Growing a modular model of language processing at the single-word level from neuropsychological data; and making it computational.

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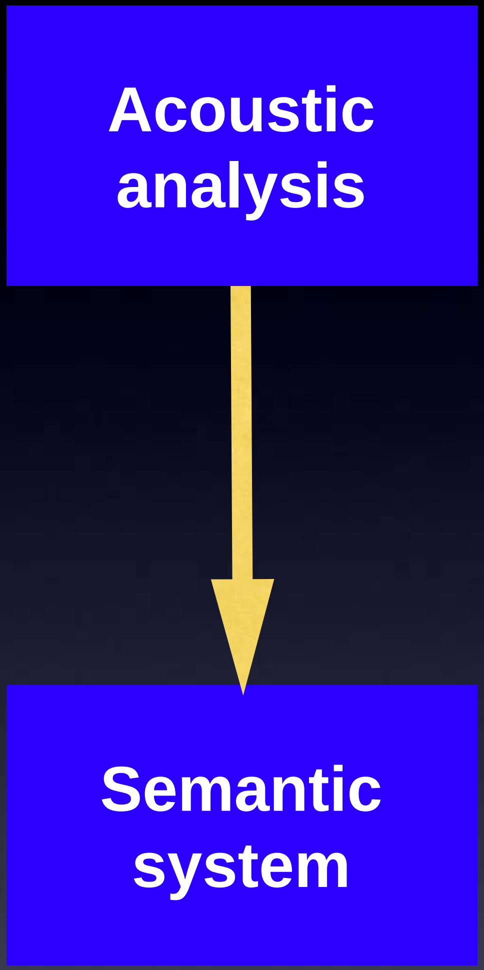
Processing acoustic input

Understanding what we hear: Model 1



Bramwell, *The Lancet,* 1897.

- Bramwell’s patient was a twenty-six-year-old Scottish woman who had recently given birth.

- Eleven days after the birth, when she was still in hospital, she complained of numbness in her left arm, and had difficulty using that arm.

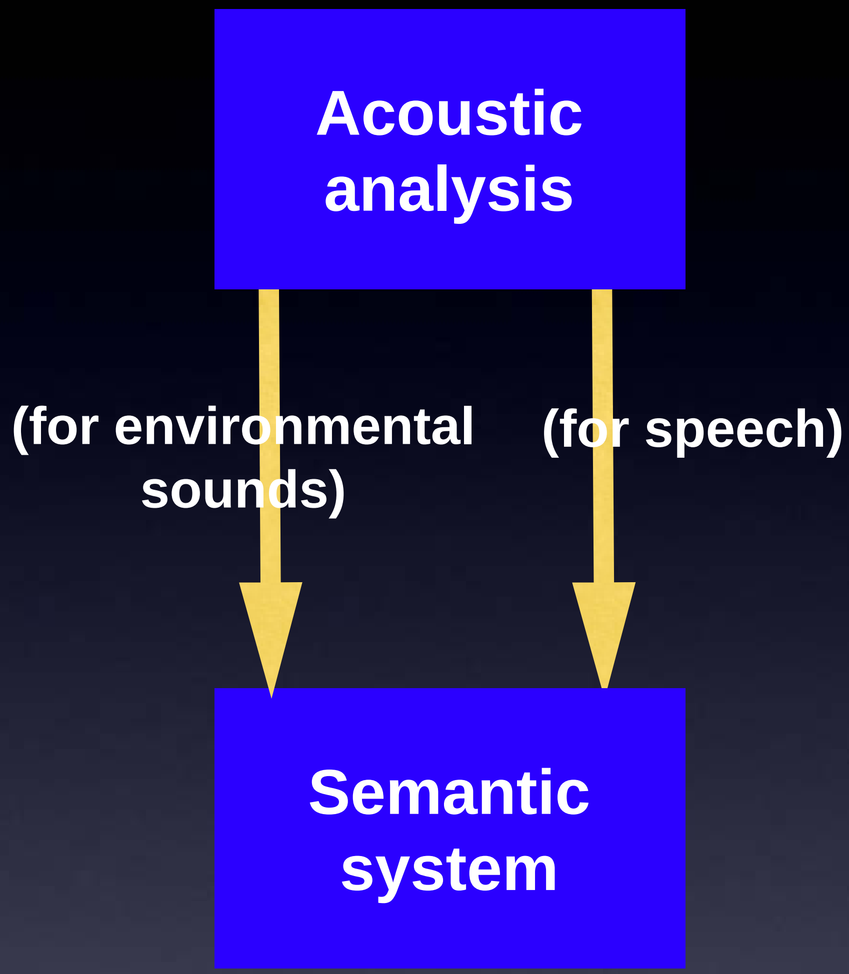
- The next day she was found to be in a drowsy state in her bed, and could not understand or respond to what was going on around her. Almost certainly, she had suffered a stroke.

- She observed to Bramwell: "Is it not strange that I can hear the clock ticking and cannot hear you speak? Now let me think what that means".

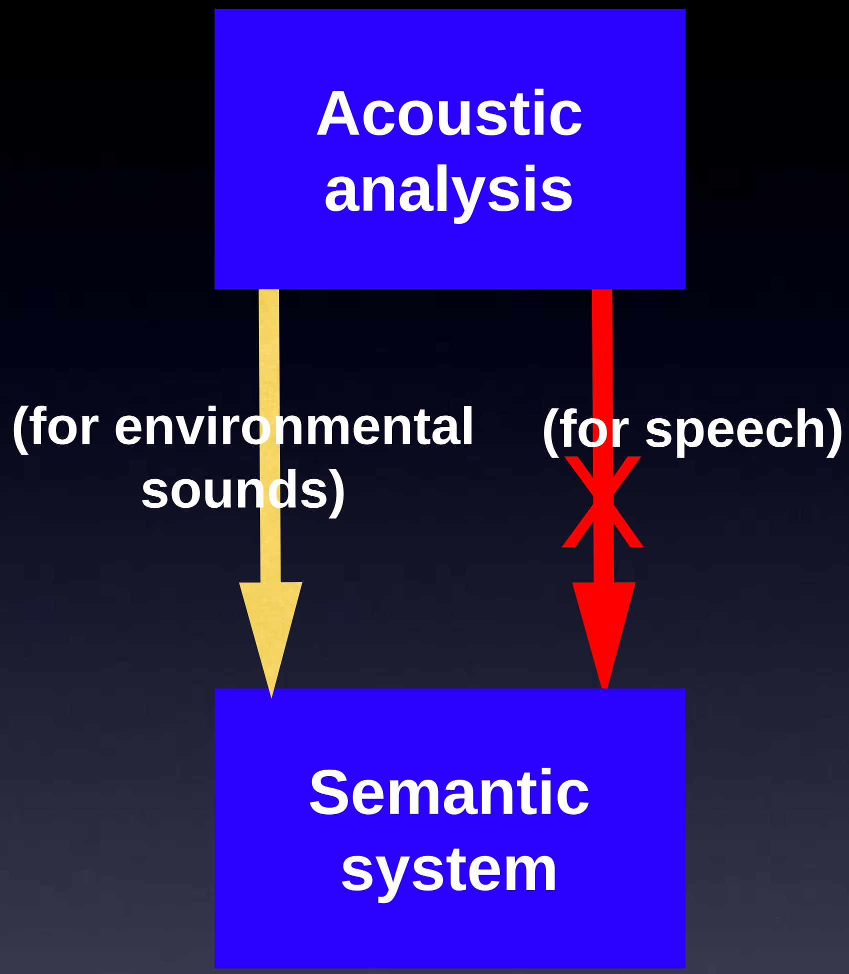
- Well, let ***us*** think about what that means.

- She could understand printed words, so she has not lost all knowledge of word meanings. And she can understand environmental sounds, so she is not deaf. So why can't she understand spoken words?

Understanding what we hear: Model 2

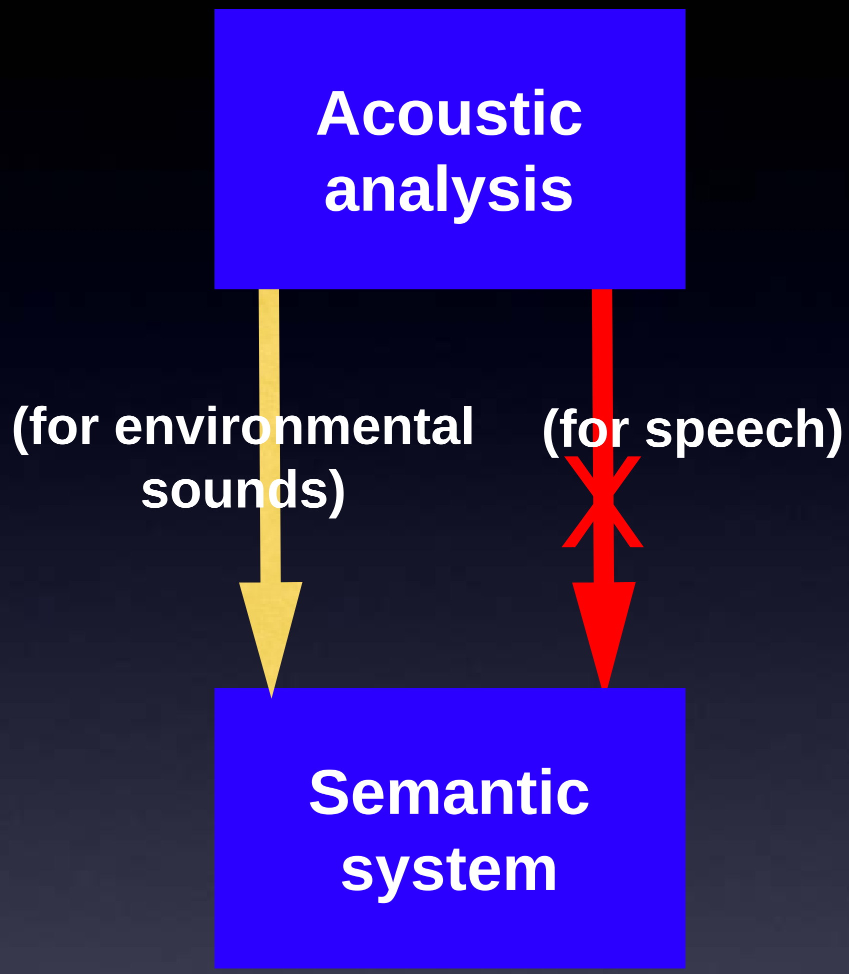


Understanding what we hear: Model 2



This is “word deafness”. Various cases subsequently reported.

Understanding what we hear: Model 2



But perhaps there are not two pathways here: perhaps there is just one, and speech is harder for it than environmental sounds.

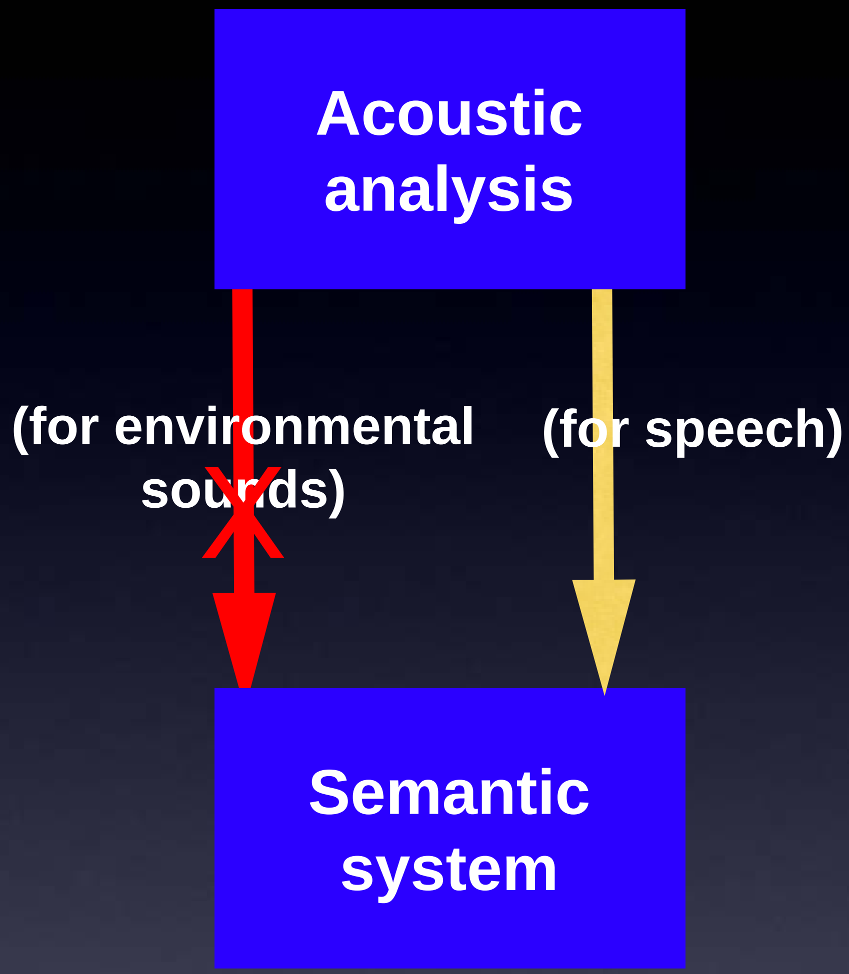
Albert, Sparks, von Stockert & Sax, *Cortex*, 1972

• When tested on ability to comprehend environmental sounds and spoken words, he said to the investigators: “How come I can understand your voice but not these sounds?

• Formal testing confirmed very impaired comprehension of environmental sounds with intact comprehension of spoken words.

