5. Forms of Thinking

5.1 Retrieving Answers to Questions

5.1.1 Example of a token line

owner record *member records*

$$[\text{noun: } girl] \quad \begin{bmatrix}\text{noun: girl}\\ \text{fnc: walk}\\ \text{mdr: young}\\ \text{prn: 10}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: sleep}\\ \text{mdr: blond}\\ \text{prn: 12}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: eat}\\ \text{mdr: small}\\ \text{prn: 15}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: read}\\ \text{mdr: smart}\\ \text{prn: 19}\end{bmatrix}$$

5.1.2 Definition of **LA-think.LINE**

ST_S: $\{([\text{RA.1: } \alpha]\{1\ \text{r}_{forwd}\ 2\ \text{r}_{bckwd}\})\}$

r_{forwd} $\begin{bmatrix}\text{RA.1: } \alpha\\ \text{prn: } n\end{bmatrix} \begin{bmatrix}\text{RA.1: } \alpha\\ \text{prn: } n\text{+}1\end{bmatrix}$ output position nw $\{\text{r}_{forwd}\}$

r_{bckwd} $\begin{bmatrix}\text{RA.1: } \alpha\\ \text{prn: } n\end{bmatrix} \begin{bmatrix}\text{RA.1: } \alpha\\ \text{prn: } n\text{-}1\end{bmatrix}$ output position nw $\{\text{r}_{bckwd}\}$

ST_F: $\{([\text{RA.1: } \alpha]\ \text{rp}_{forwd}), ([\text{RA.1: } \alpha]\ \text{rp}_{bckwd})\}$

5.1.3 Example of an **LA-think.LINE** rule application

	rule name	*ss pattern*	*nw pattern*	*operations*	*rule package*
rule level	r$_{forwd}$:	$\begin{bmatrix}\text{RA.1: } \alpha \\ \text{prn: n}\end{bmatrix}$	$\begin{bmatrix}\text{RA.1: } \alpha \\ \text{prn: n+1}\end{bmatrix}$	output position nw	{r$_{forwd}$}
proplet level		$\begin{bmatrix}\text{noun: girl} \\ \text{fnc: sleep} \\ \text{mdr: blonde} \\ \text{prn: 12}\end{bmatrix}$			

5.1.4 Result of the **LA-think.LINE** rule application

$$\begin{bmatrix}\text{noun: girl} \\ \text{fnc: sleep} \\ \text{mdr: blonde} \\ \text{prn: 12}\end{bmatrix} \begin{bmatrix}\text{noun: girl} \\ \text{fnc: eat} \\ \text{mdr: small} \\ \text{prn: 15}\end{bmatrix}$$

5.1.5 BASIC KINDS OF QUERY IN NATURAL LANGUAGE

wh-question	*yes/no-question*
Which girl walked?	Did the young girl walk?

5.1.6 SEARCH PROPLETS ILLUSTRATING THE TWO BASIC TYPES OF QUESTIONS

wh-question   *yes/no-question*

$$\begin{bmatrix}\text{noun:}\textit{girl}\\ \text{fnc: walk}\\ \text{mdr: }\sigma\\ \text{prn: }n\end{bmatrix} \qquad \begin{bmatrix}\text{noun:}\textit{girl}\\ \text{fnc: walk}\\ \text{mdr: young}\\ \text{prn: }n\end{bmatrix}$$

5.1.7 WH-SEARCH PATTERN CHECKING A TOKEN LINE

$$\begin{bmatrix}\text{noun:}\textit{girl}\\ \text{fnc: walk}\\ \text{mdr: }\sigma\\ \text{prn: n}\end{bmatrix} \quad \textit{search pattern}$$

matching?

$$\begin{bmatrix}\text{noun: }\textit{girl}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: walk}\\ \text{mdr: young}\\ \text{prn: 10}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: sleep}\\ \text{mdr: blonde}\\ \text{prn: 12}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: eat}\\ \text{mdr: small}\\ \text{prn: 15}\end{bmatrix} \begin{bmatrix}\text{noun: girl}\\ \text{fnc: read}\\ \text{mdr: smart}\\ \text{prn: 19}\end{bmatrix} \quad \textit{token line}$$

