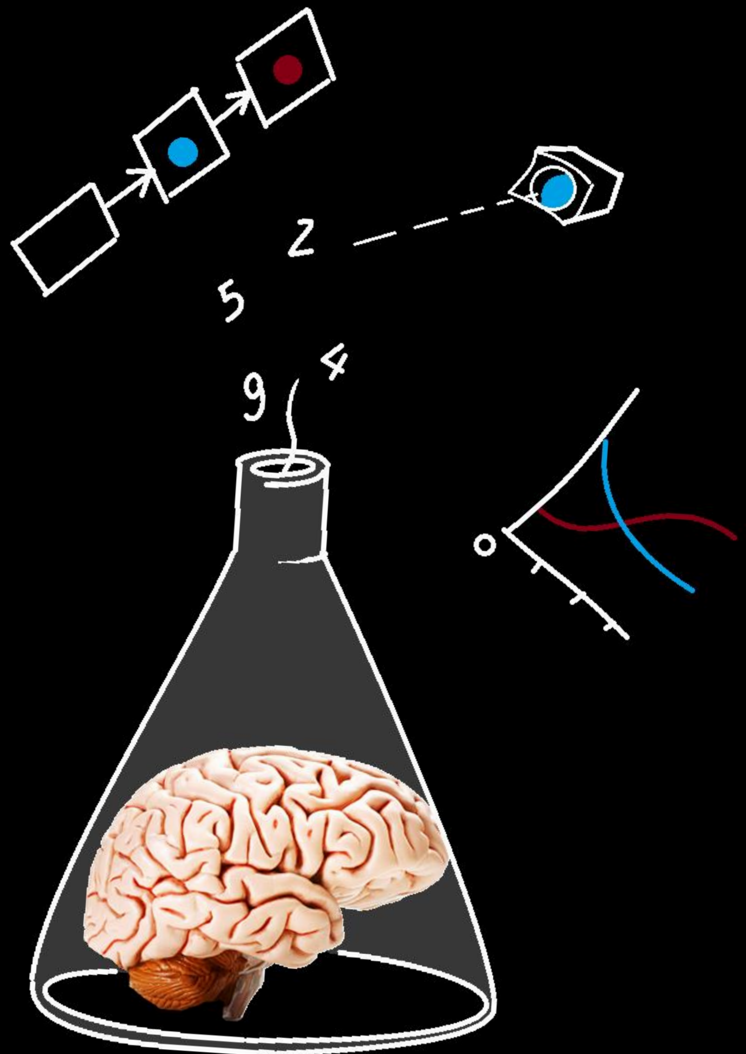
21-09

Response time, accuracy & signal detection theory

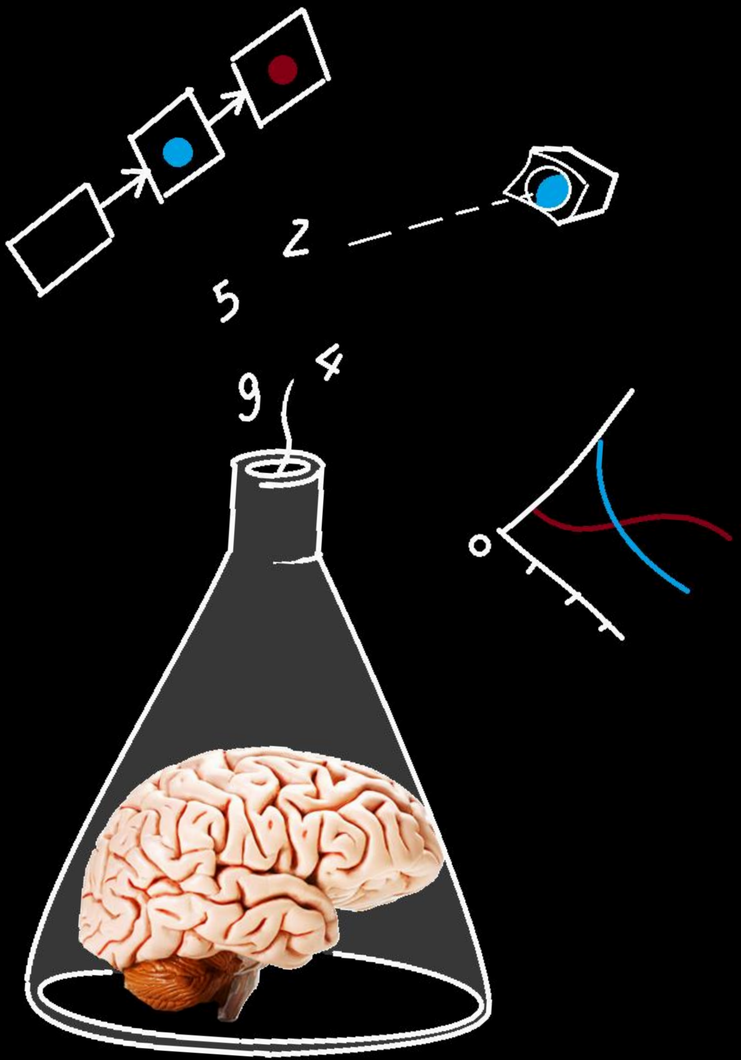


21-09

Practical points

- Start implementing your experiment
- Helpdesk opened on Canvas > Discussions

- Recorded lecture *Memory & Decision-making* online tomorrow
- Monday 25th: eye-tracking & pupillometry