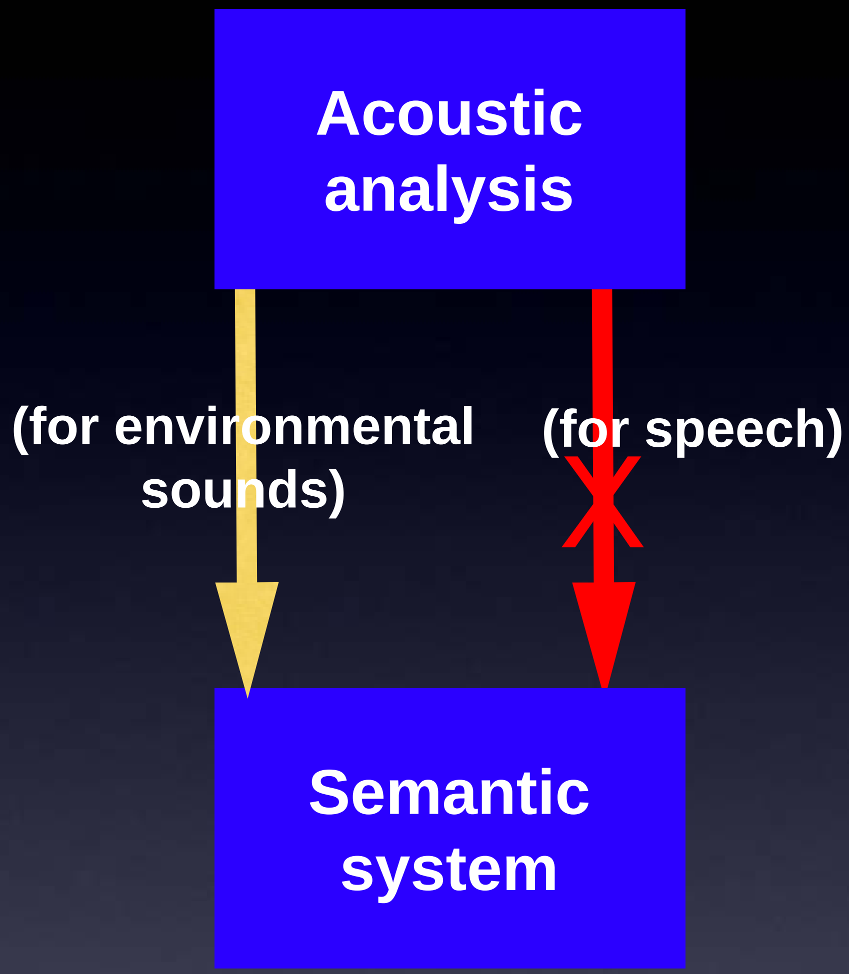
• He could understand printed words, so had not lost all knowledge of meanings. And he could understand spoken words, so he was not deaf. So why couldn’t he understand environmental sounds?

Understanding what we hear: Model 2



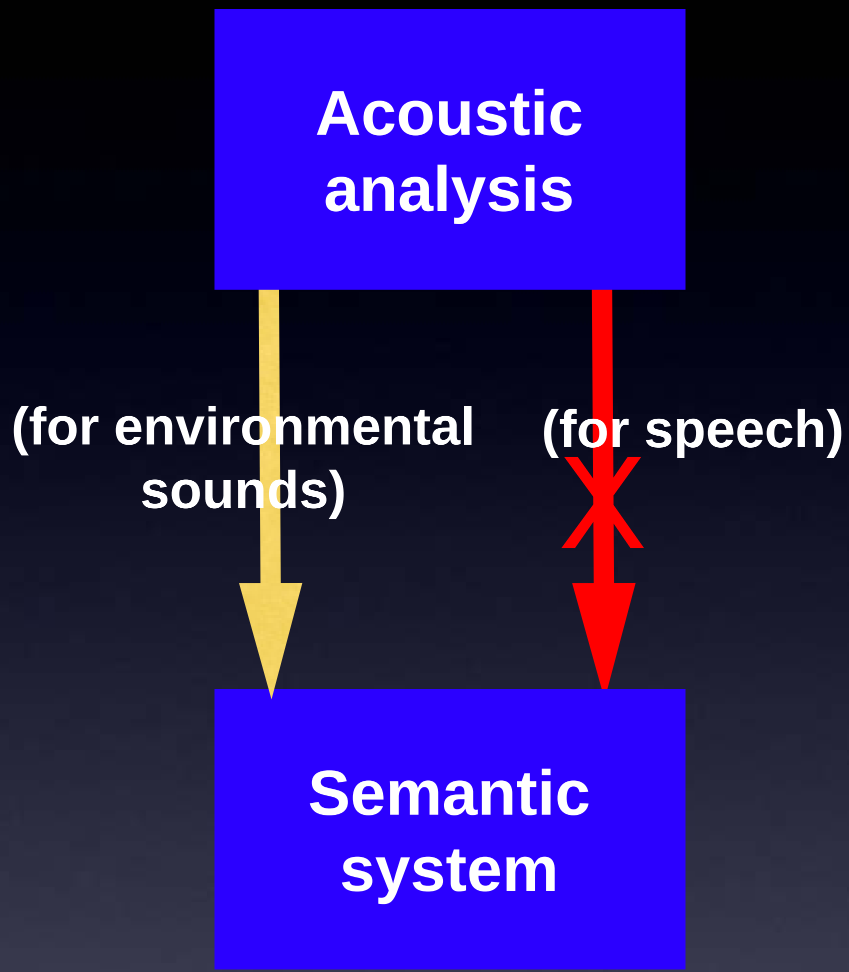
This is “auditory agnosia”. Various cases subsequently reported.

Back to Bramwell's case: "word deafness"



What are these patients like at tests of phonemic perception? And what are they like at repeating nonwords spoken to them?

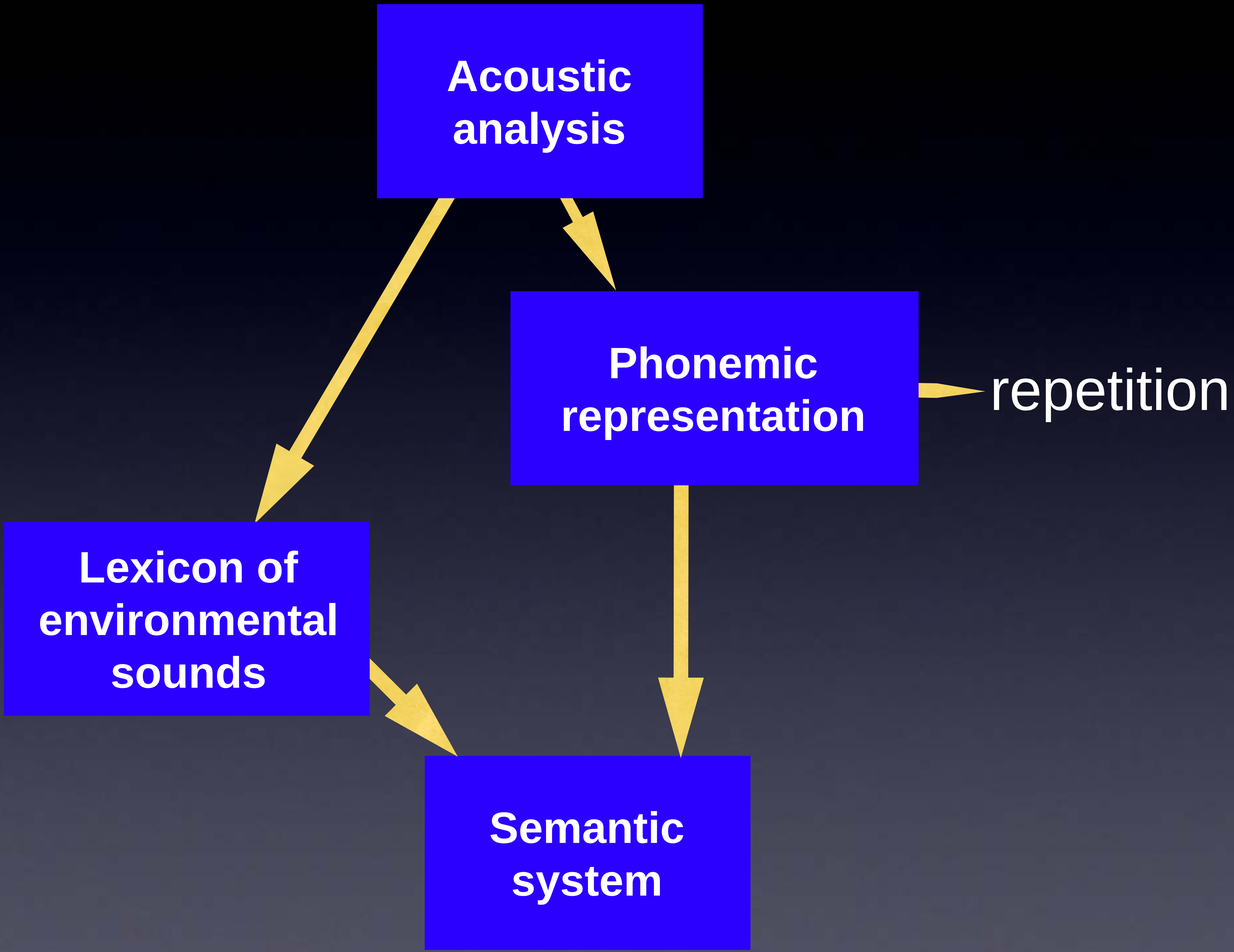
Understanding what we hear: Model 2



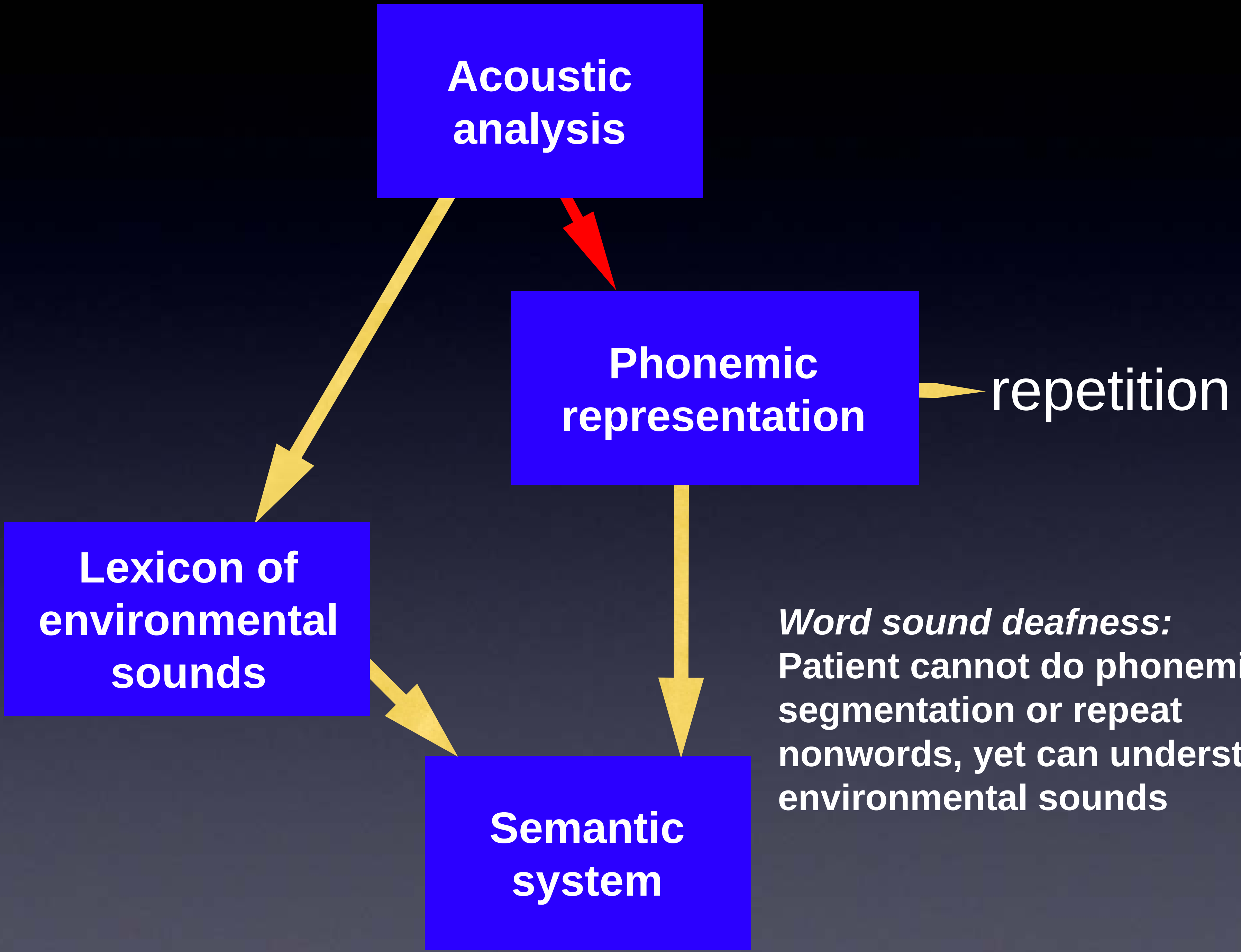
Some word-deaf patients can't do phoneme perception or repeat nonwords. Others are intact on these tasks.

Model 2 cannot explain this so it can't be right.