5.1.8 Definition of LA-think.Q1 (*wh-question*)

$$\mathrm{ST}_S\text{: } \{ \left(\begin{bmatrix} \text{noun: RV.1} \\ \neg\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n \end{bmatrix} \{\mathrm{r}_1, \mathrm{r}_2\} \right), \left(\begin{bmatrix} \text{noun: RV.1} \\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n \end{bmatrix} \{\ \} \right) \}$$

$$\mathrm{r}_1\text{: } \begin{bmatrix} \text{noun: RV.1} \\ \neg\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n \end{bmatrix} \begin{bmatrix} \text{noun: RV.1} \\ \neg\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n\text{-}1 \end{bmatrix} \text{ output position nw } \{\mathrm{r}_1\ \mathrm{r}_2\}$$

$$\mathrm{r}_2\text{: } \begin{bmatrix} \text{noun: RV.1} \\ \neg\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n \end{bmatrix} \begin{bmatrix} \text{noun: RV.1} \\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n\text{-}1 \end{bmatrix} \text{ output position nw } \{\ \}$$

$$\mathrm{ST}_F\text{: } \{ \left(\begin{bmatrix} \text{noun: RV.1} \\ \neg\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n\text{-}1 \end{bmatrix} \mathrm{rp}_1 \right), \left(\begin{bmatrix} \text{noun: RV.1} \\ \text{fnc: RV.2} \\ \text{mdr: } \sigma \\ \text{prn: } n\text{-}1 \end{bmatrix} \mathrm{rp}_2 \right) \}$$

5.1.9 DEFINITION OF **LA-think.Q2** (*yes/no-question*)

$$\mathrm{ST}_S\text{: }\{(\begin{bmatrix}\text{noun: RV.1}\\ \neg\text{ fnc: RV.2}\\ \neg\text{ mdr: RV.3}\\ \text{prn: }n\end{bmatrix}\{\mathrm{r}_1, \mathrm{r}_2\}),\ (\begin{bmatrix}\text{noun: RV.1}\\ \text{fnc: RV.2}\\ \text{mdr: RV.3}\\ \text{prn: }n\end{bmatrix}\{\ \})\ \}$$

$$\mathrm{r}_1\text{: }\begin{bmatrix}\text{noun: RV.1}\\ \neg\text{ fnc: RV.2}\\ \neg\text{ mdr: RV.3}\\ \text{prn: }n\end{bmatrix}\begin{bmatrix}\text{noun: RV.1}\\ \neg\text{ fnc: RV.2}\\ \neg\text{ mdr: RV.3}\\ \text{prn: }n\text{-}1\end{bmatrix}\quad\text{output position nw}\ \ (\{\mathrm{r}_1\ \mathrm{r}_2\})$$

$$\mathrm{r}_2\text{: }\begin{bmatrix}\text{noun: RV.1}\\ \neg\text{ fnc: RV.2}\\ \neg\text{ mdr: RV.3}\\ \text{prn: }n\end{bmatrix}\begin{bmatrix}\text{noun: RV.1}\\ \text{fnc: RV.2}\\ \text{mdr: RV.3}\\ \text{prn: }n\text{-}1\end{bmatrix}\quad\text{output position nw}\ \ (\{\ \})$$

$$\mathrm{ST}_F\text{: }\{(\begin{bmatrix}\text{noun: RV.1}\\ \neg\text{ fnc: RV.2}\\ \neg\text{ mdr: RV.3}\\ \text{prn: }n\text{-}1\end{bmatrix}\ \mathrm{rp}_1),\ (\begin{bmatrix}\text{noun: RV.1}\\ \text{fnc: RV.2}\\ \text{mdr: RV.3}\\ \text{prn: }n\text{-}1\end{bmatrix}\ \mathrm{rp}_2)\ \}$$

5.2 Episodic versus Absolute Propositions

5.2.1 Absolute and episodic proplets in a Word Bank (context level)

owner records		*absolute proplets*		*episodic proplets*
[noun: animal]	. . .	[noun: animal fnc: is mdr: prn: a-11]		
[verb: be]	. . .	[verb: be arg: dog animal mdr: prn: a-11]	. . .	[verb: be arg: dog mdr: tired prn: e-23]
[noun: dog]	. . .	[noun: dog fnc: be mdr: prn: a-11]	. . .	[noun: dog fnc: be mdr: prn: e-23]
[adj: tired]	. . .		. . .	[adj: tired mdd: be mdr: prn: e-23]