Response times

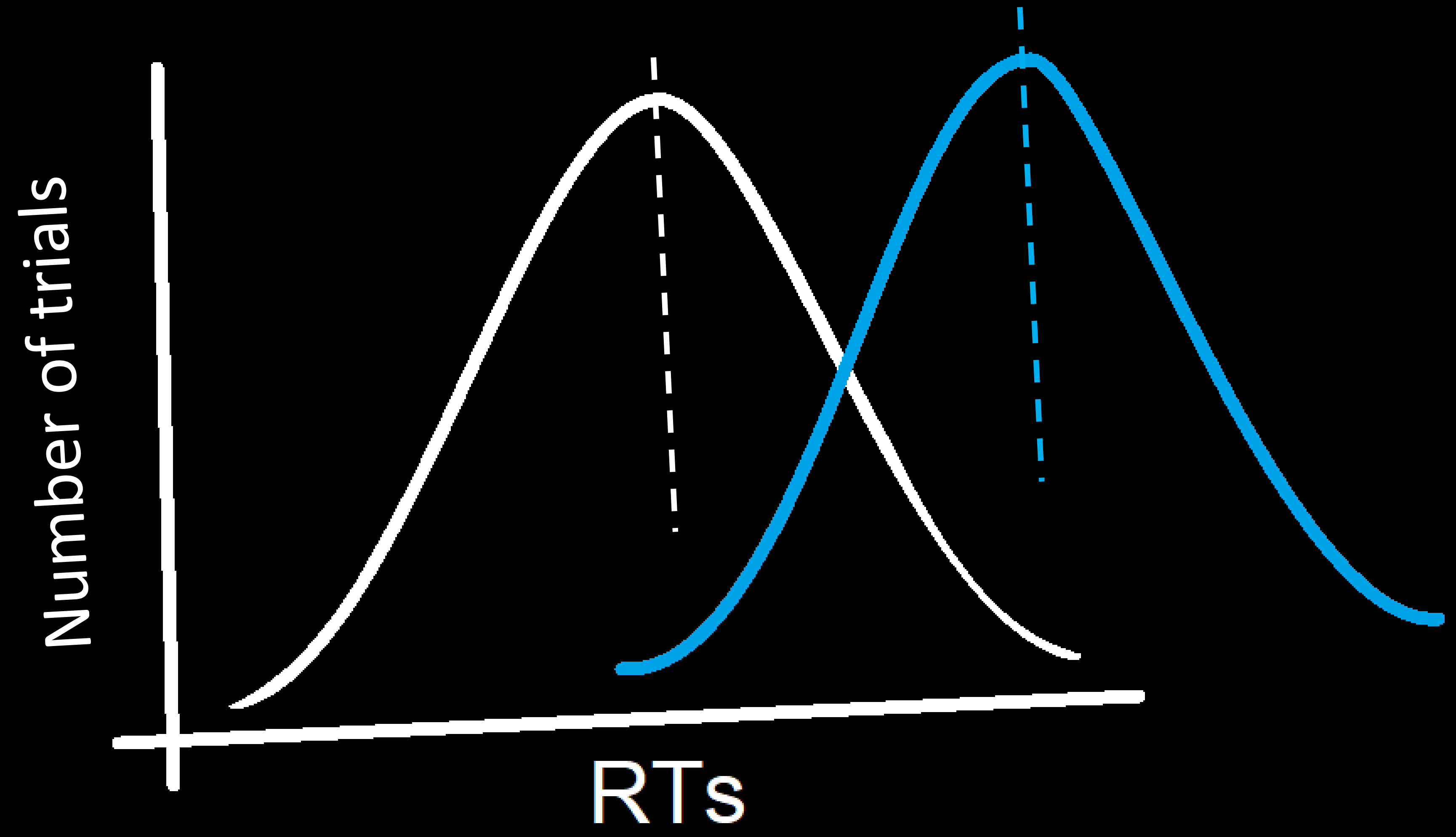
input input

input

response
output

Response times

Certainty that an effect exists depends not just on the means, but on the spread.
→ The extent to which distributions overlap



Response times

What we typically do in processing RTs:

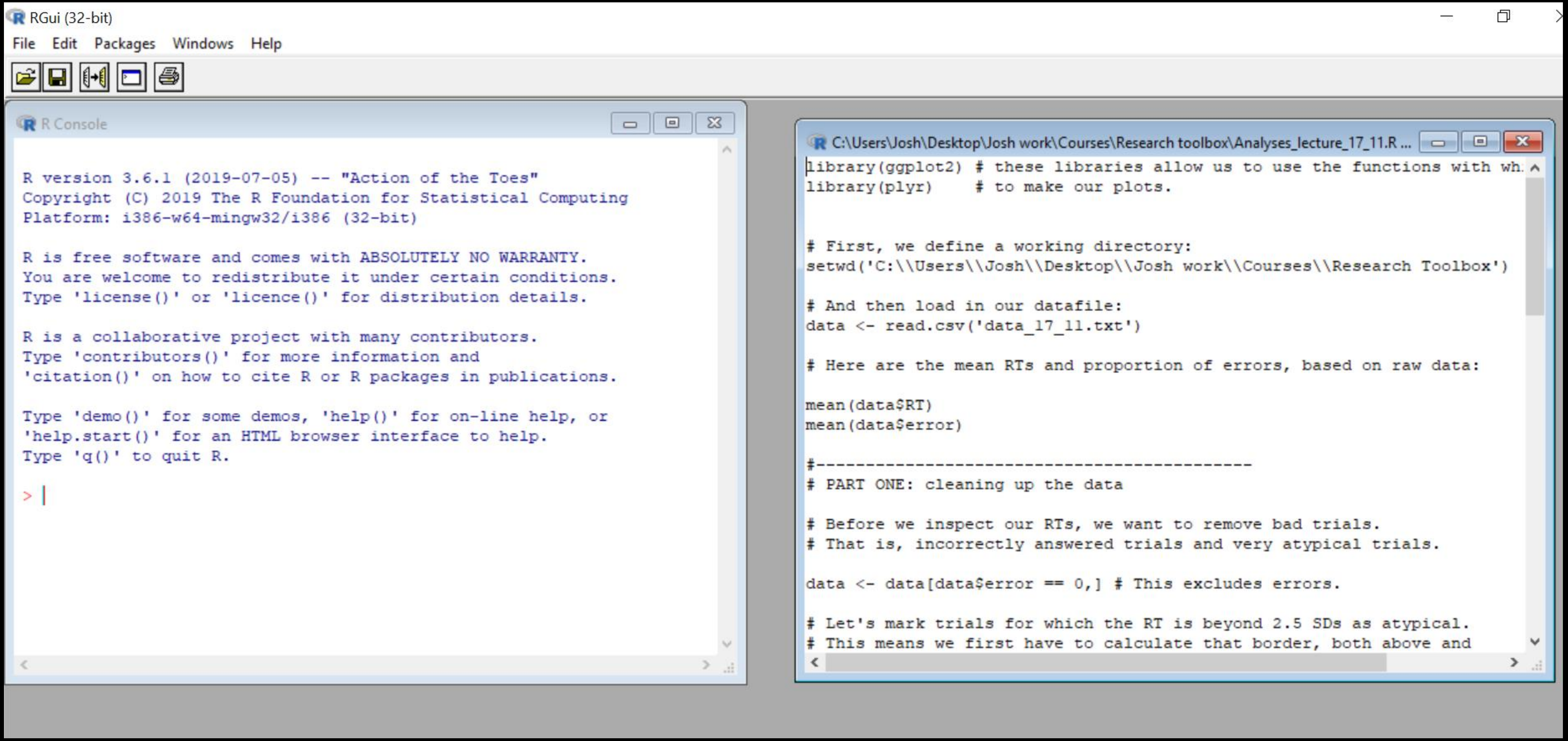
- exclude incorrectly answered trials
- exclude very atypical trials (i.e., trials with RT beyond several SDs from the mean)

From today's module, download data_21_09.txt and Analyses_lecture_21_09.R

Response times

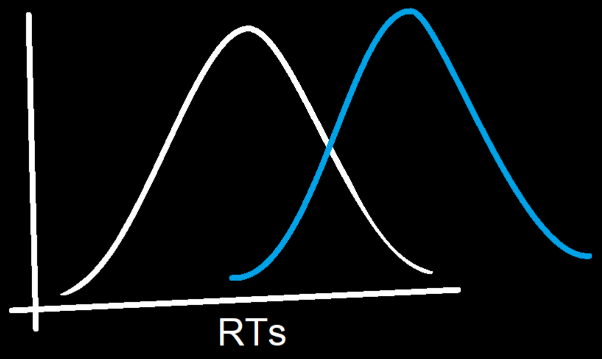
From today's module, download data_21_09.txt and Analyses_lecture_21_09.R

Execute any command by selecting it and pressing ctrl+r

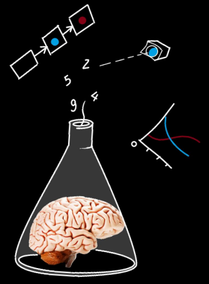


Response times

Is this all that there is to RTs?



