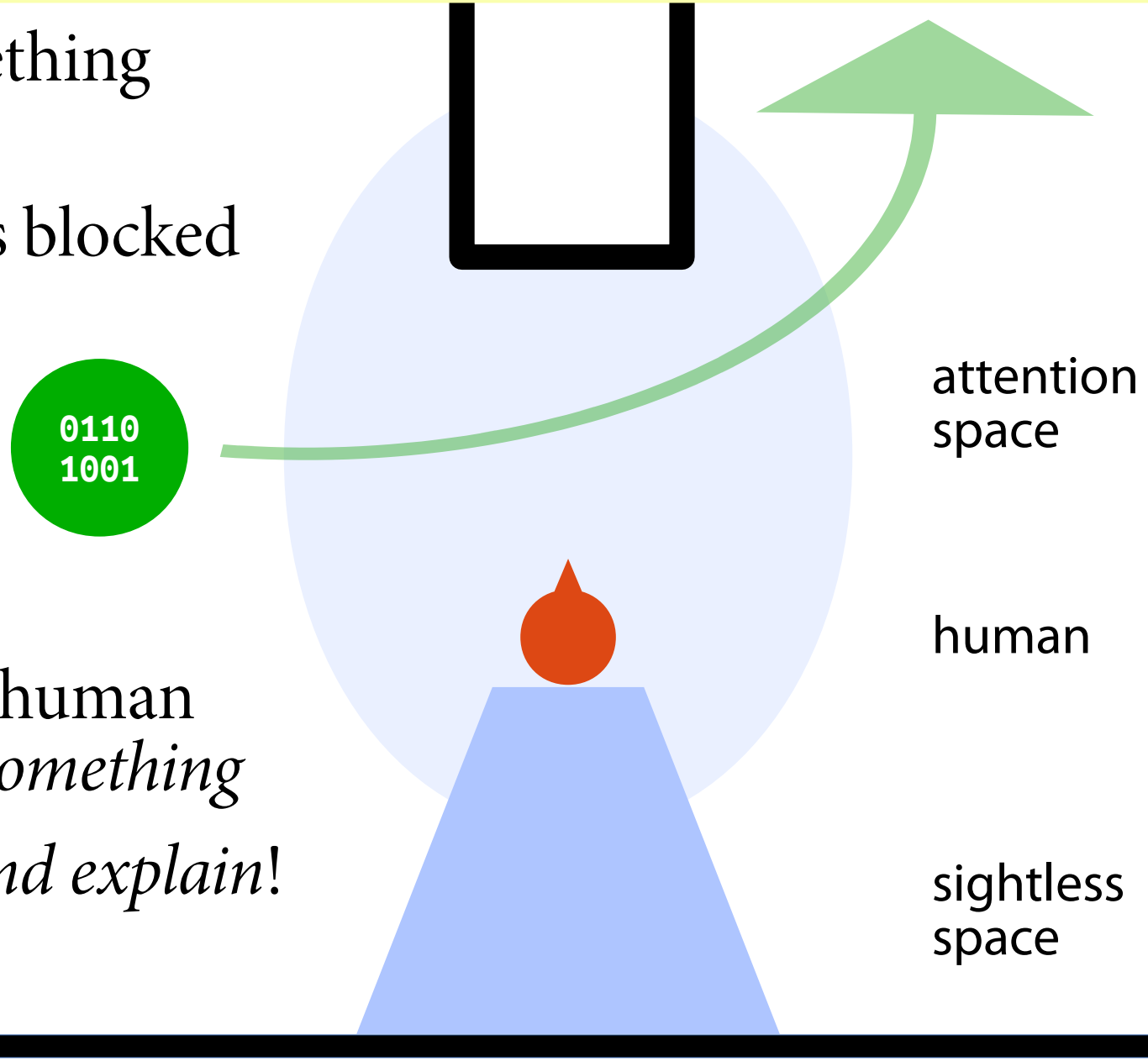
Incremental speech output in social robot navigation