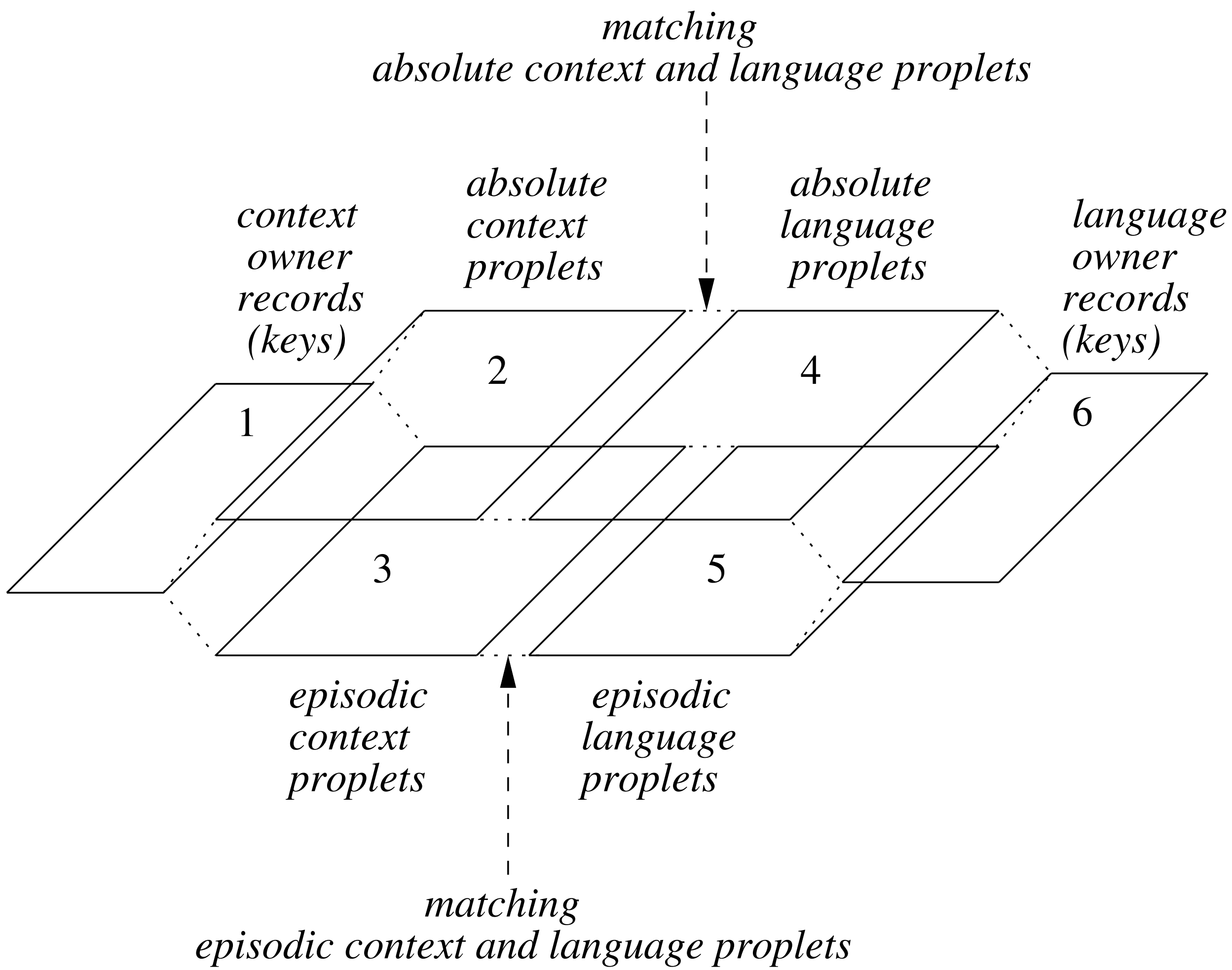
5.2.2 Core values as concept types and concept tokens

	type		*type*		*token*
token line:	[noun: dog]	. . . .	noun: dog fnc: be mdr: prn: a–11	. . . .	noun: dog fnc: be mdr: prn: e–23
	owner record (key)		*absolute proplet*		*episodic proplet*

5.2.3 Areas of episodic vs. absolute proplets in a Word Bank

context owner records	*absolute context proplets*	*episodic context proplets*	*episodic language proplets*	*absolute language proplets*	*language owner records*
1	2	3	4	5	6

5.2.4 3-dimensional representation indicating matching frontiers



5.2.5 From episodic propositions to an absolute proposition

Mary takes a nap after lunch. *absolute proposition*

$\Uparrow$

(Friday) Mary takes a nap after lunch.