Distributions could reveal more information
→ A difference between two response conditions may be more strongly expressed in the faster portion of RTs than in the slower portion.
(Gomez & Perea, 2020)



Response times

A case study: the Stroop task (Stroop, 1935)

Word meaning impacts processing of the word's print color – and vice versa

RED RED BLUE BLUE

Response times

Let’s check it out ourselves with a (simulated) experiment

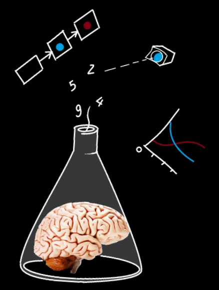
Participants saw the words RED and BLUE, in red or blue print. In one block, they responded the meaning of the word. In another block, they responded the print colour of the word.

H: slower responses when the meaning and color don’t match

RED RED BLUE BLUE

Response times

data_21_09.txt on Canvas in today’s module
Analyses_lecture_21_09.R in today’s module



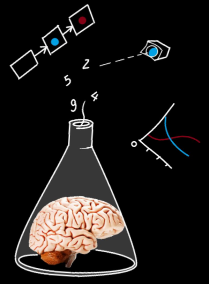
Response times

data_21_09.txt on Canvas in today’s module
Analyses_lecture_21_09.R in today’s module

When calculating the mean response times (RTs) in each condition, we indeed see effects of meaning/print congruency:

meaning decision
congruent: 587 ms
incongruent: 611 ms

print decision
congruent: 489 ms
incongruent: 510 ms



Response times

data_21_09.txt on Canvas in today's module
Analyses_lecture_21_09.R in today's module

Are these two effects the same thing, cognitively speaking?
→ Let's look at some density plots

meaning decision
congruent: 587 ms
incongruent: 611 ms

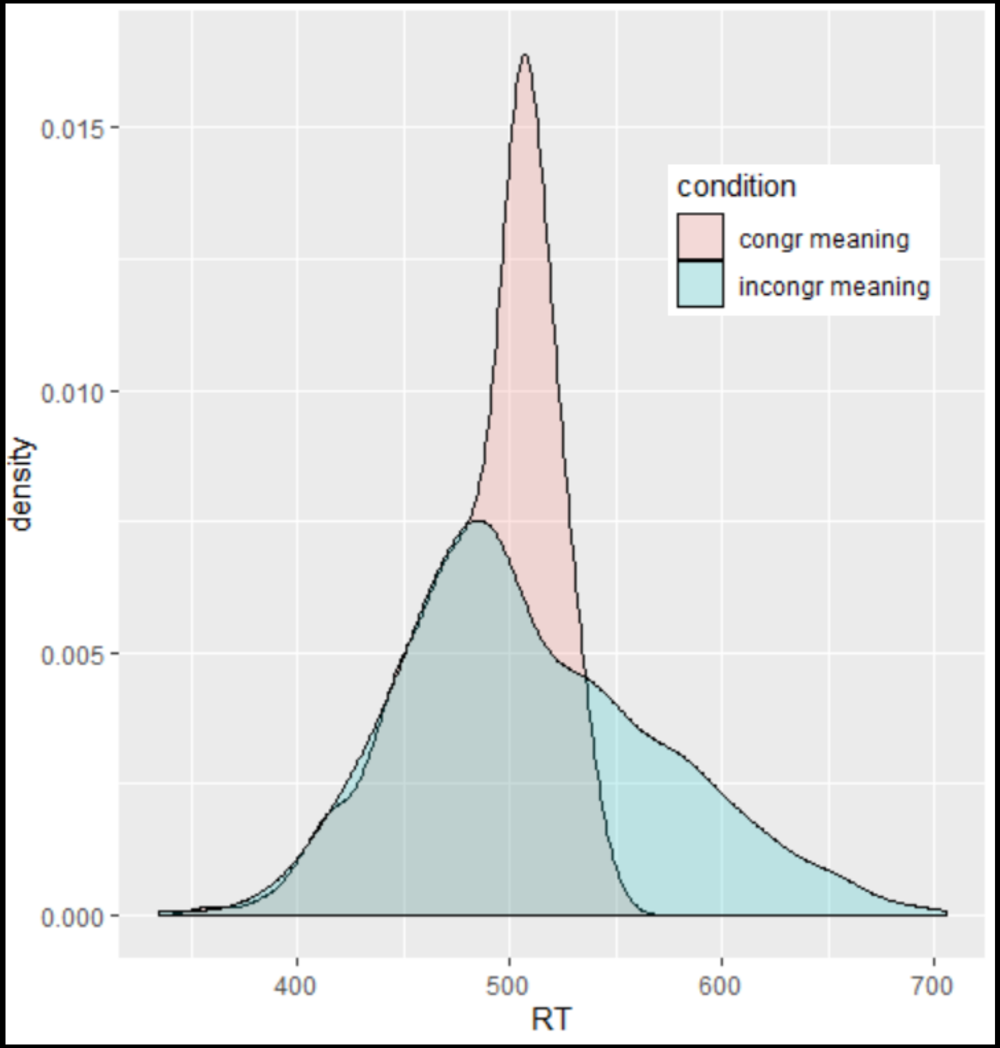
print decision
congruent: 489 ms
incongruent: 510 ms

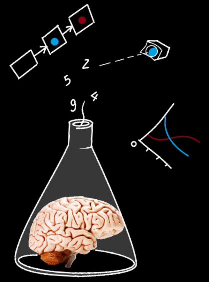
Response times

Early RTs are very similar between conditions, late RTs differ a lot.

...so this effect has a late temporal locus.