- personal space intrusion:
  dispreferred but sometimes necessary



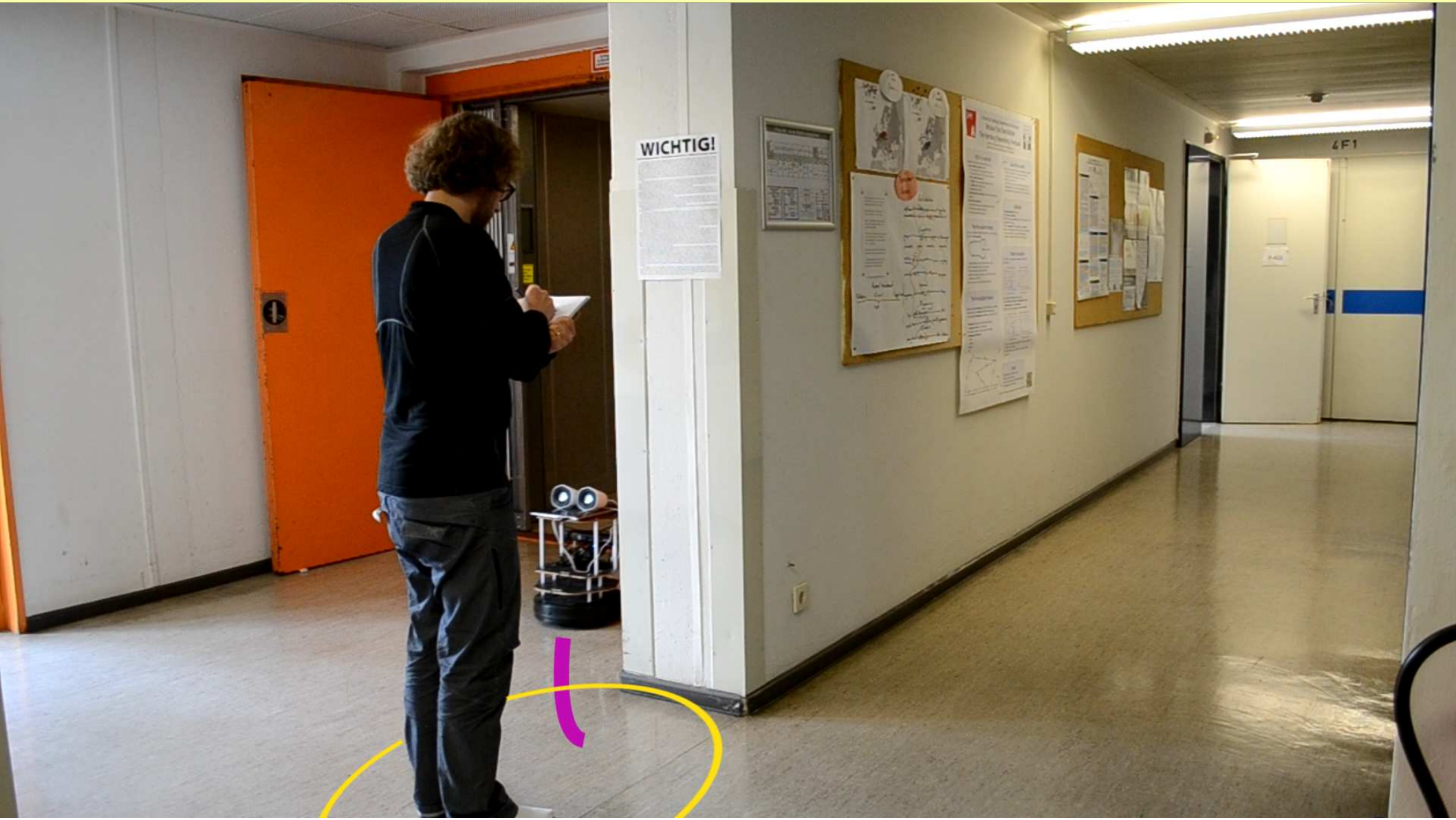
Personal Space Intrusion

- human reads something in front of her
- space behind her is blocked



- impossible to pass human without violating *something*
- at least *apologize and explain*!