Understanding what we hear: Model 3



Understanding what we hear: Model 3

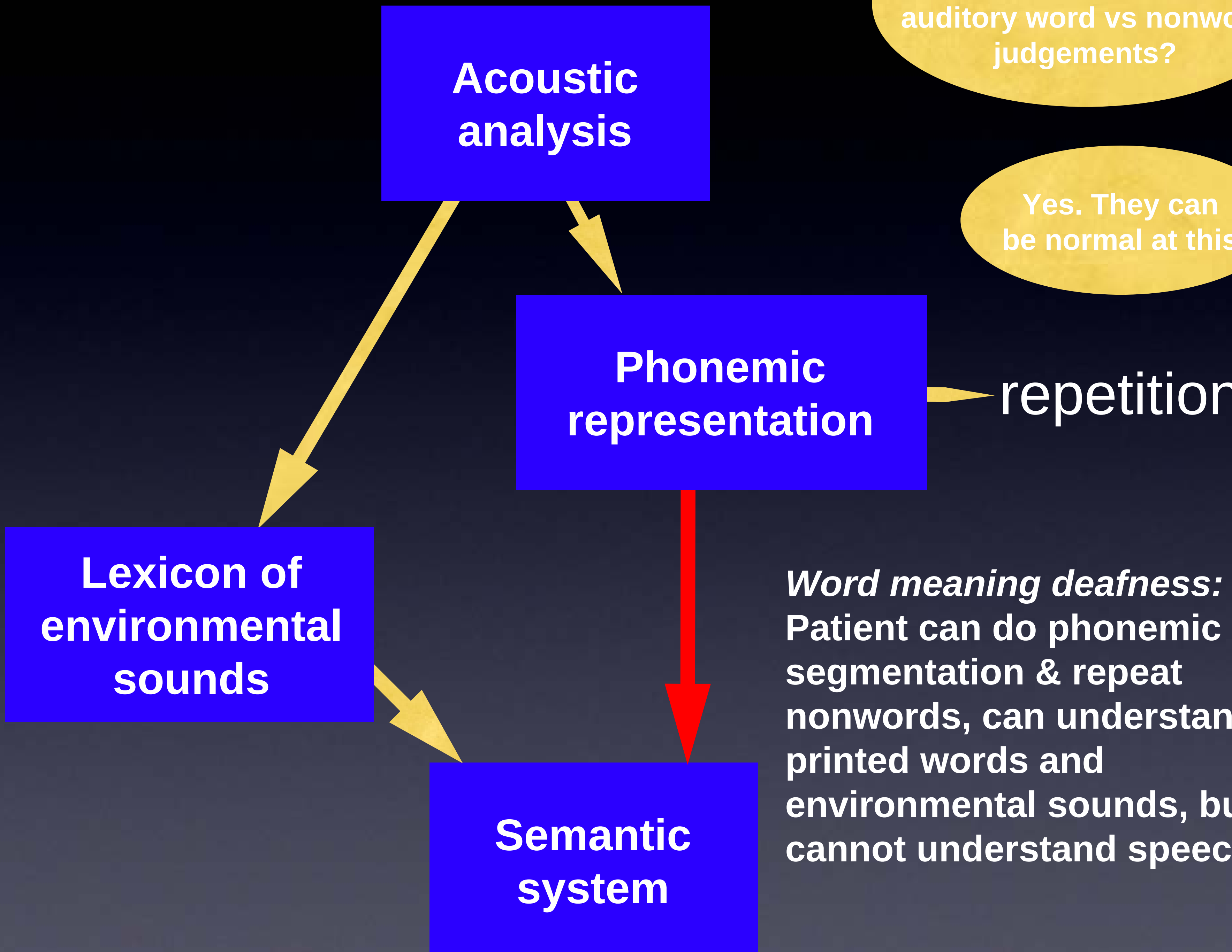


Word sound deafness:
Patient cannot do phonemic segmentation or repeat nonwords, yet can understand environmental sounds

Understanding what we hear: Model 3

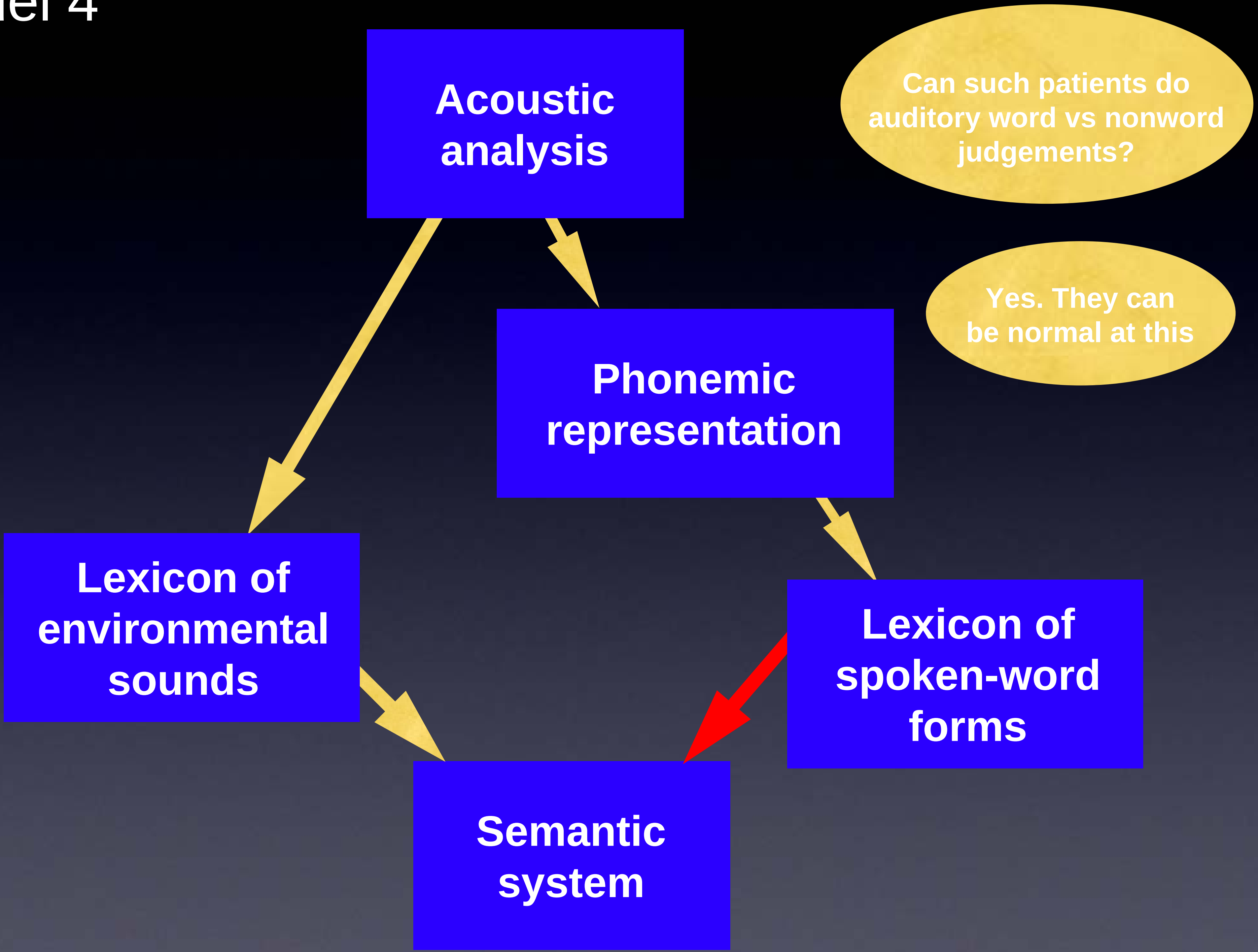
Can such patients do auditory word vs nonword judgements?

Yes. They can be normal at this



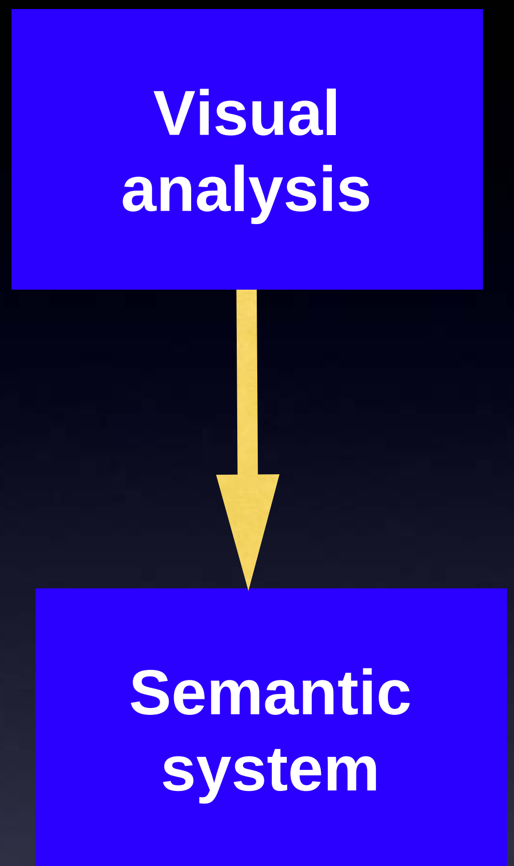
Word meaning deafness: **Patient can do phonemic segmentation & repeat nonwords, can understand printed words and environmental sounds, but cannot understand speech**

Recognizing and understanding what we hear: model 4



Processing visual input

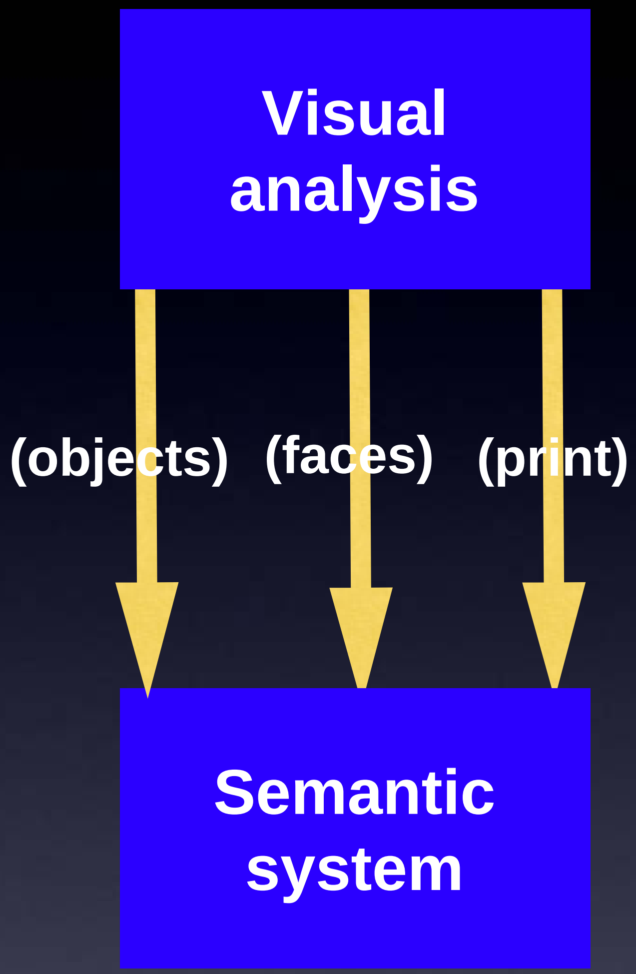
Understanding what we see: Model 1



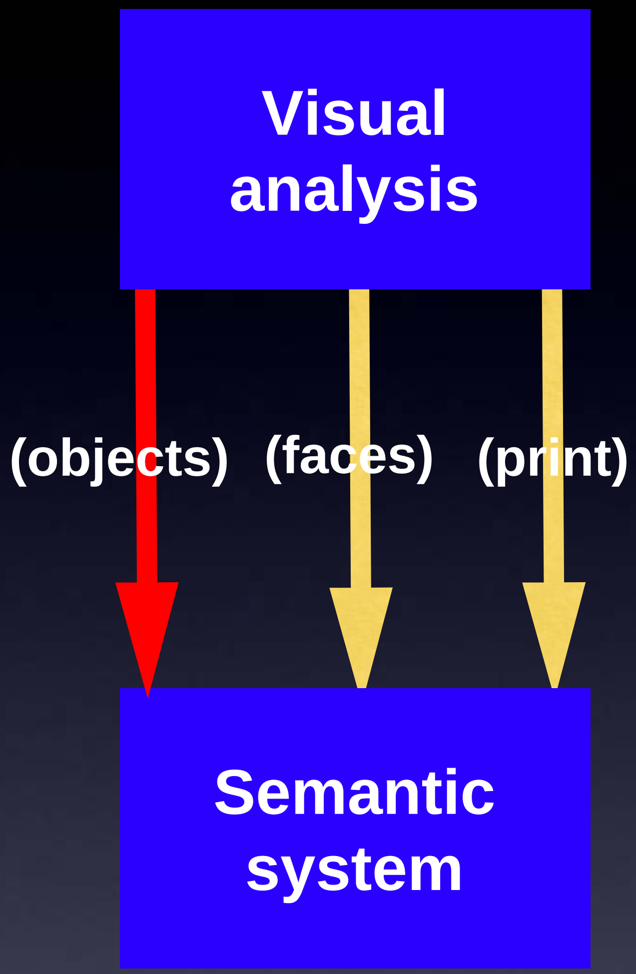
But failure to access meaning from vision can be specific to:

- just faces (prosopagnosia)
- just objects (visual object agnosia)
- just printed words (pure alexia)

Understanding what we see: Model 2



Understanding what we see: Model 2

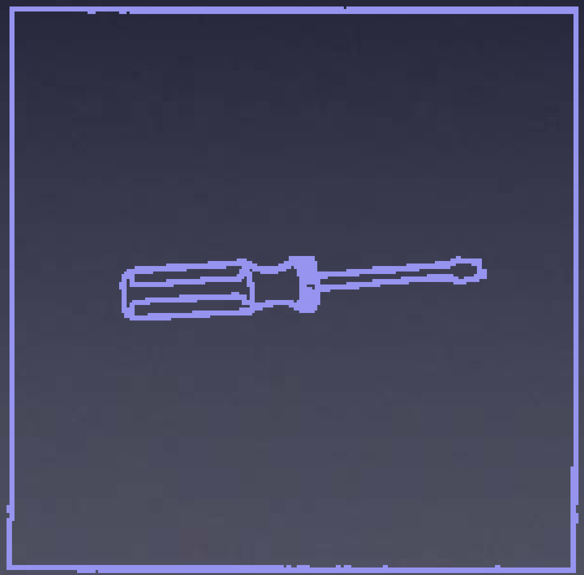


Visual object agnosia

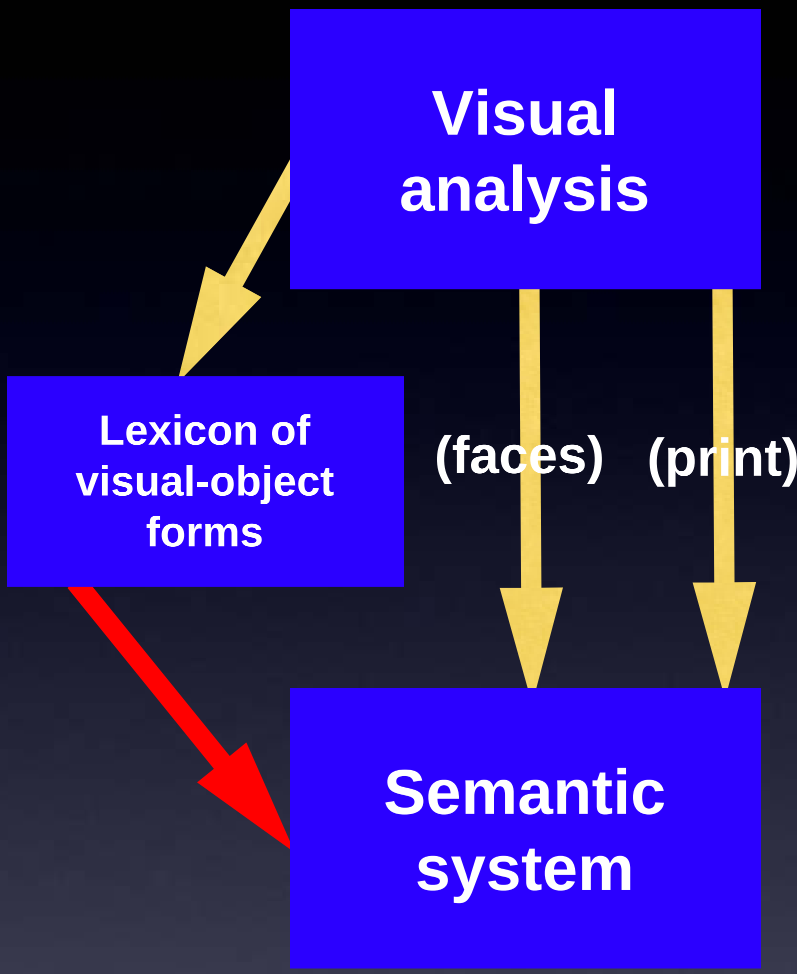
The object decision task: Is this a real object or not?