Decisions about stimulus color



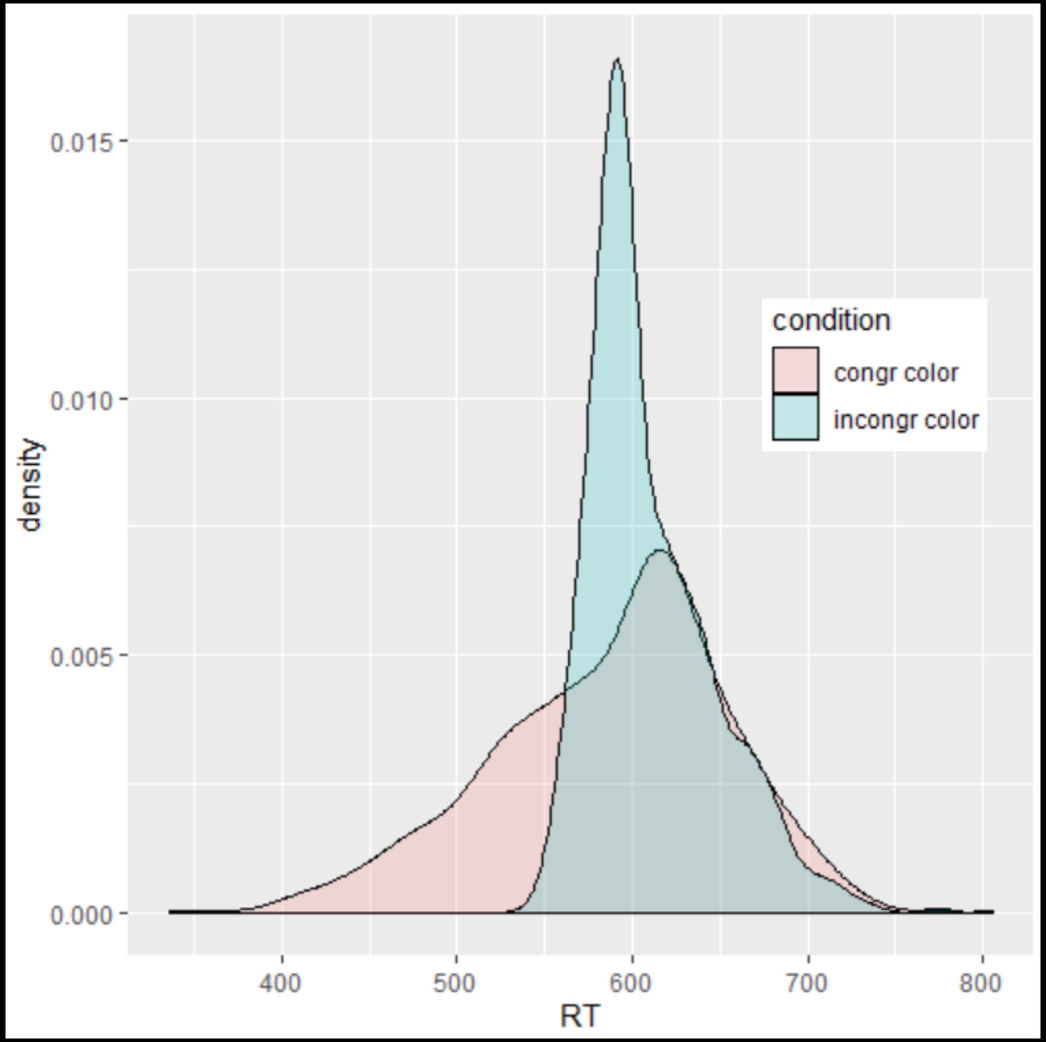


Response times

Late RTs are very similar between conditions, early RTs differ a lot

...so this effect has an early temporal locus.

Decisions about word meaning

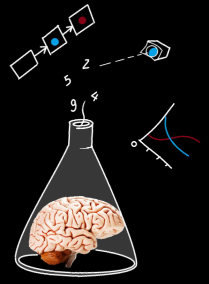


Accuracy

Analyses of accuracy are often regarded as being interchangeable with analyses of RT. (better performance: shorter RTs and fewer errors)

In most behavioral tasks we look at both. Having more measures provides a broader picture.

Sometimes we only look at one measure. (e.g., many lines of memory research)



Accuracy

Is it problematic if we find an effect in accuracy but not in RTs?
→ No.

Persons A and B are equally fast, but A is more accurate: A performed better

A and B are equally accurate, but A did it quicker: A performed better.

Accuracy

Is it problematic if opposite effects are found in accuracy and RT?
→ Yes.
Person A is better at shooting, but person B is better at skiing. We cannot tell who is the better biathlete.

Combining RTs and accuracy
Inverse efficiency scores

Combining RTs and accuracy into one measure (IES) may allow us to make better direct comparisons.

$$\textbf{IES = RT / P}_{\textbf{(correct)}}$$

RT = 500 ms, accuracy = 0.90 → IES = 500/0.90 = 556 ms.

RT = 480 ms, accuracy = 0.80 → IES = 480/0.80 = 600 ms.

A deeper look into accuracy

Signal detection theory

Only applicable in the context of binary decisions

A deeper look into accuracy
Signal detection theory

A more elaborate measure of accuracy: *Sensitivity*

The world around us is noisy
→ How well can we distinguish the relevant from the irrelevant?

Sensitivity doesn't only look at our ability to spot the relevant, but also at our ability to ignore the irrelevant

What is the key challenge in perception?

To resolve ambiguity

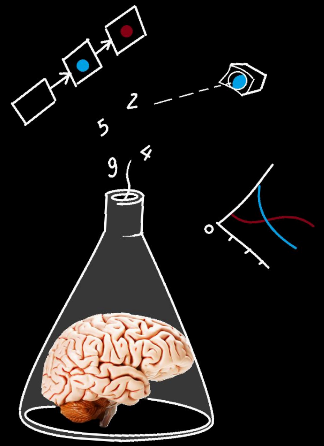
What is the key challenge in perception?

To resolve ambiguity; and to *distinguish the relevant from the irrelevant*

Signal Detection Theory:
A way to quantify perceptual skill

Why do we need to do this?

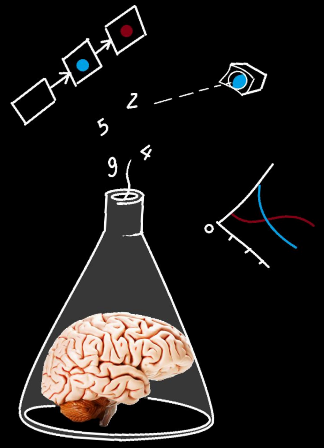
NEW YORK, 1999. Amadou Diallo, a 22-year-old immigrant from Guinea, was shot and killed by four white police officers. The officers fired a combined total of 41 shots. The officers claimed they misperceived Diallo's wallet as being a gun.



Signal Detection Theory:
A way to quantify perceptual skill

Why do we need to do this?

London, 2005. Jean Charles de Jimenez (27), a Brazilian immigrant, was shot eight times while boarding the undergound at Stockwell Underground Station. The shooters were special ops police officers looking for a known terrorist who had bombed the underground the week before. *The police admitted its mistake but reported that the victim resembled the terrorist.*



Signal Detection Theory:
A way to quantify perceptual skill

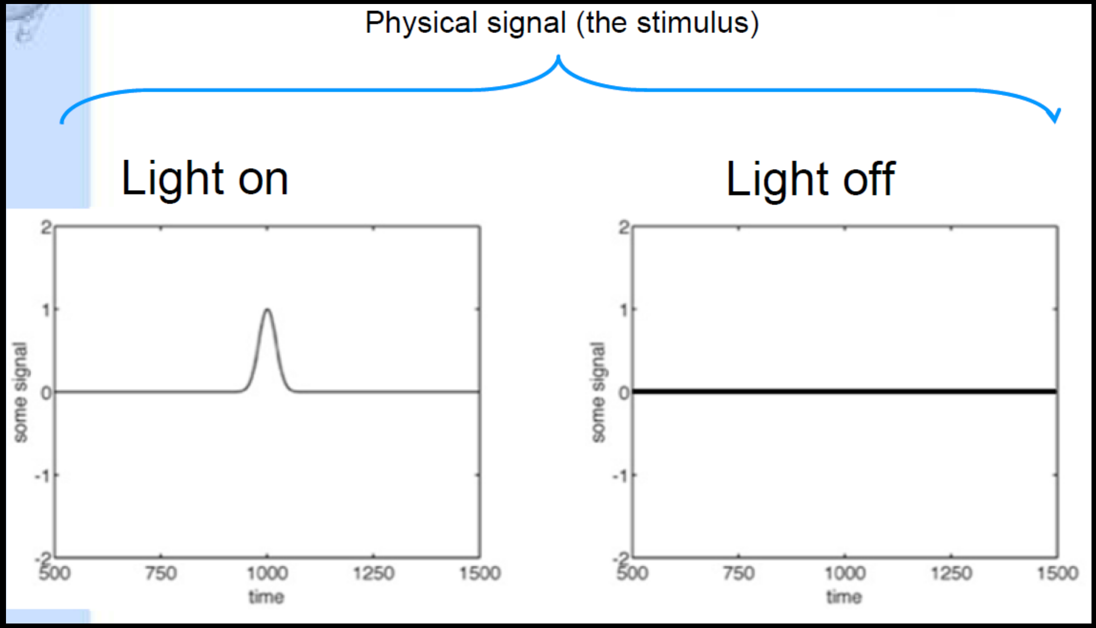
Task: push button when detecting an unnatural source of light