Example



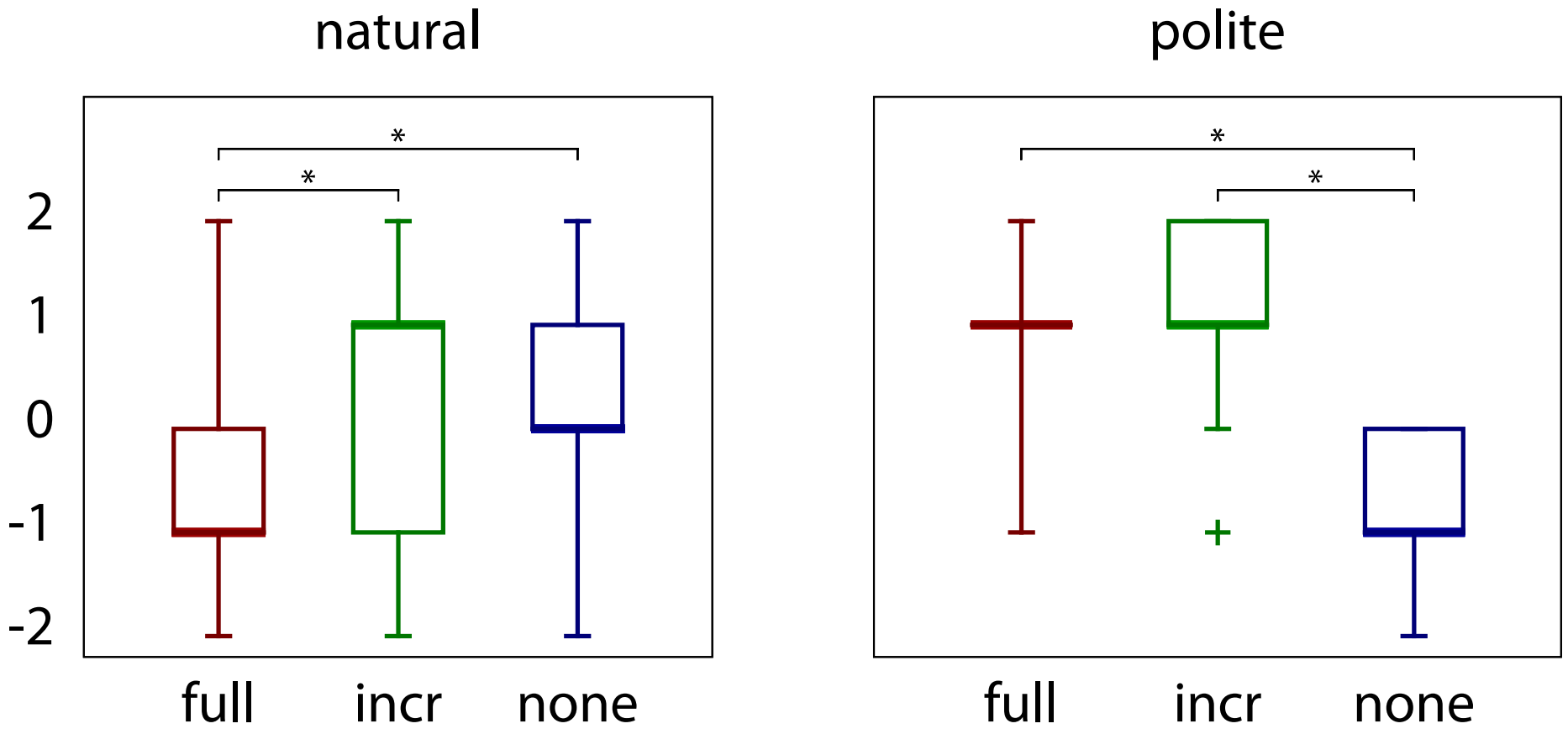

WICHTIG!

Controlled study

- simulated robot environment
- different robot speed/human movement conditions
- three speaking conditions:
  - silent
  - apologize, explain and thank when entering the personal space
    → what if we only touch the personal space briefly?
  - skip forward to „thank you“ when we exit the personal space

- 13 students, 12 videos, three questions:
  robot naturalness, politeness, route&speed