Some patients with visual agnosia can succeed on this task even though

- they cannot understand pictures of objects
- they ***can*** tell you what “screwdriver” means

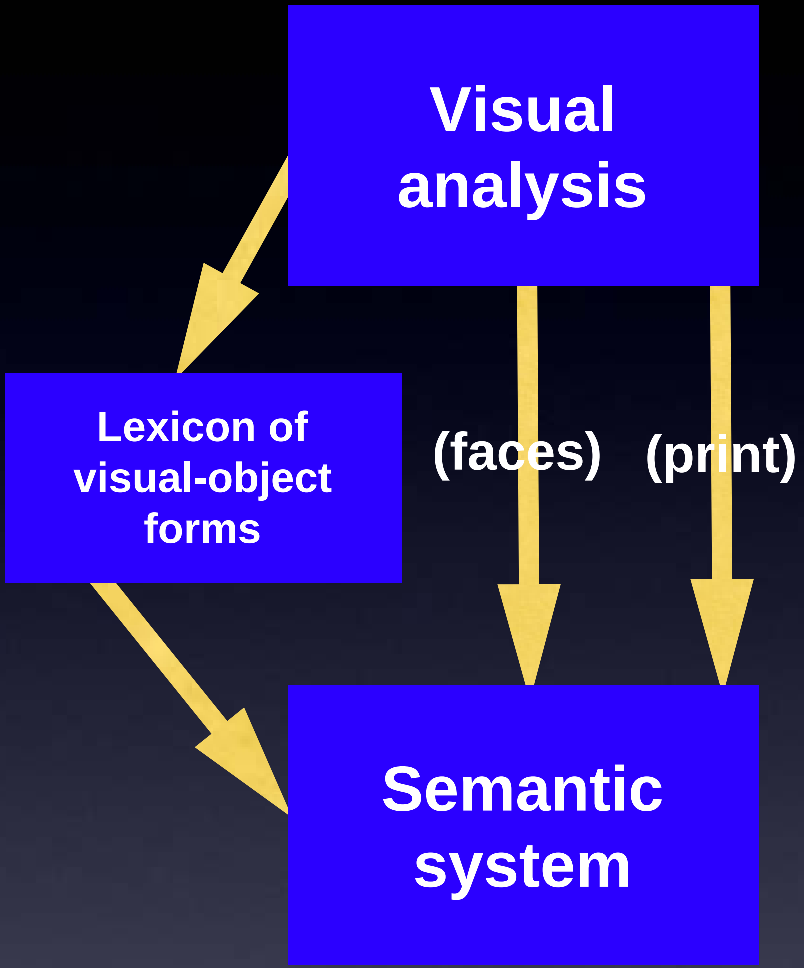


Understanding what we see: Model 2



Visual object agnosia with preserved object decision

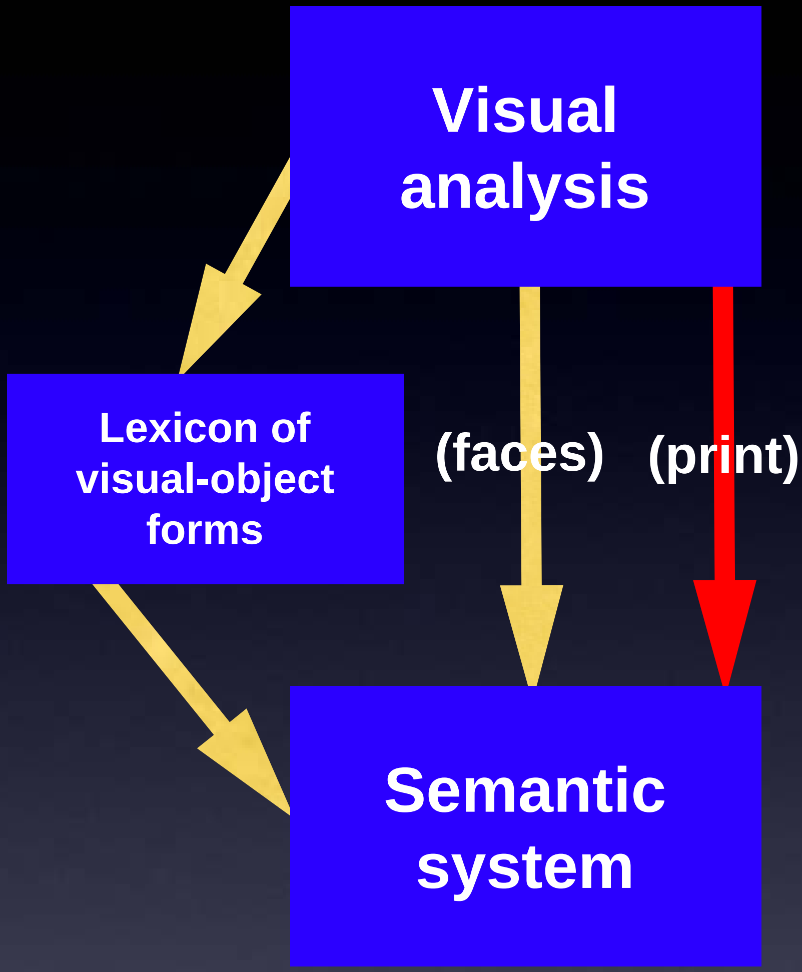
Understanding what we see: Model 2



Patient JO: could match spoken words to pictures normally (so was not blind and had an intact semantic system.

But scored only 40% correct on matching print to picture

Understanding what we see: Model 2

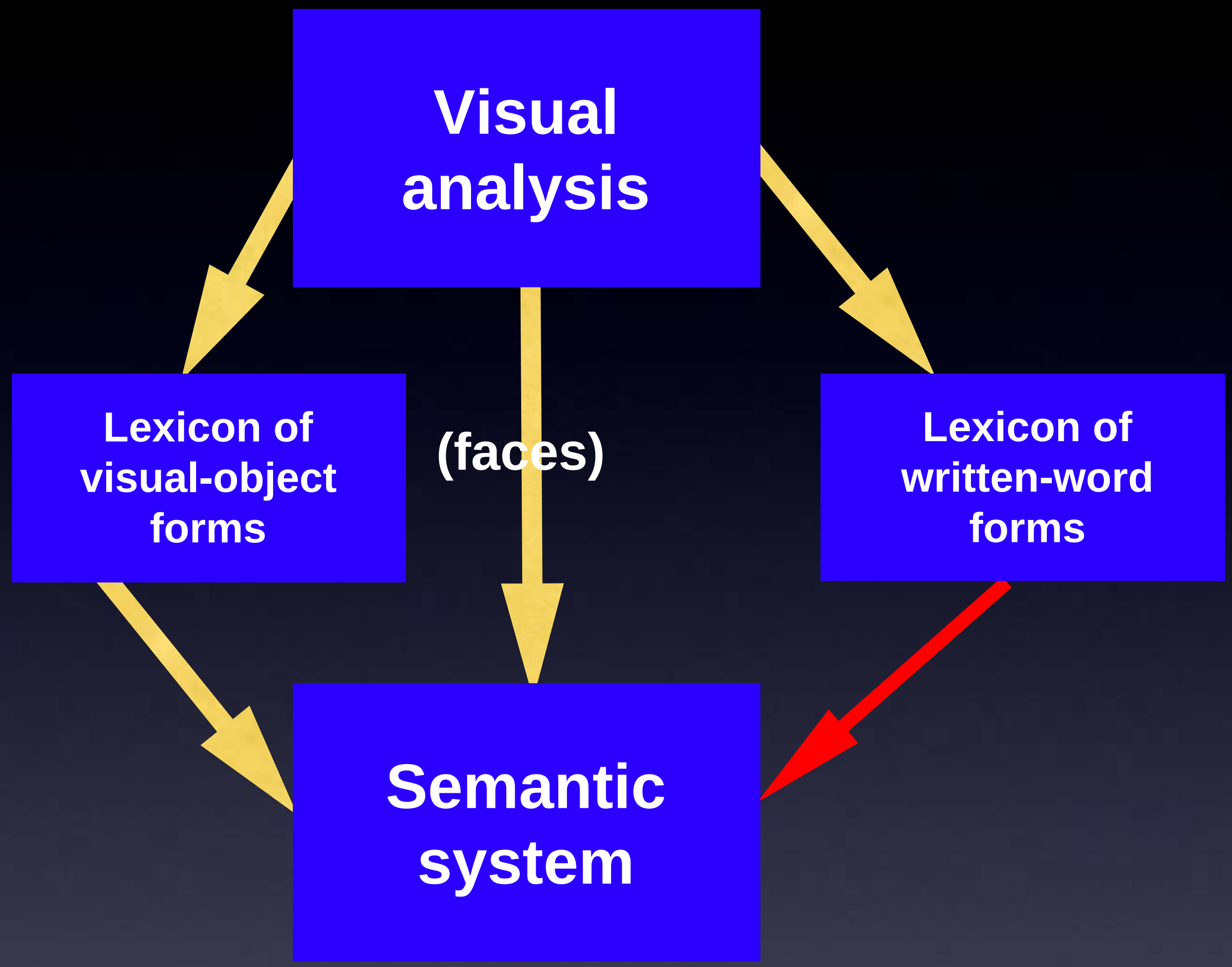


Patient JO: “word meaning blindness”

What about the lexical decision task: SLINT vs SLANT?

100% correct

Understanding what we see: Model 3



Patient JO: “word meaning blindness”

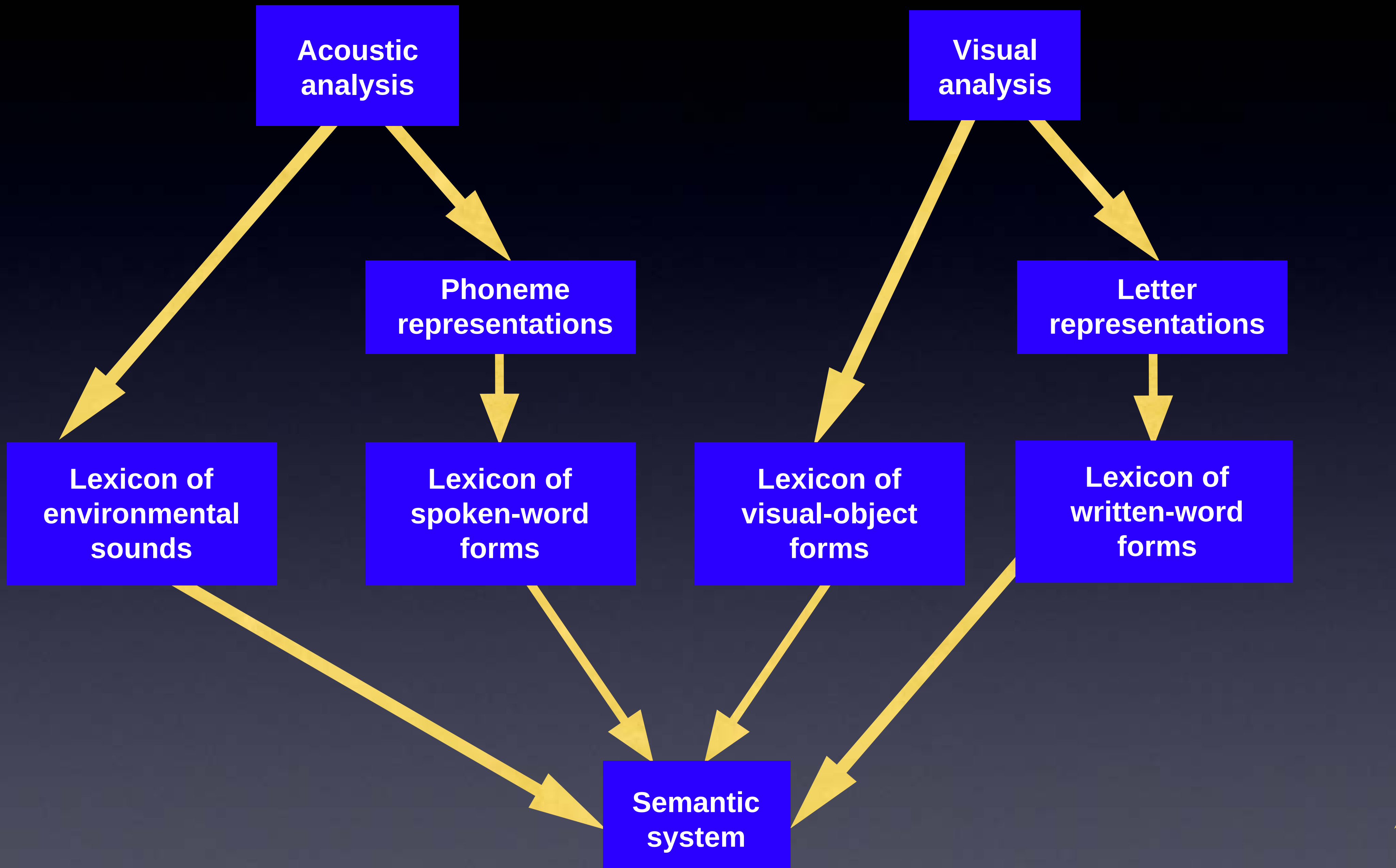
Perfect at the visual lexical decision task: SLINT vs SLAN