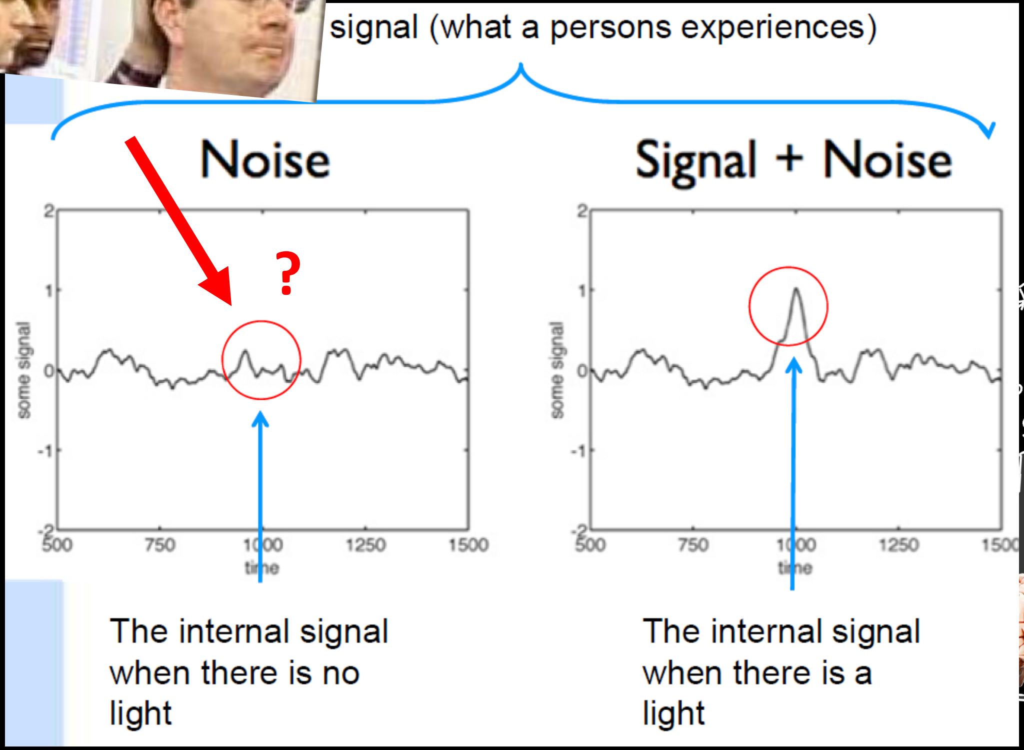
– "Simple! Simulate situation, test soldiers 100 times. If Observer A responds more often to the light than Observer B, then Observer A is the better soldier.

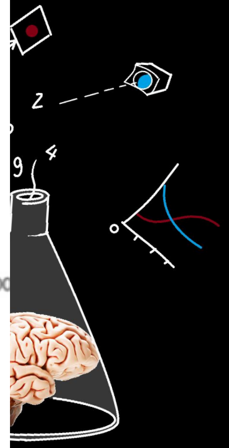
	Observer A	Observer B
Light on	Responded 81 times	Responded 62 times

Signal Detection Theory:
A way to quantify perceptual skill

BUT… the universe is noisy
and so are our senses







Signal Detection Theory:
A way to quantify perceptual skill

Who is the better observer now?

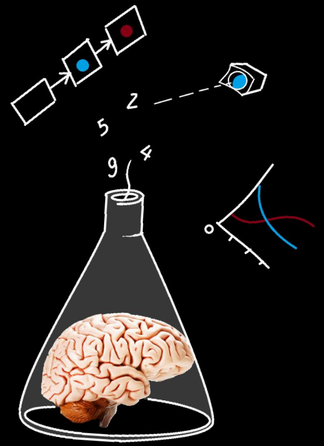
– "Simple! Simulate situation, test soldiers 100 times. If Observer A responds more often to the light than Observer B, then Observer A is the better soldier.

	Observer A	Observer B
Light on	Responded 81 times	Responded 62 times

	Observer A	Observer B
Light present	81 times	62 times
Light absent	78 times	4 times