(Thursday) Mary takes a nap after lunch.

(Wednsday) Mary takes a nap after lunch. *episodic propositions*

(Tuesday) Mary takes a nap after lunch.

(Monday) Mary takes a nap after lunch.

5.3 Inference: Reconstructing *Modus Ponens*

5.3.1 Inference schemata of Propositional Calculus

1. $\dfrac{A, B}{\vdash\ A \& B}$
2. $\dfrac{A \vee B, \neg A}{\vdash\ B}$
3. $\dfrac{A \rightarrow B, A}{\vdash\ B}$
4. $\dfrac{A \rightarrow B, \neg B}{\vdash\ \neg A}$
5. $\dfrac{A \& B}{\vdash\ A}$
6. $\dfrac{A}{\vdash\ A \vee B}$
7. $\dfrac{\neg A}{\vdash\ A \rightarrow B}$
8. $\dfrac{\neg\neg A}{\vdash\ A}$

5.3.2 LA-rule for the inference of *conjunction* (hypothetical)

$$\text{inf}_1\text{:} \quad \begin{bmatrix}\text{verb: } \alpha \\ \text{prn: } m\end{bmatrix} \begin{bmatrix}\text{verb: } \beta \\ \text{prn: } n\end{bmatrix} \Longrightarrow \begin{bmatrix}\text{verb: } \alpha \\ \text{prn: } m \\ \text{cnj: } m \textit{ and } n\end{bmatrix} \begin{bmatrix}\text{verb: } \beta \\ \text{prn: } n \\ \text{cnj: } m \textit{ and } n\end{bmatrix}$$

5.3.3 *modus ponens* in Propositional Calculus

Premise 1:	If the sun is shining, Mary takes a walk.	$A \rightarrow B$
Premise 2:	The sun is shining.	$\underline{A \qquad}$
Conclusion:	Mary takes a walk.	$\vdash B$

5.3.4 *modus ponens* in Predicate Calculus

$$\frac{\forall x[\mathsf{f}(x) \rightarrow \mathsf{g}(x)],\ \exists x[\mathsf{f}(x)\ \&\ \mathsf{h}(x)]}{\vdash \exists x[\mathsf{g}(x)\ \&\ \mathsf{h}(x)]}$$

Premise 1:	For all x, if x is a dog, then x is an animal.	$\forall$x[dog(x) $\rightarrow$ animal(x)]
Premise 2:	There exists an x, x is a dog and x is tired.	$\underline{\exists\text{x[dog(x) \& tired(x)]}}$
Conclusion:	There exists an x, x is an animal and x is tired.	$\vdash \exists$x[animal(x)&tired(x)]

5.3.5 INFERENCE RULE INF$_2$ FOR RECONSTRUCTING *modus ponens*

$$\text{inf}_2: \begin{bmatrix}\text{verb: be}\\ \text{arg: } \alpha\\ \text{mdr: } \beta\\ \text{prn: } \textit{e-n}\end{bmatrix} \begin{bmatrix}\text{noun: } \alpha\\ \text{fnc: be}\\ \text{prn: } \textit{e-n}\end{bmatrix} \begin{bmatrix}\text{adj: } \beta\\ \text{mdd: be}\\ \text{mdr:}\\ \text{prn: } \textit{e-n}\end{bmatrix} \begin{bmatrix}\text{verb: is-a}\\ \text{arg: } \delta\ \gamma\\ \text{prn: } \textit{a-m}\end{bmatrix} \begin{array}{l}\text{if } \alpha \text{ instantiates } \delta,\\ \text{replace } \alpha \text{ with } \gamma\\ \text{and replace } \textit{e-n} \text{ with } \textit{e-n'}\end{array} \quad \{\ \dots\ \}$$

5.3.6 Abstract Paraphrase

1. Absolute premise: noun type δ is-a noun type γ.
2. Episodic premise: noun token α happens to be adjective β.
3. Episodic conclusion: If noun token α instantiates noun type δ, then noun token γ happens to be adjective β.