Very poor single-word reading comprehension

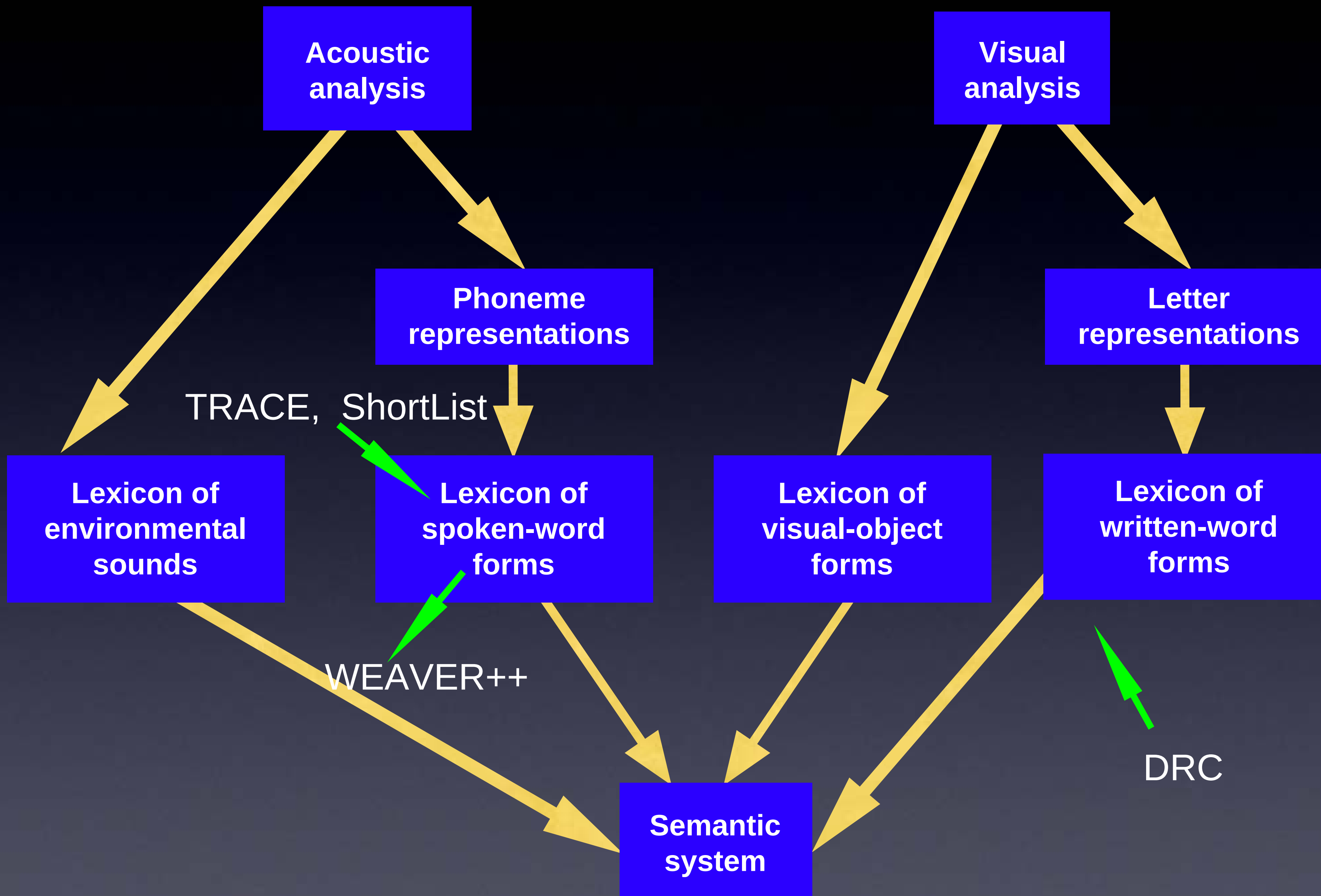
Where we have ended up:

A model for recognizing and understanding environmental sounds, seen objects, spoken words and printed words

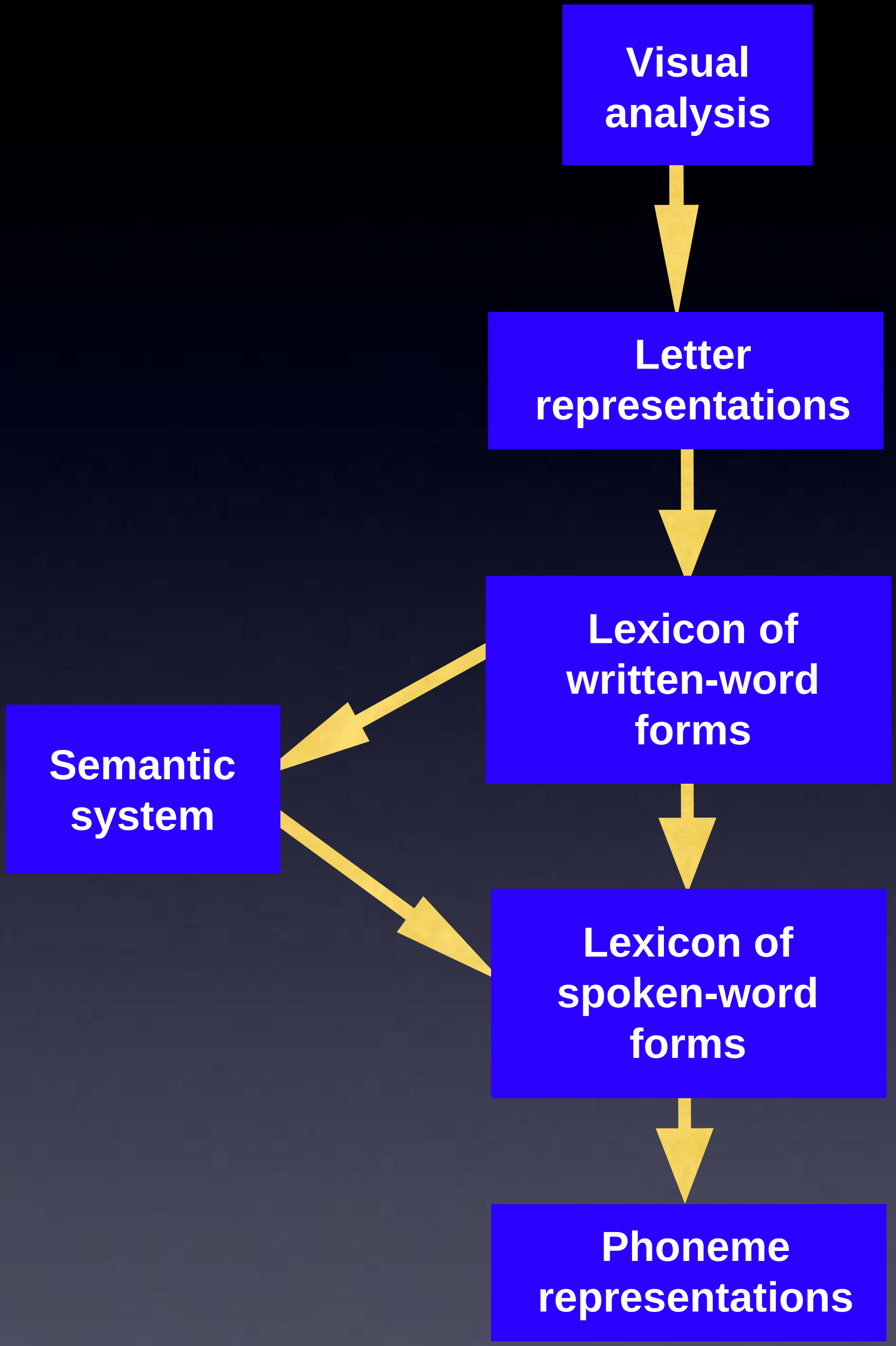
Recognizing and understanding environmental sounds, seen objects, spoken words and printed words



Computational modelling: write a program that does all this ***and does it the way people do it***