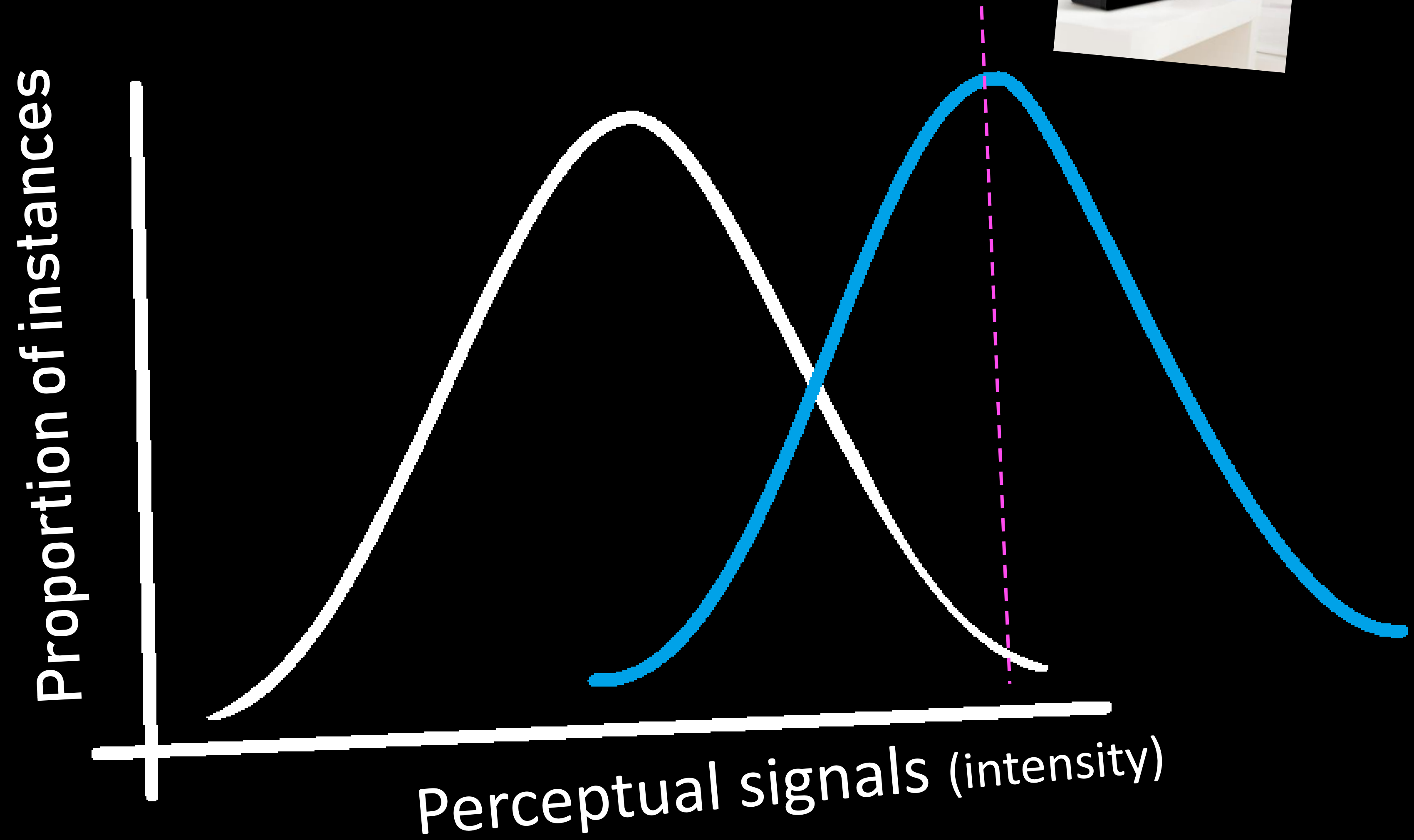
= hits

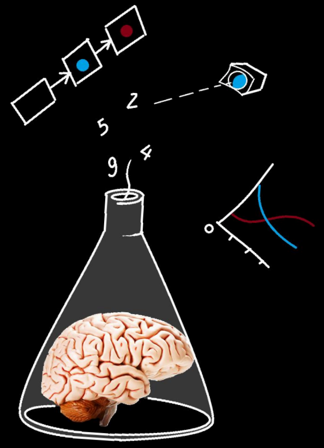
= false alarms



Sound intensity without vs. with alarm

NOISE **SIGNAL**





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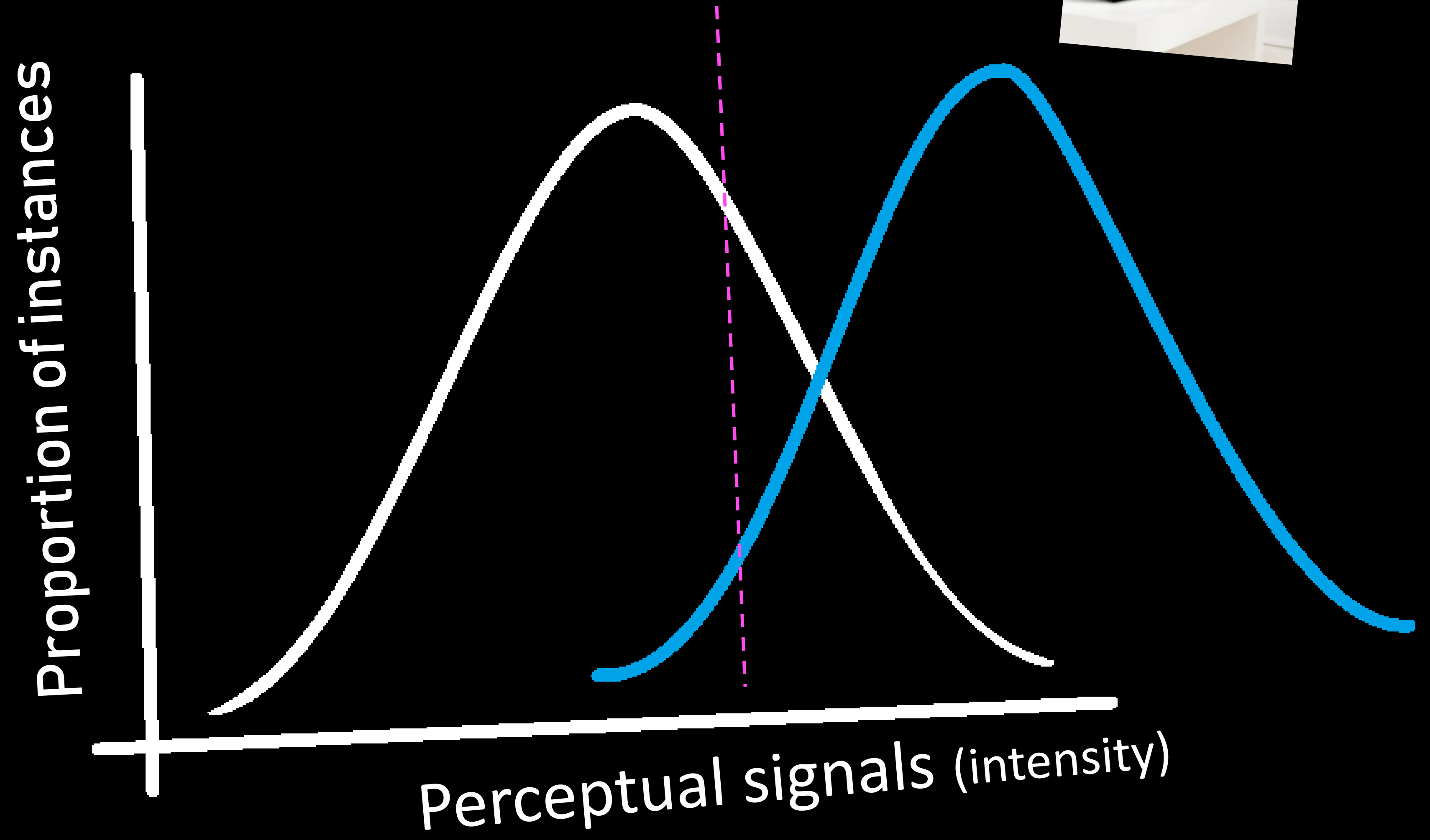