5.3.7 Concrete example based on the abstract paraphrase

1. Absolut premise: *dog* type is-a(n) *animal* type.
2. Episodic premise: *dog* token happens to be *tired*.
3. Episodic conclusion: If *dog* token instantiates *dog* type, then *animal* token happens to be *tired*

5.3.8 Applying INF_2 to the Word Bank 5.2.1

$$\text{inf}_2\text{:} \begin{bmatrix}\text{verb: be}\\ \text{arg: } \alpha \\ \text{mdr: } \beta \\ \text{prn: } e\text{-}n\end{bmatrix} \begin{bmatrix}\text{noun: } \alpha \\ \text{fnc: be} \\ \text{prn: } e\text{-}n\end{bmatrix} \begin{bmatrix}\text{adj: } \beta \\ \text{mdd: be} \\ \text{mdr:} \\ \text{prn: } e\text{-}n\end{bmatrix} \begin{bmatrix}\text{verb: is-a} \\ \text{arg: } \delta\ \gamma \\ \text{prn: } a\text{-}m\end{bmatrix} \begin{array}{l}\text{if } \alpha \text{ instantiates } \delta, \\ \text{replace } \alpha \text{ with } \gamma \\ \text{and replace } e\text{-}n \text{ with } e\text{-}n\text{'}\end{array} \quad \{\ldots\}$$

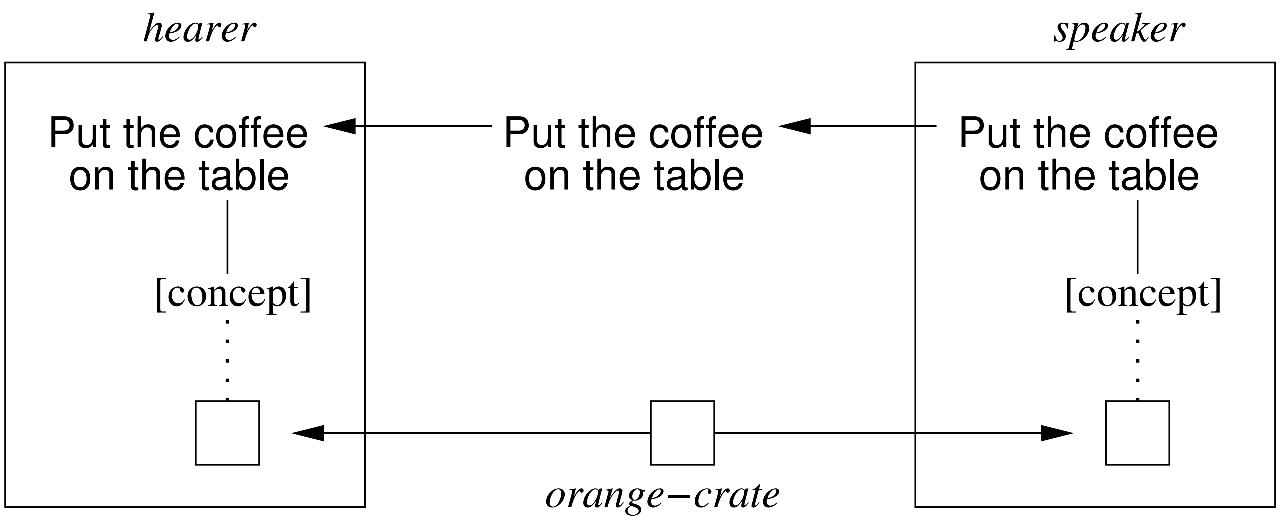
$$\begin{bmatrix}\text{verb: be}\\ \text{arg: dog} \\ \text{mdr: tired} \\ \text{prn: e-23}\end{bmatrix} \begin{bmatrix}\text{noun: dog} \\ \text{fnc: be} \\ \text{mdr:} \\ \text{prn: e-23}\end{bmatrix} \begin{bmatrix}\text{adj: tired} \\ \text{mdd: be} \\ \text{mdr:} \\ \text{prn: e-23}\end{bmatrix} \begin{bmatrix}\text{verb: is-a} \\ \text{arg: dog animal} \\ \text{mdr:} \\ \text{prn: a-11}\end{bmatrix}$$