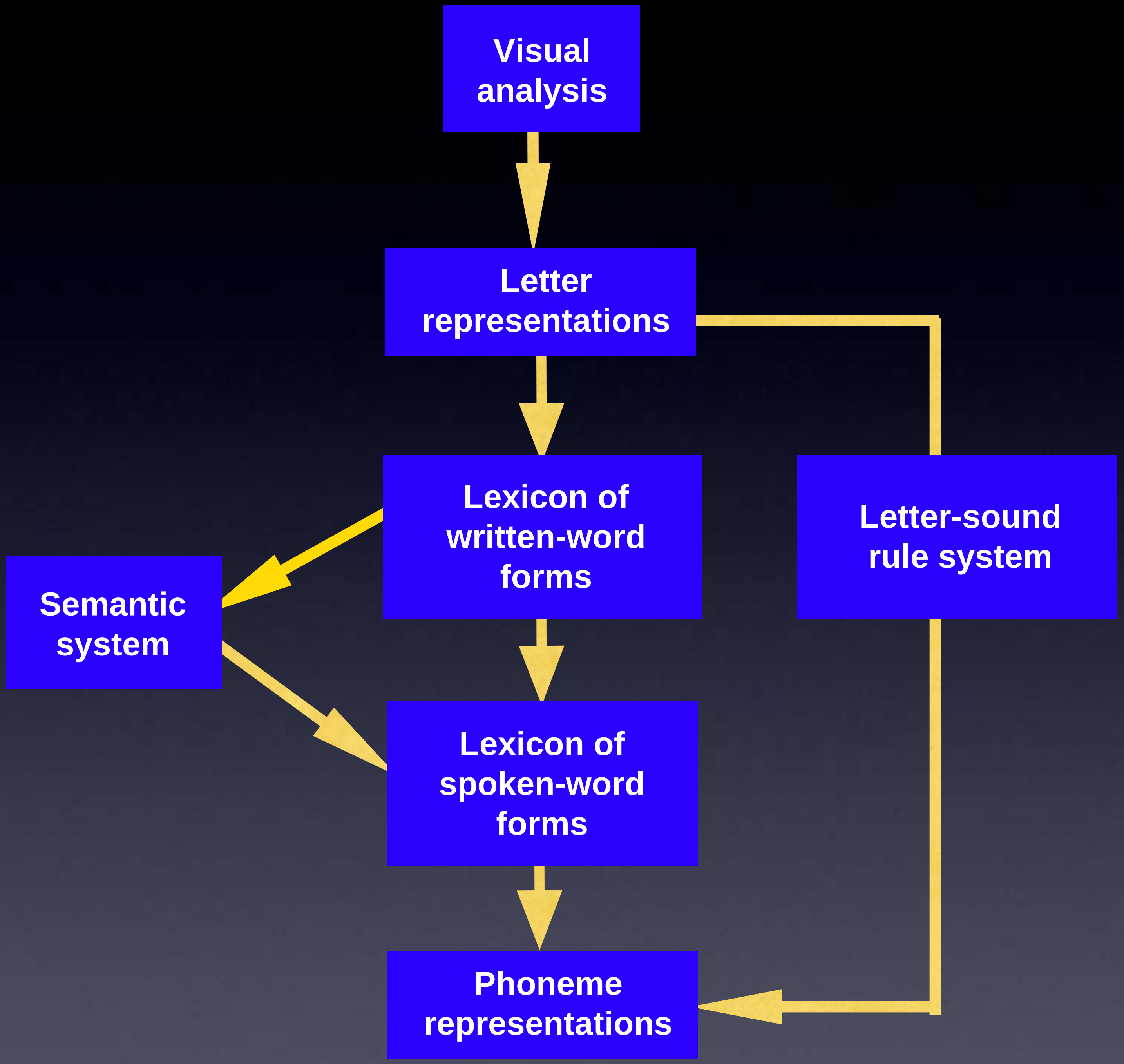


The DRC computational model of reading

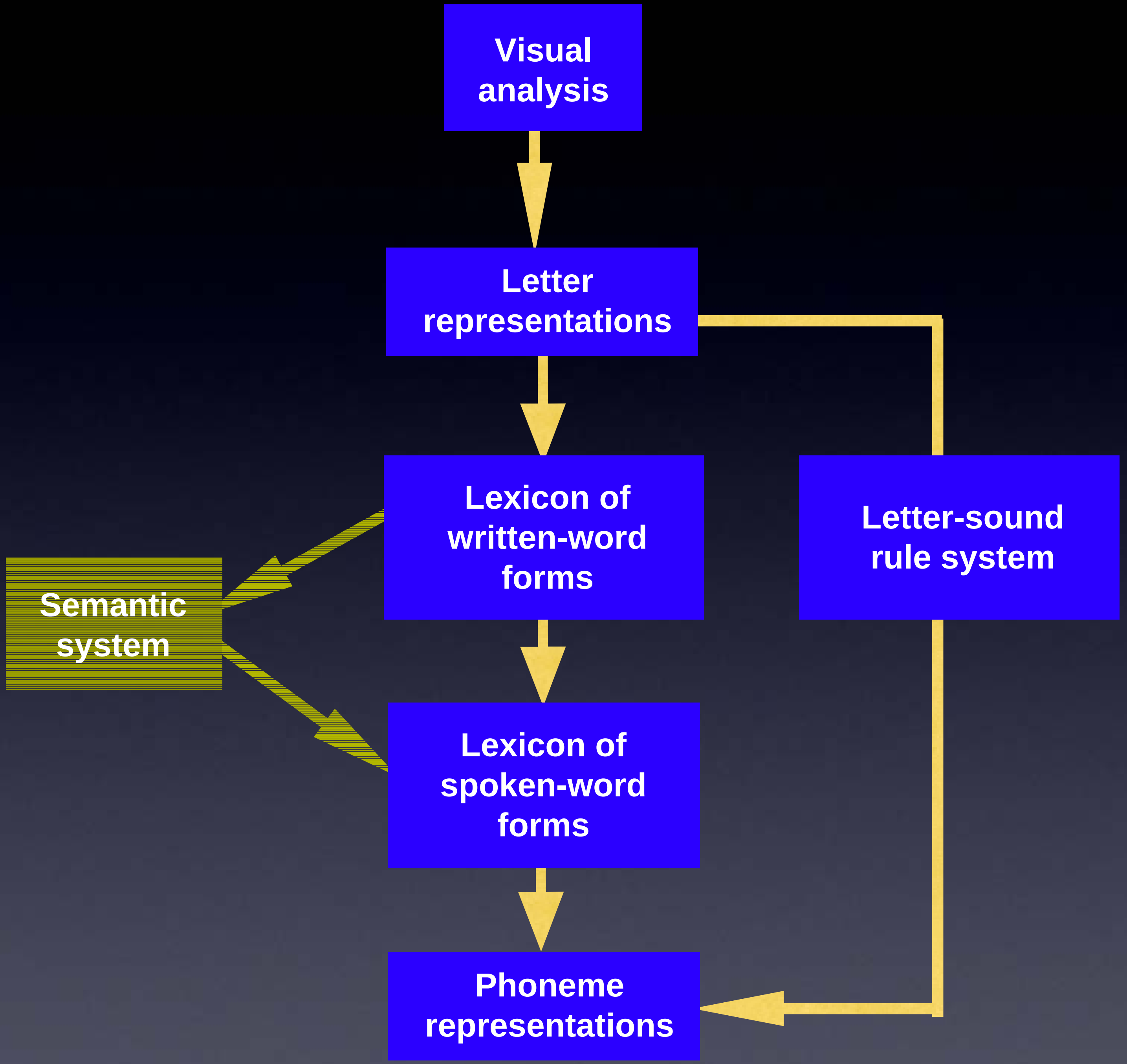


But how do we read aloud unfamiliar words or nonwords like SLINT?

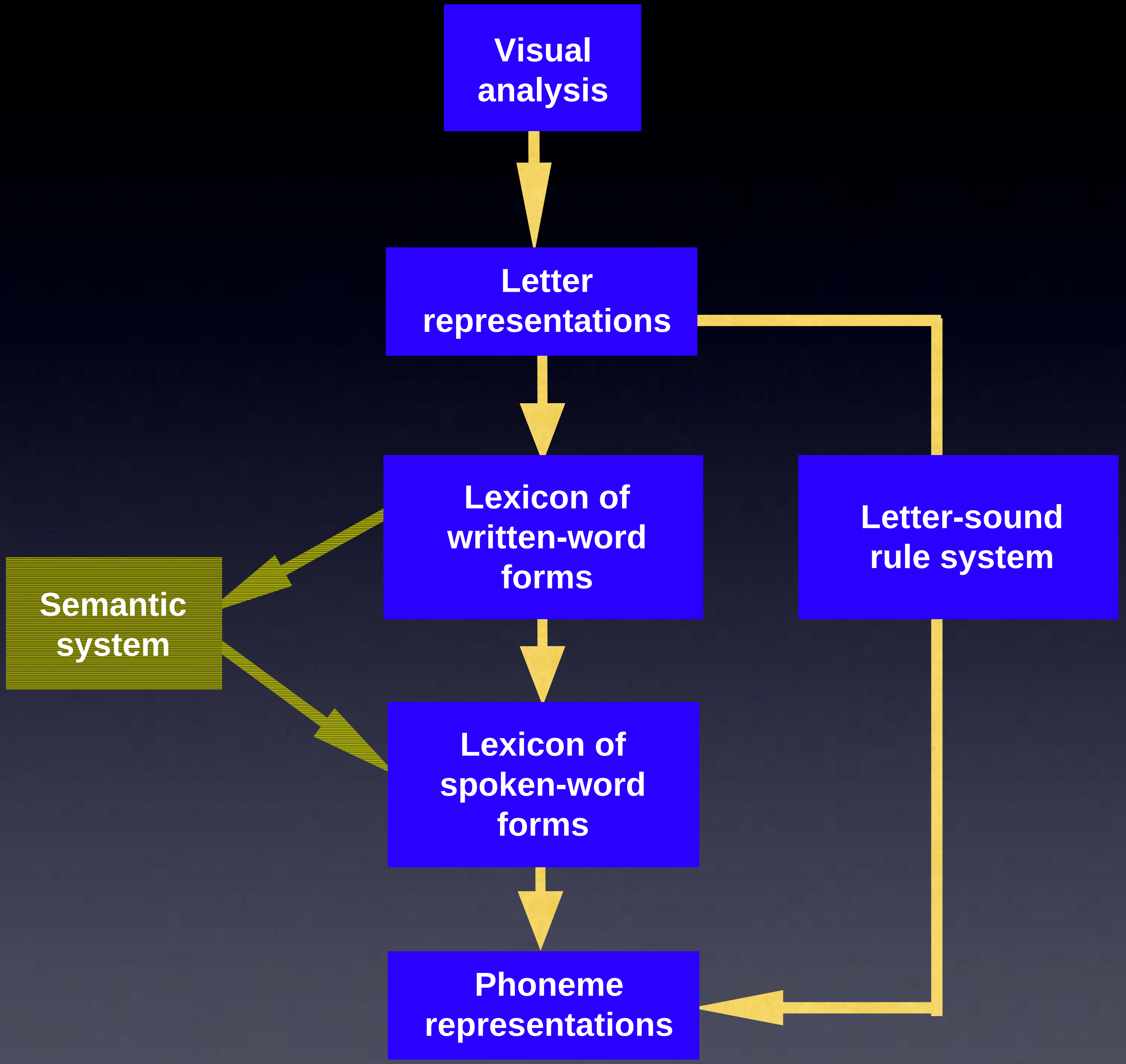
The DRC computational model of reading



The DRC computational model of reading



Two key points



This system operates left-to-right

This system misreads all irregular words (those that don't obey spelling-sound rules) -- YACHT

The DRC model of reading offers an account of:

Reading aloud effects

- Word frequency
- Regularity of spelling-sound correspondence
- Freq X reg
- PosReg
- Pseudo-homophony
- Whammy
- Strategy
- Onset priming
- Length
- Length X lexicality

Acquired dyslexia

- Surface dyslexia
- Semantic dementia
- Phonological dyslexia

Lexical decision effects

- Frequency
- Pseudo-homophony
- Orthographic neighbourhood size

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- **Surface dyslexia**
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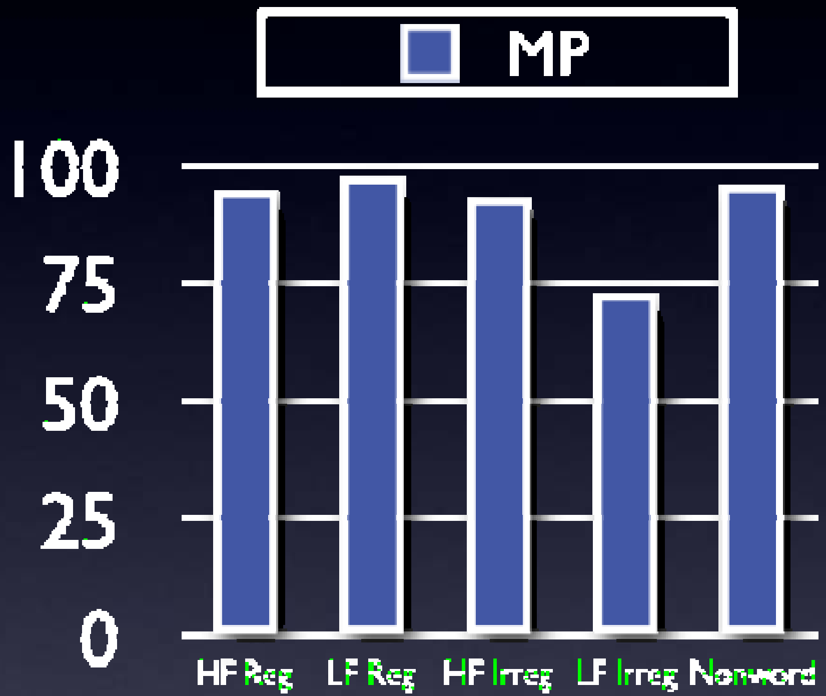
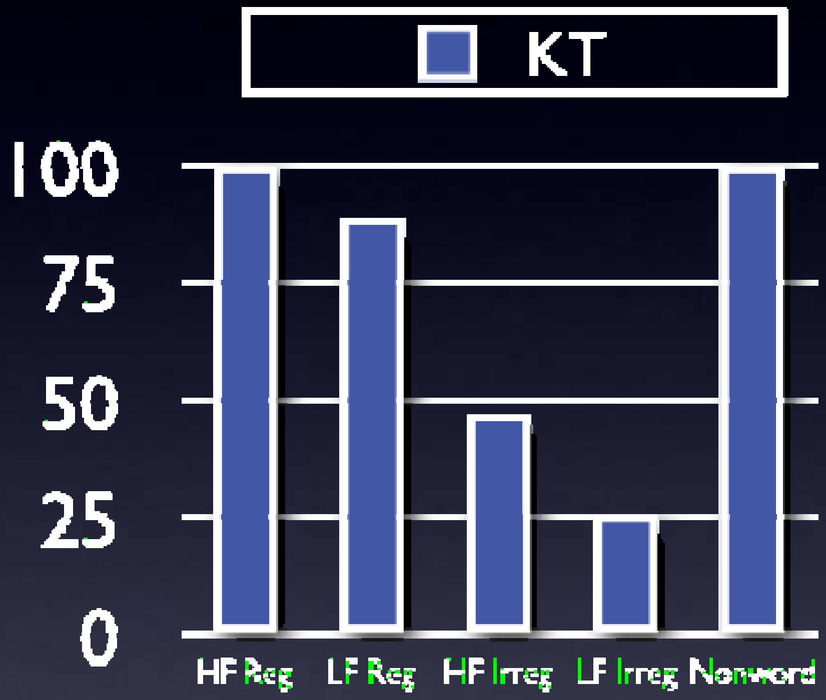
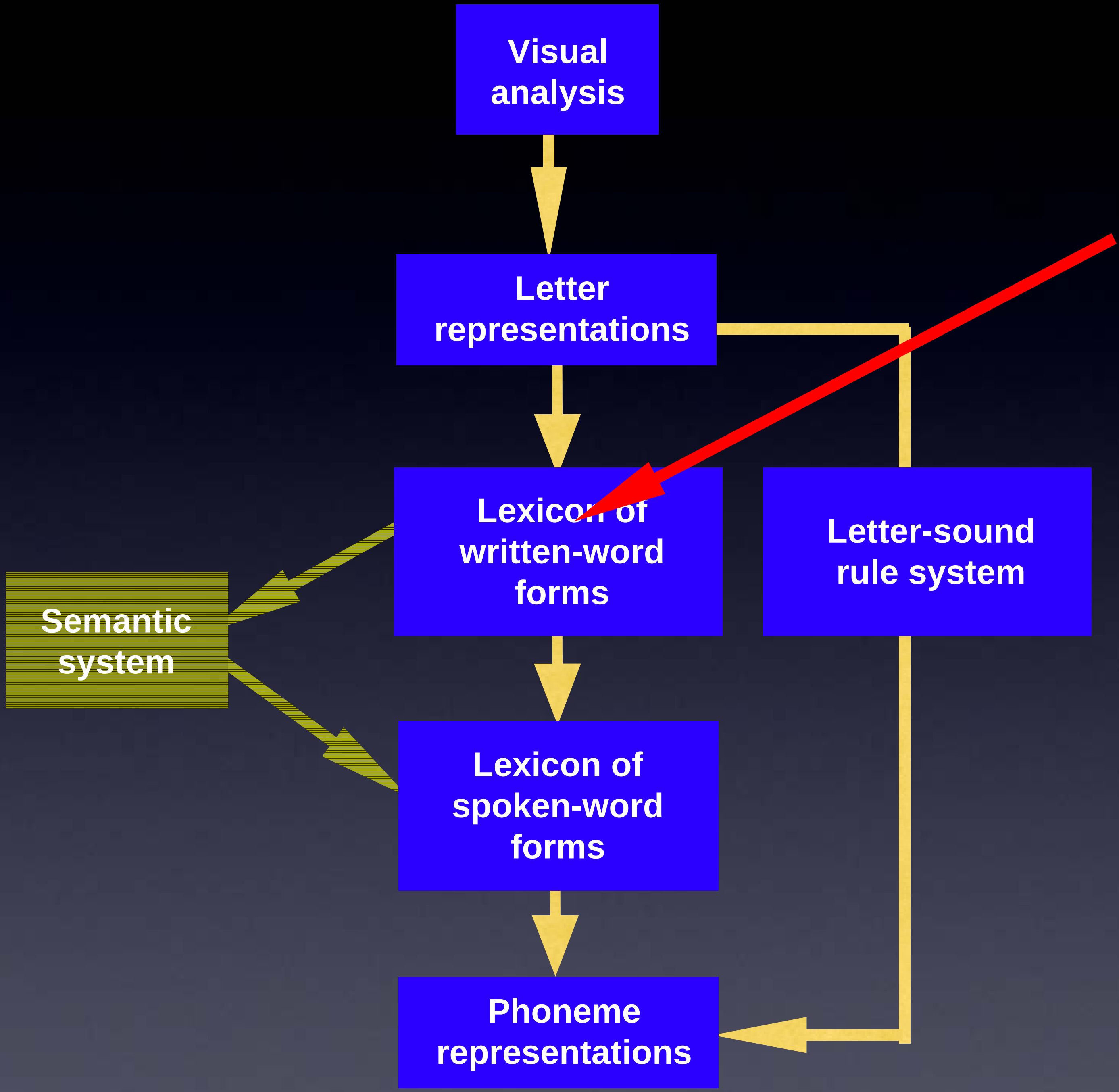
Surface dyslexia: a relatively mild case