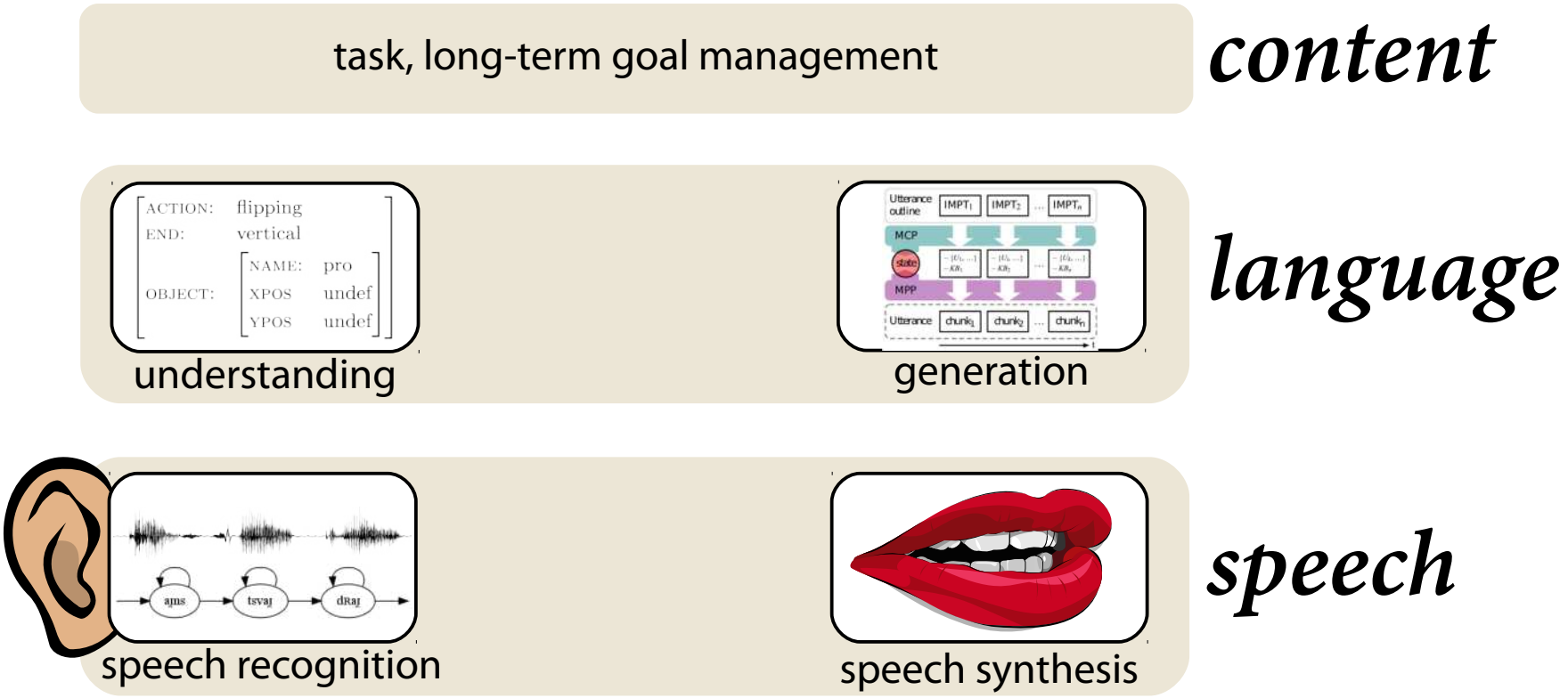
Results



- we find that the incremental speech production strategy is both natural and polite.

Langzeitperspektive auf Incrementalität und Integration

- "Stratifikation" der Abstraktionsebenen ermöglicht fortgeschrittene konversationale Fähigkeiten