5.3.9 Result of applying INF_2 to the Word Bank 5.2.1

$$\begin{bmatrix}\text{verb: be}\\ \text{arg: animal} \\ \text{mdr: tired} \\ \text{prn: e-23'}\end{bmatrix} \begin{bmatrix}\text{noun: animal} \\ \text{fnc: be} \\ \text{mdr:} \\ \text{prn: e-23'}\end{bmatrix} \begin{bmatrix}\text{adj: tired} \\ \text{mdd: be} \\ \text{mdr:} \\ \text{prn: e-23'}\end{bmatrix}$$

5.4 Indirect Uses of Language

5.4.1 NON-LITERAL USE OF THE WORD table

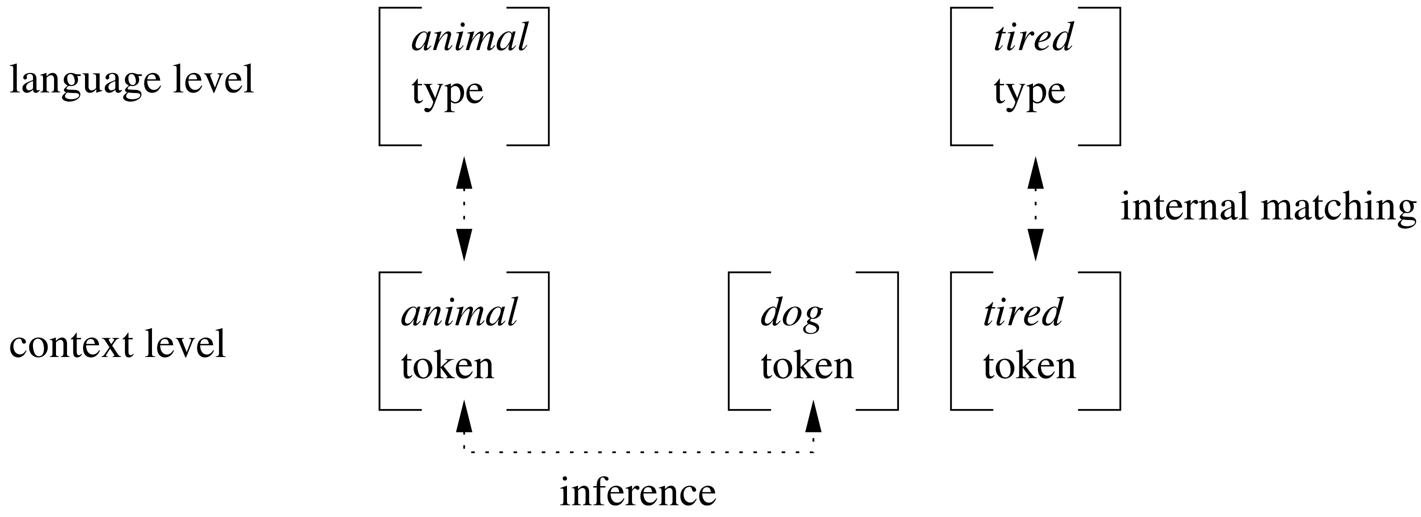


5.4.2 Grice's definition of meaning

Definiendum: U meant something by uttering x.

Definiens: For some audience A, U intends his utterance of x to produce in A some effect (response) E, by means of A's recognition of the intention.