Surface dyslexia: a more severe case



Simulating surface dyslexia

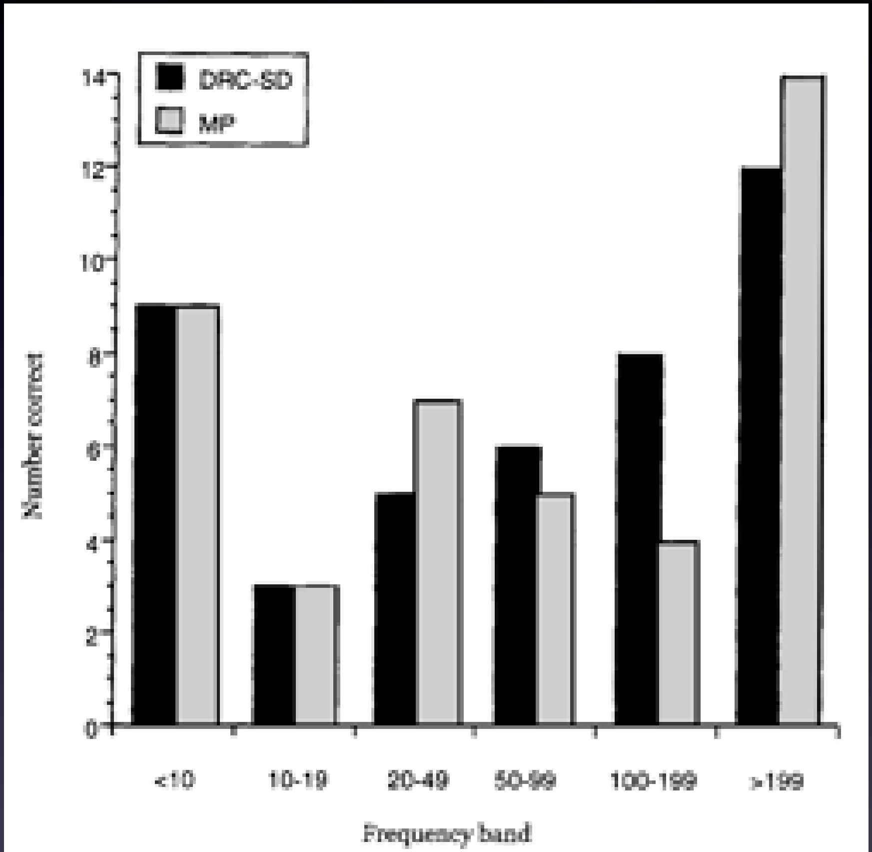


Reducing the sensitivity to letter input of the entries in this lexicon causes the output of the system sometimes to be generated by the rule system, especially when words are low in frequency

So irregular words will be misread, especially when they are low in frequency

The greater the reduction in sensitivity, the more severe the problem with reading irregular words will be

Reading of regular words and nonwords will remain normal



DRC-SD
MP
14
12
10
8
6
4
2
0
Number correct
<10
10-19
20-49
50-99
100-199
>199
Frequency band

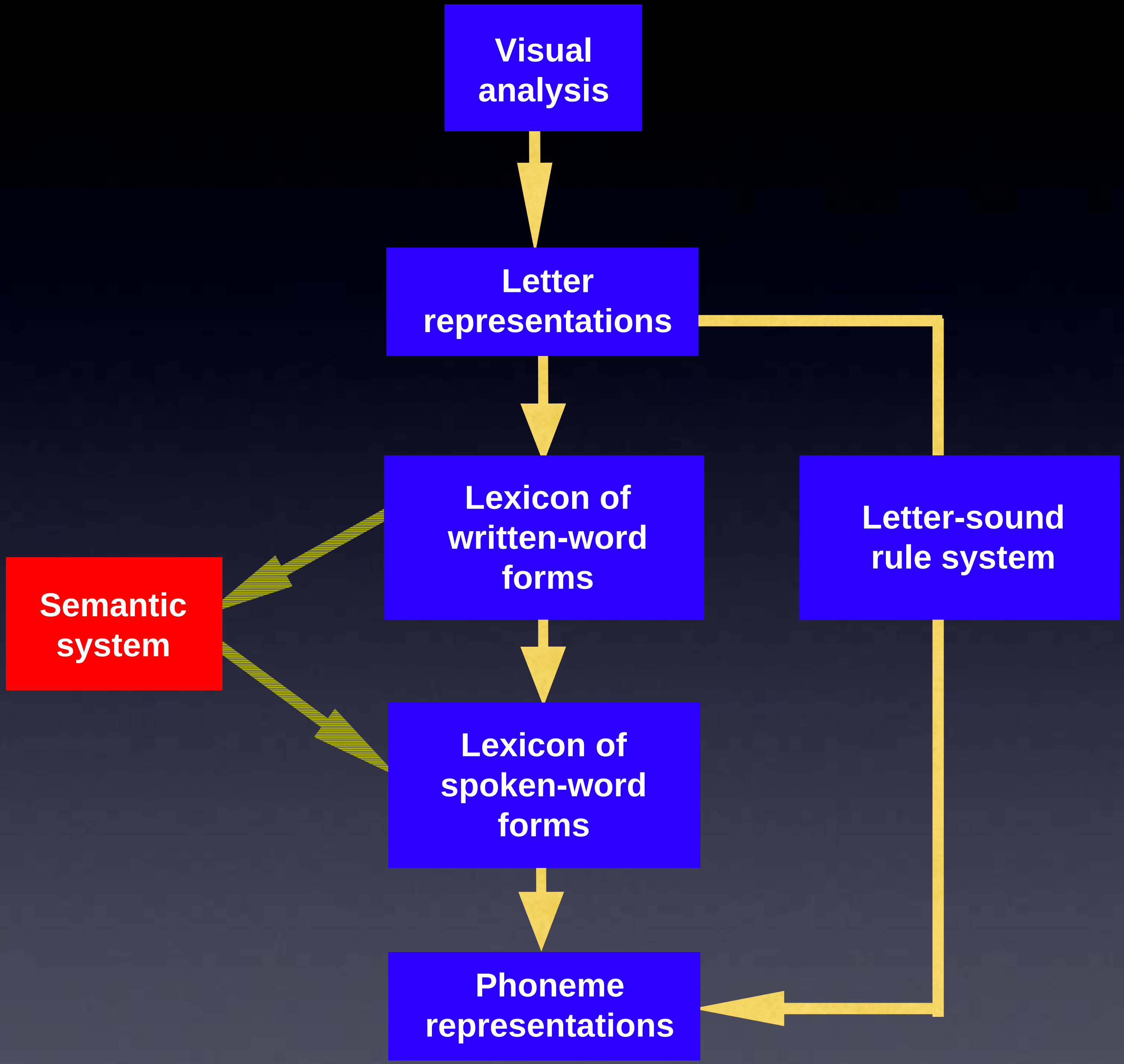
Simulating reading in semantic dementia

Semantic dementia is a progressive brain pathology whose first symptom is increasingly poor ability to understand spoken or written words.

Speech is fluent but empty. Although reading comprehension is impaired, reading aloud at the early stage of the disease is preserved.

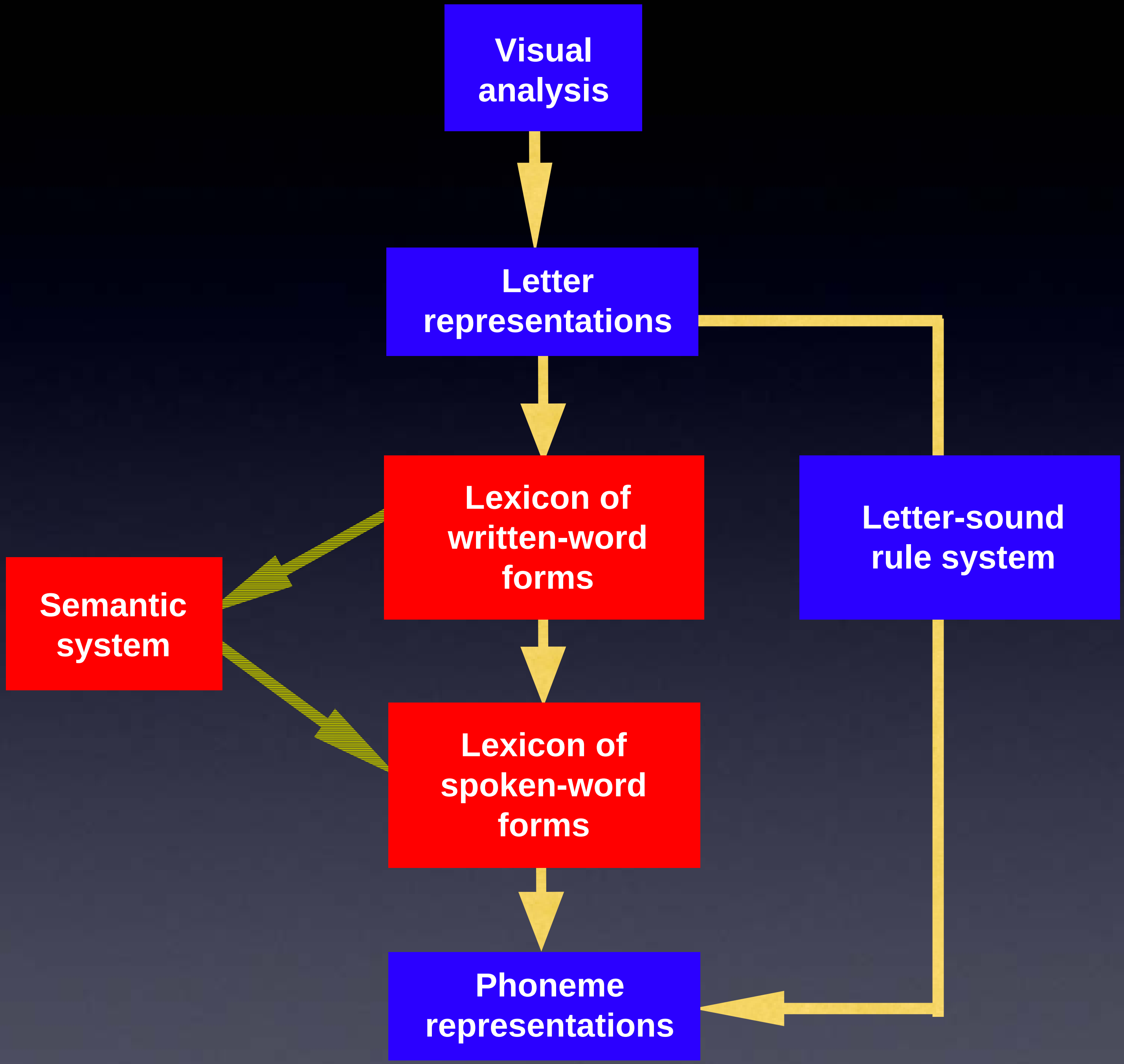
As the disease progresses, impaired reading develops

Simulating reading in semantic dementia



Phase 1: comprehension of written and spoken words impaired but reading aloud still normal

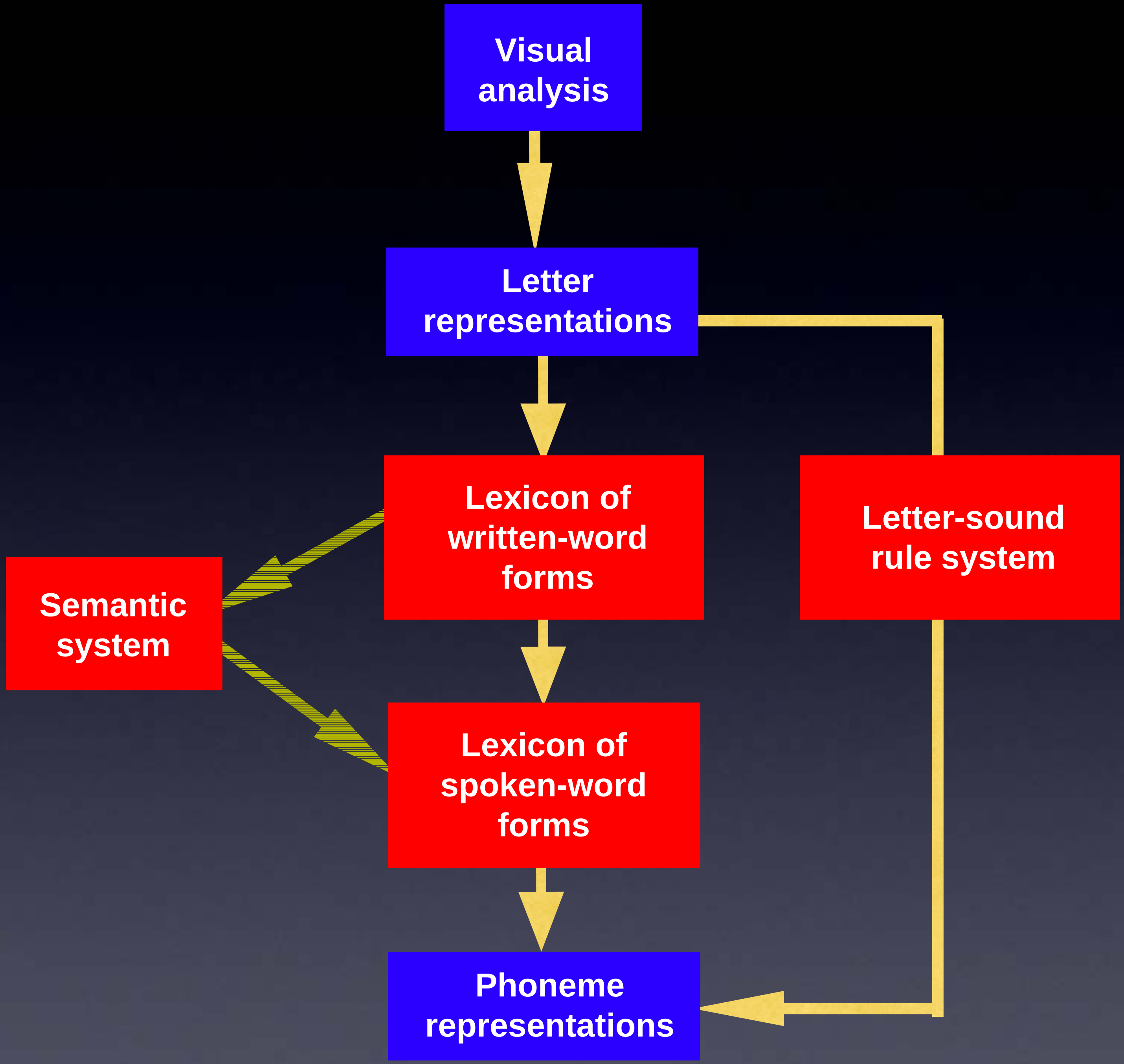
Simulating reading in semantic dementia



Phase 2: comprehension of written and spoken words impaired.