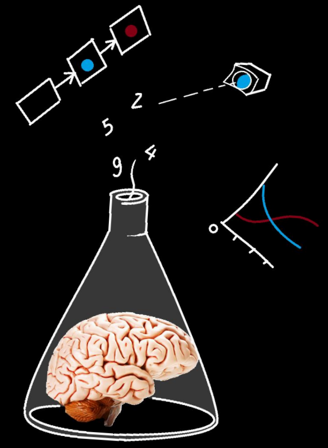

Sound intensity without vs. with alarm

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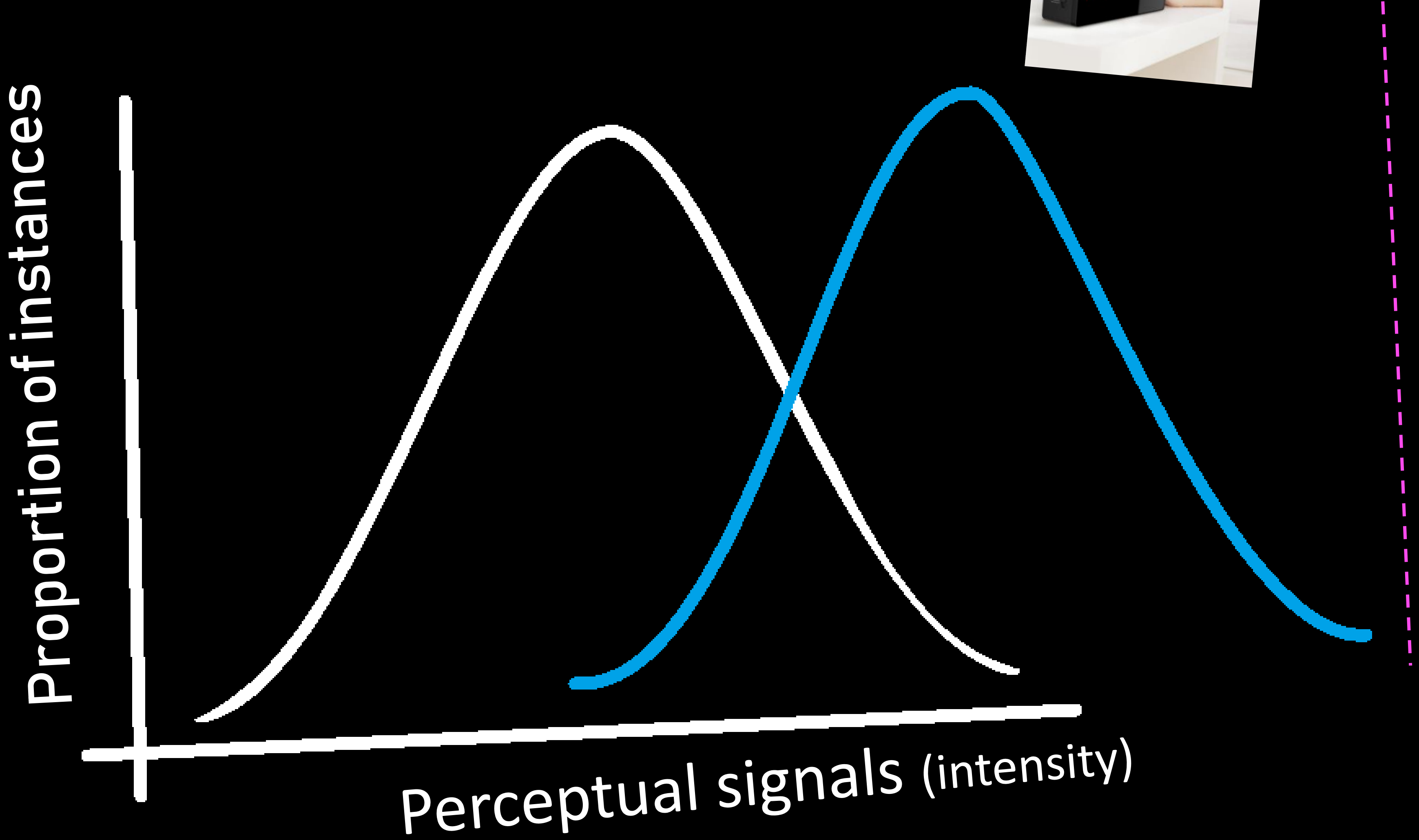
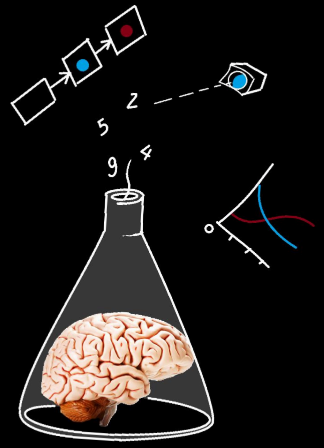
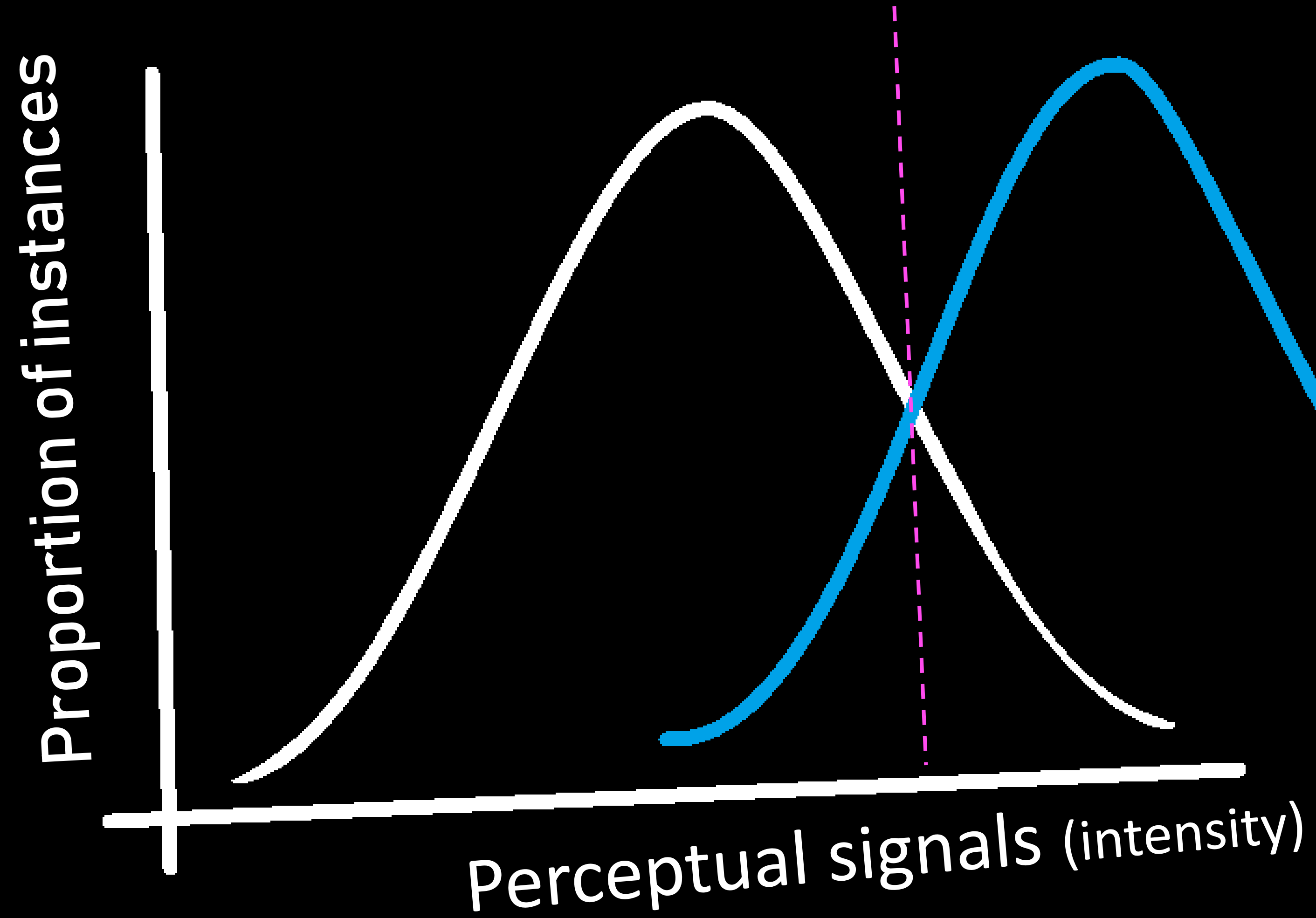
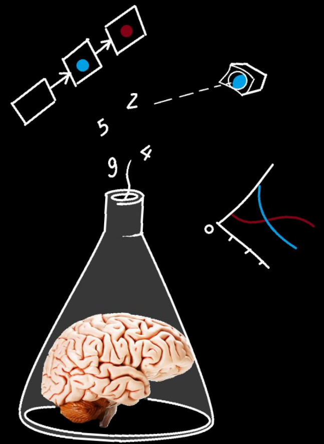