5.4.3 CONTEXTUAL INFERENCE UNDERLYING A NON-LITERAL USE

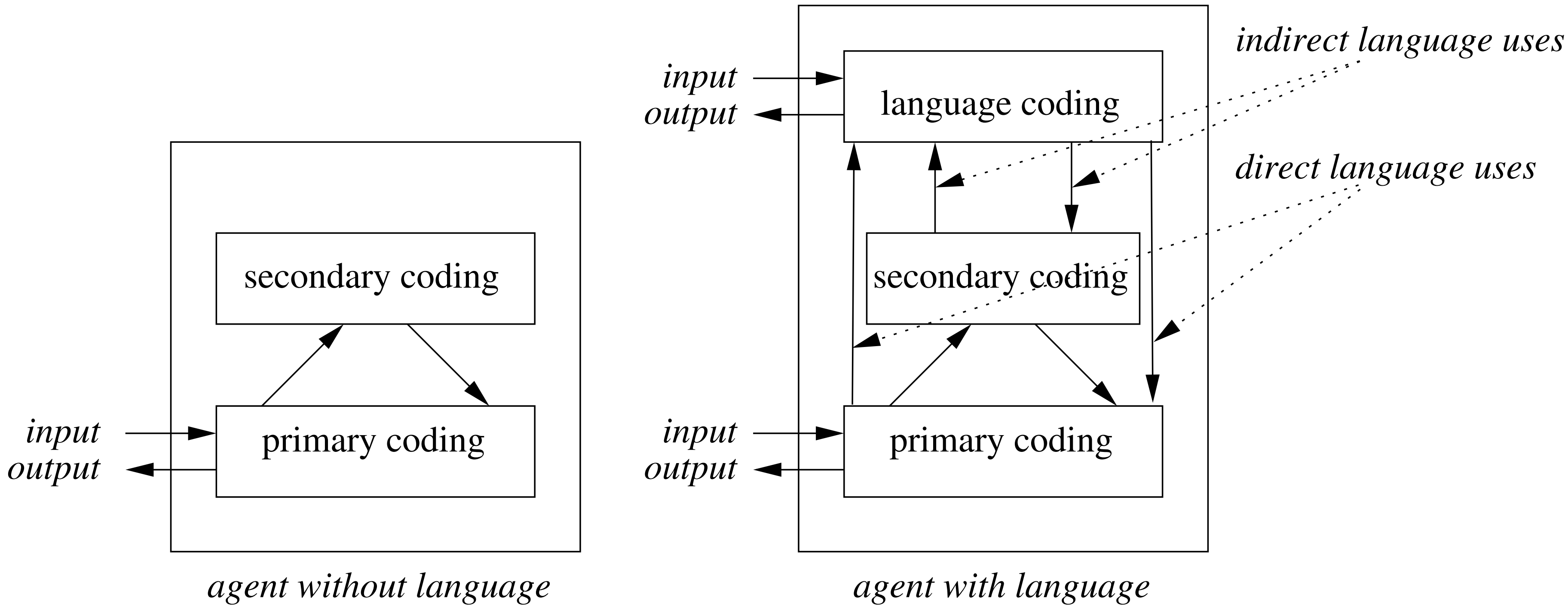


5.4.4 ADVANTAGES OF HANDLING INDIRECT USES VIA INFERENCES

1. Direct and indirect uses of language are based on the same method of strict internal matching (cf. 3.2.3), which greatly facilitates computational realization.
2. The inferencing underlying indirect uses is restricted to the level of context. Therefore, agents with and without language can use the same cognitive system.
3. Inferencing at the level of context is much more powerful and flexible than the traditional inferencing based on isolated signs of language.
4. Assuming that natural language directly reflects the contextual coding, the contextual inferences can be studied by analyzing their language reflections.

5.5 Secondary Coding as Perspective Taking

5.5.1 CODING LEVELS IN AGENTS WITH AND WITHOUT LANGUAGE



5.5.2 FUNCTIONS OF CODING LEVELS IN DATABASE SEMANTICS

1. *Primary coding* at the context level
   Represents contextual recognition and action at a low level of abstraction in a simple standardized format in order to ensure veracity.
2. *Secondary coding* at the context level
   Consists of inferencing over the primary coding in order to obtain sufficient expressive power at varying levels of abstraction.
3. *Language coding*
   Represents primary and secondary context coding in a natural language.

5.6 Shades of Meaning

5.6.1 Lexical lookup of the word dog

$$\begin{bmatrix} \text{sur: } \mathsf{dog} \\ \text{noun: } \textit{dog} \\ \text{fnc:} \\ \text{mdr:} \\ \text{prn:} \end{bmatrix}$$

5.6.2 Absolute part of the token line of *dog*

$$\begin{bmatrix} \text{noun: } \textit{dog} \end{bmatrix} \begin{bmatrix} \text{noun: dog} \\ \text{fnc: be} \\ \text{mdr:} \\ \text{prn: a-1} \end{bmatrix} \begin{bmatrix} \text{noun: dog} \\ \text{fnc: have} \\ \text{mdr:} \\ \text{prn: a-2} \end{bmatrix} \ldots$$

5.6.3 Complementation of a literal meaning$_1$ (concept type)