Surface dyslexia: reading aloud of irregular words is impaired but reading aloud of regular words and nonwords intact

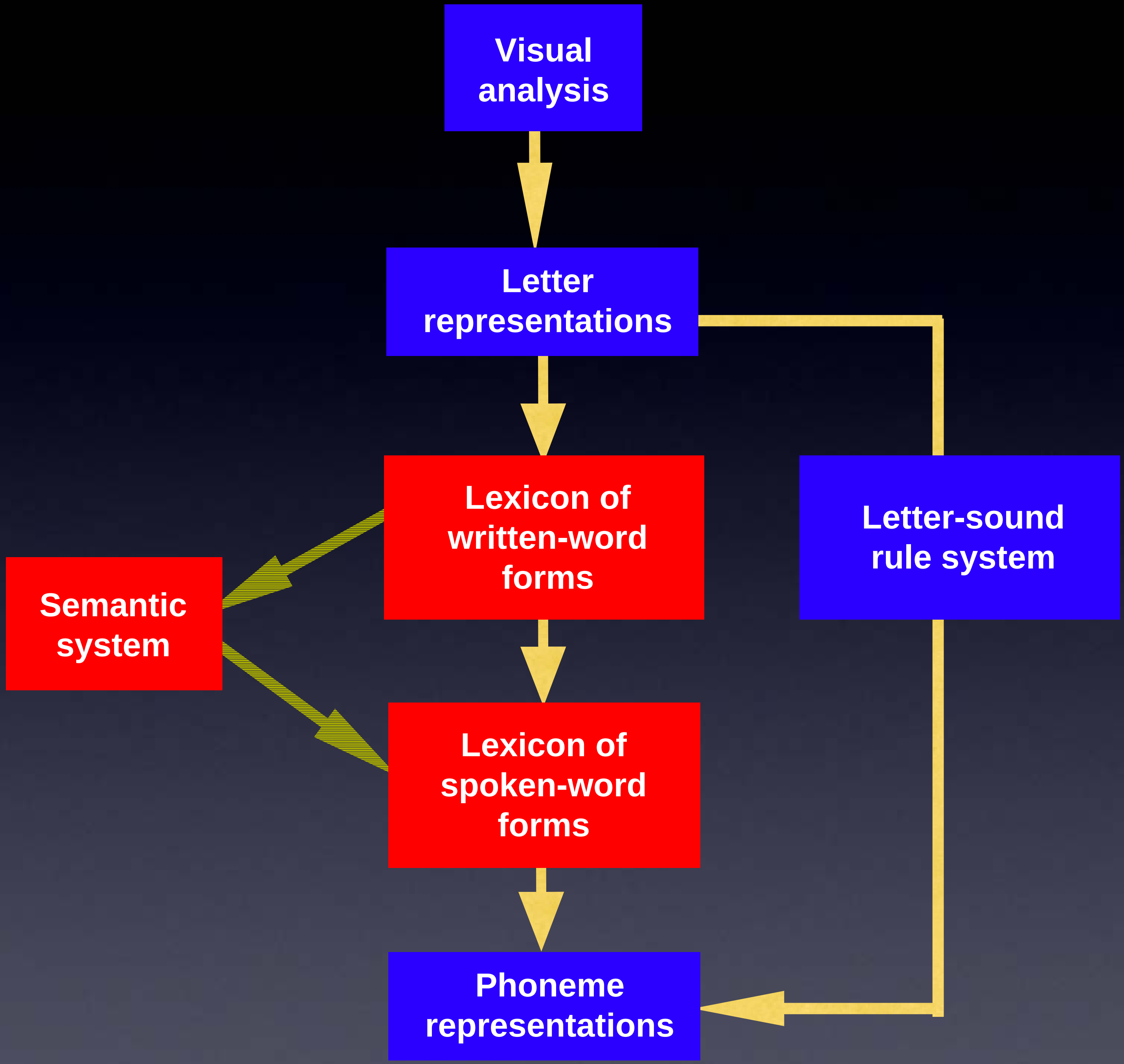
Simulating reading in semantic dementia



Phase 3: comprehension of written and spoken words impaired.

Impaired reading aloud of irregular words, regular words and nonwords.

Simulating reading in semantic dementia

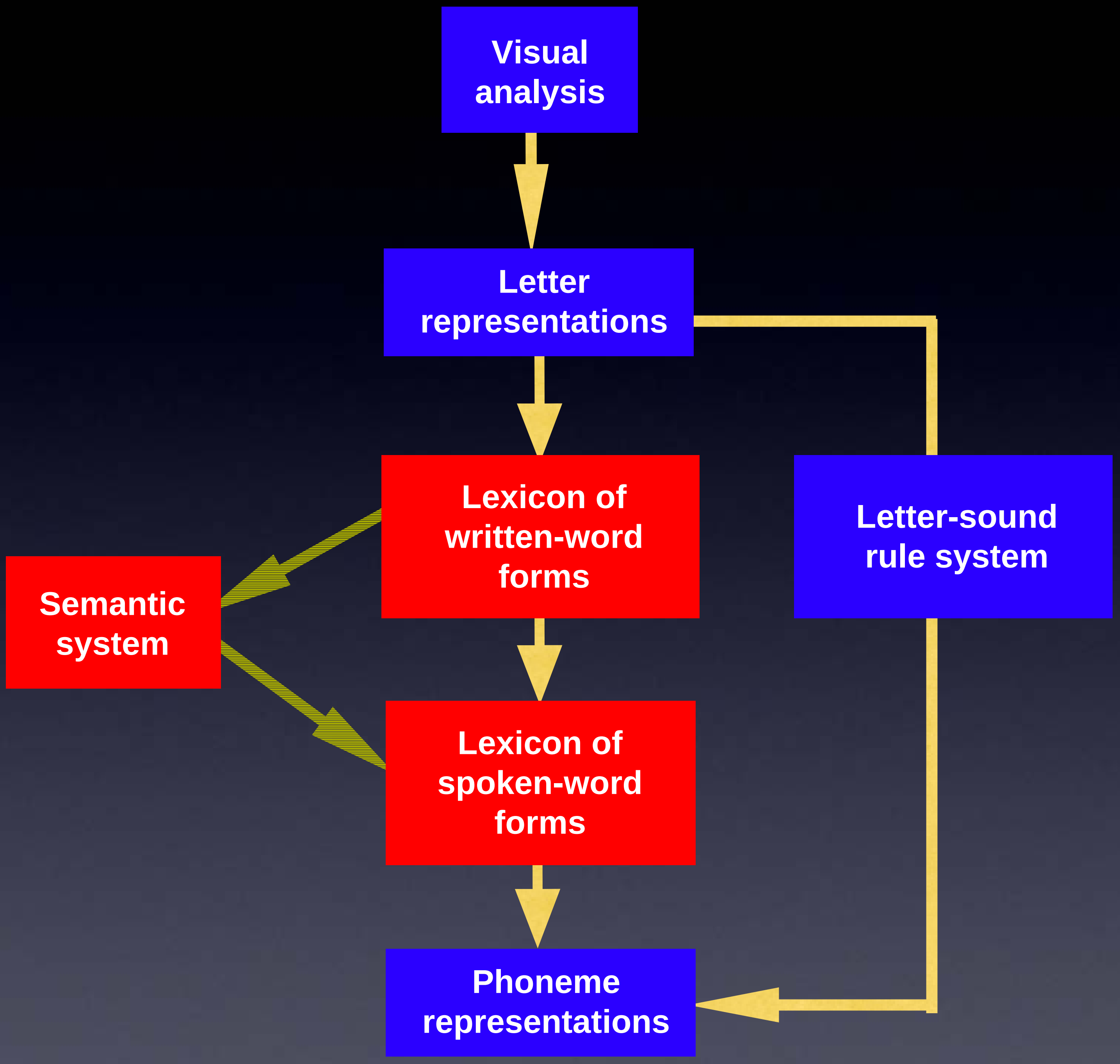


Phase 2: comprehension of written and spoken words impaired.

Surface dyslexia: reading aloud of irregular words is impaired but reading aloud of regular words and nonwords intact

A PREDICTION!

Simulating reading in semantic dementia



A PREDICTION!

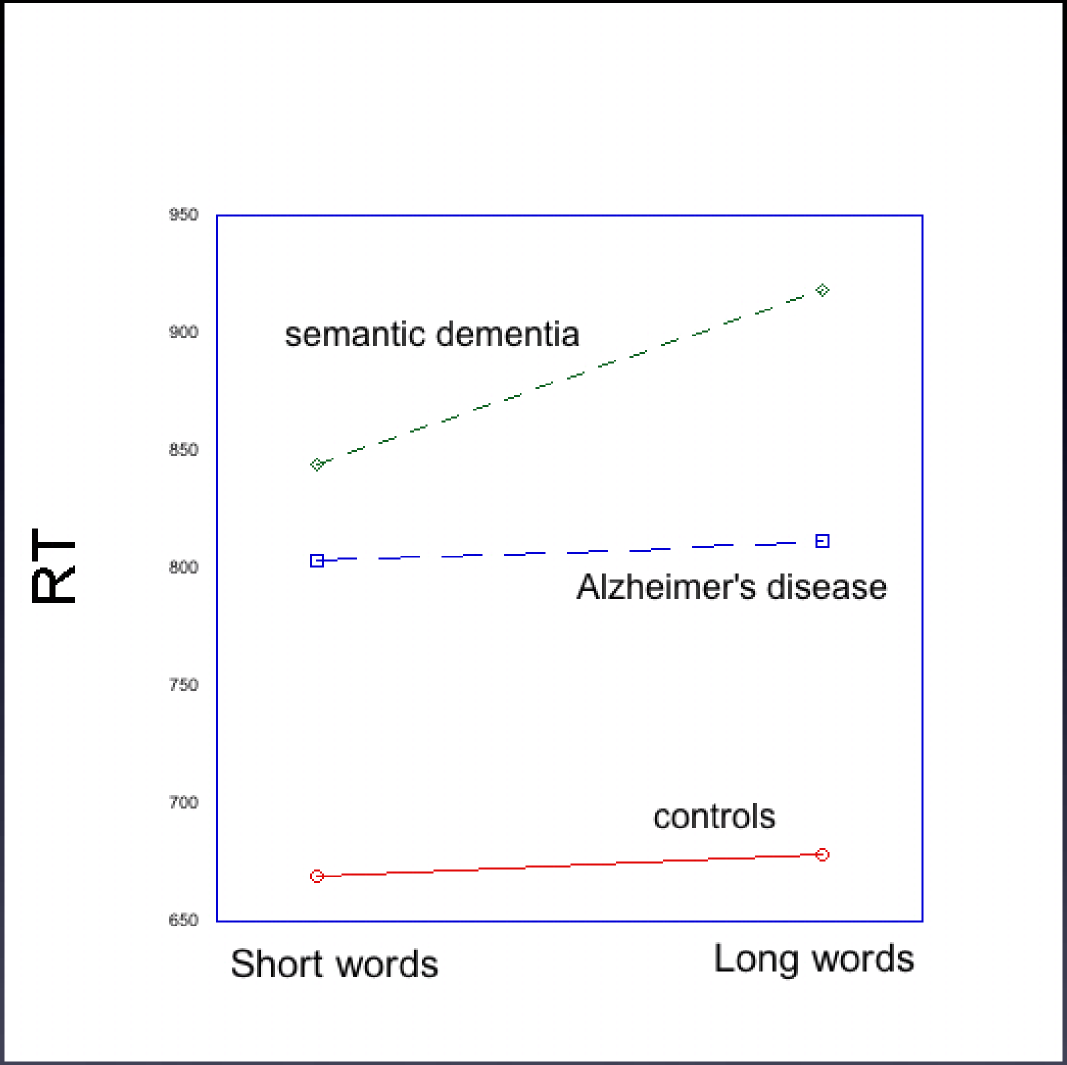
Patients and normals are 100% correct at reading regular words

But patients are relying greatly on the letter-sound rule system to do this while normals are relying on the lexicons

Since the rule system operates from left-to-right, time to generate a reading response will depend heavily on number of letters

Therefore patients' reading-aloud latencies for regular words should be much more influenced by number of letters in the word than is the case with

Effect of word length on reaction time to read regular words



Gold, Balota et al, *Neuropsychologia,* 2005

Growing a modular model of language processing at the single-word level from neuropsychological data; and making it computational.

• The first part of this endeavour has been going on since the late 19th Century (Lichtheim, Wernicke)

• The comprehensive model I describe here has gradually grown from the original Wernicke-Lichtheim model (which was only about spoken word comprehension and production)

• In recent years, parts of this model have been developed in computational form, particularly in relation to visual word recognition and reading aloud

• This modelling endeavour
• is highly modular in approach,
• uses local rather than distributed representations, and
• does not assume that all processing is parallel processing