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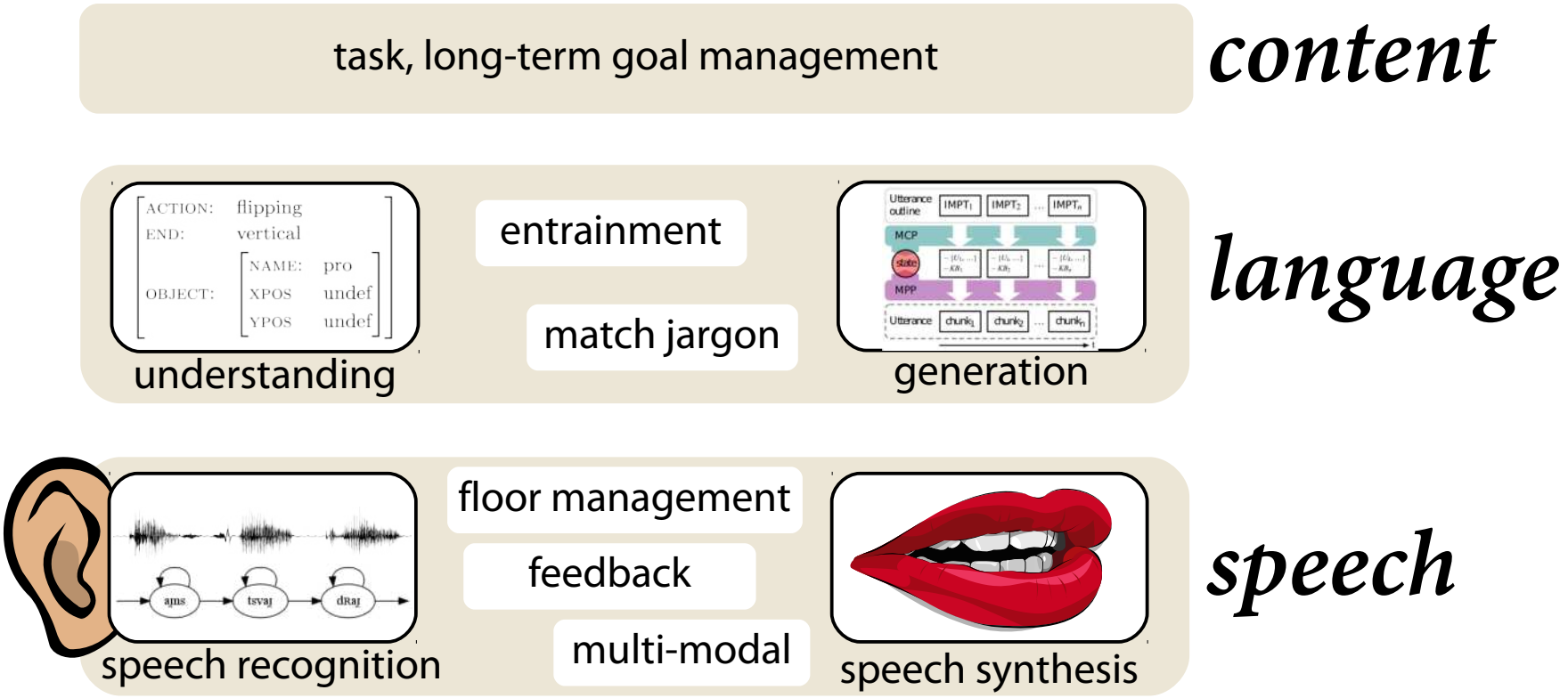

Zusammenfassung

- **Responsivität** und **Flexibilität** sind Schlüsselaspekte erfolgreicher gesprochensprachlicher Interaktion
- **incrementelle/schritthaltendeVerarbeitung** ermöglicht Responsivität
  - Aktionen basierend auf partieller Information
  - flexible Abänderung geplanter und laufender Aktionen
- Verarbeitungsparadigmen und Schnittstelen müssen für inkrementelle Verarbeitung angepasst werden

Vielen Dank für Ihre Aufmerksamkeit.

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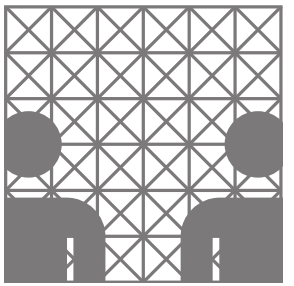

weitere Literatur

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- Incremental Speech Recognition, Speech Synthesis, Architecture:
  - Baumann (2013): *Incremental Spoken Dialogue Processing: Architecture and Lower-level Components*. PhD thesis, U Bielefeld, Germany.
- Evaluating Incremental Processing
  - Baumann et al. (2011): "Evaluation and Optimisation of Incremental Processors", *Dialogue & Discourse* **2**(1).
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  - Baumann et al. (2013): "Using Affordances to Shape the Interaction in a Hybrid Spoken Dialogue System", *Proceedings of ESSV 2013*, TUD Press.

Raum für Notizen

Lernziele

Studierende

- ... verstehen die zwei Zeitdimensionen, die in der inkrementellen Verarbeitung betrachtet werden
- ... kennen das Konzept inkrementeller Einheiten
- ... verstehen den Vorteil, partielle und vorläufige Hypothesen systematisch zu handhaben
- ... können inkrementelle Verarbeitung auf diversen linguistischen Ebenen mit Problemen der Mensch-Computer-Interaktion in Beziehung setzen