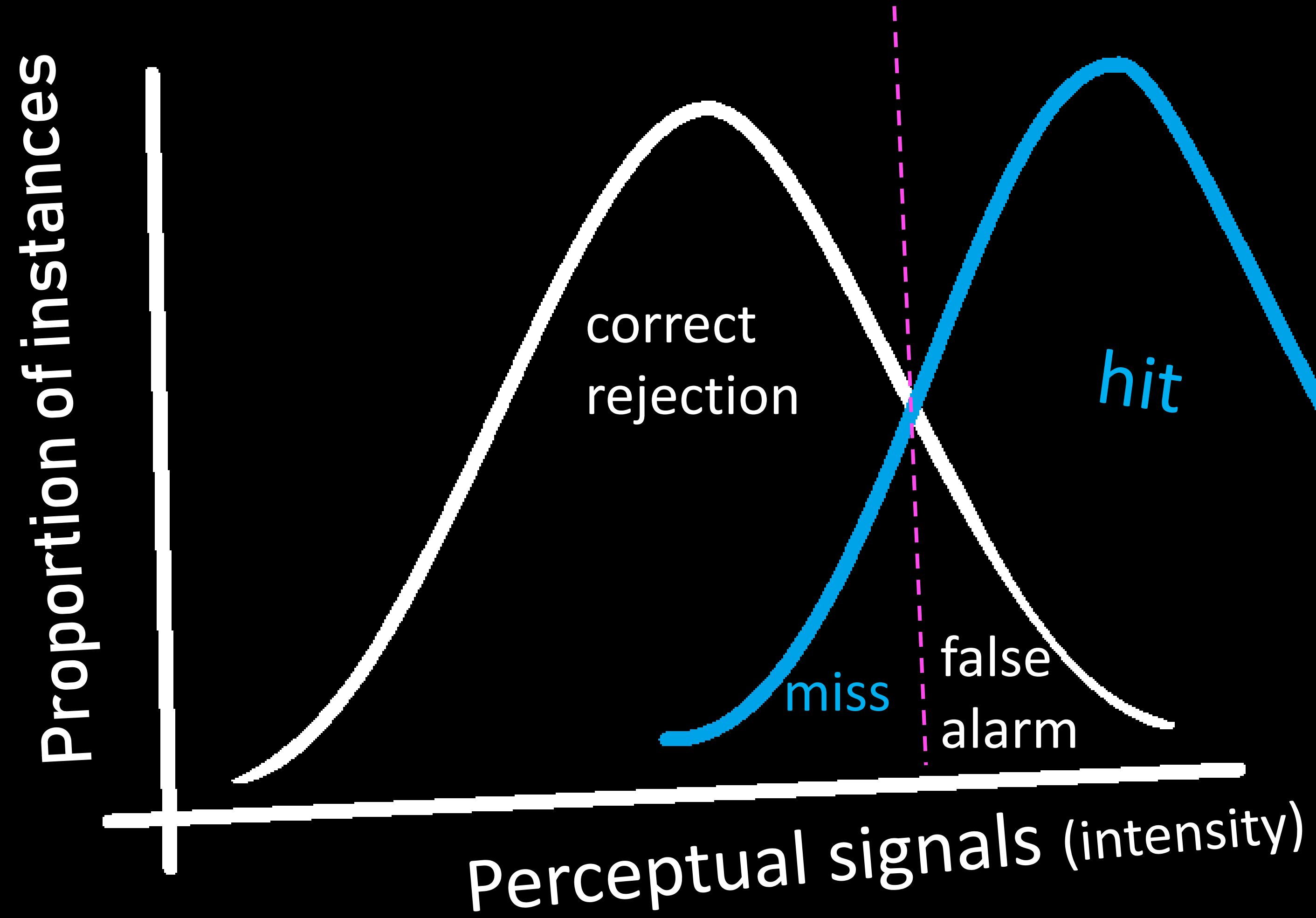
Sound intensity without vs. with alarm

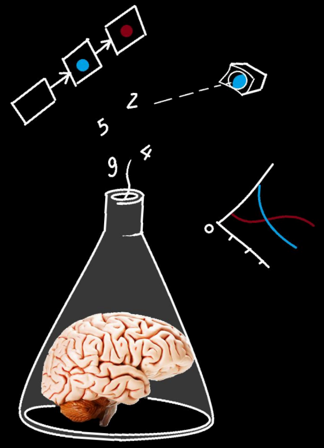
No matter where your threshold is, your ability to distinguish signal from noise is the same!





Cucumber neuron's firing rate when seeing a zuccini vs. a cucumber: *4 outcomes*

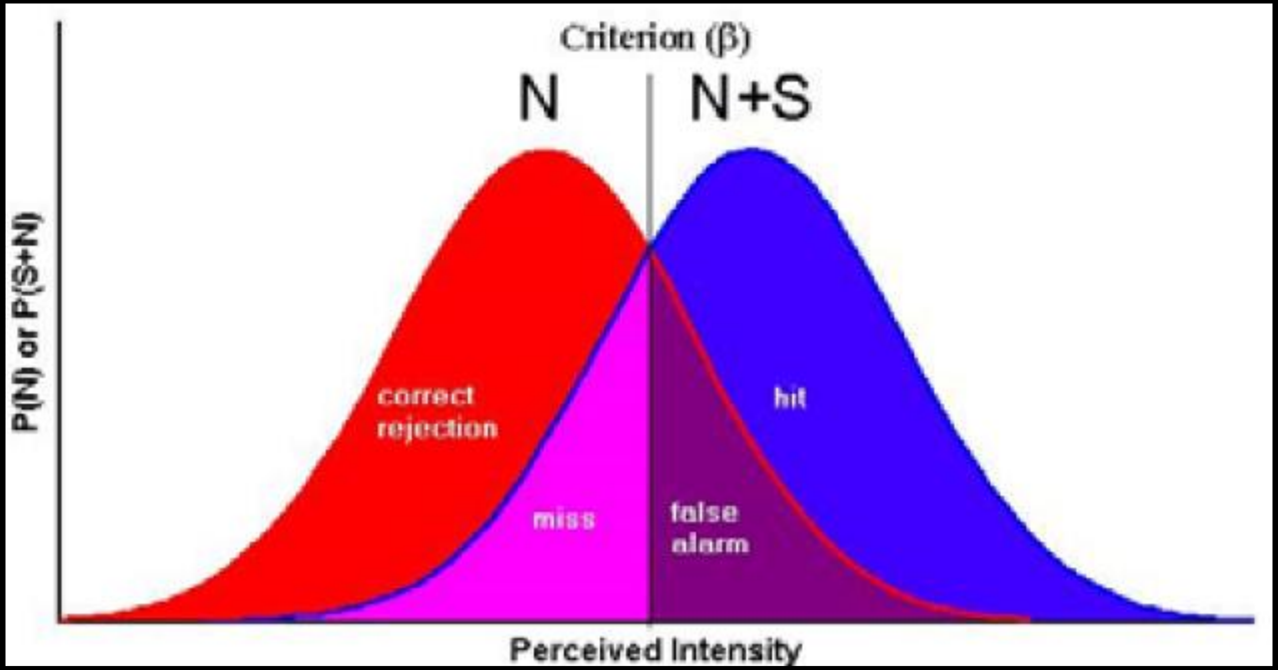


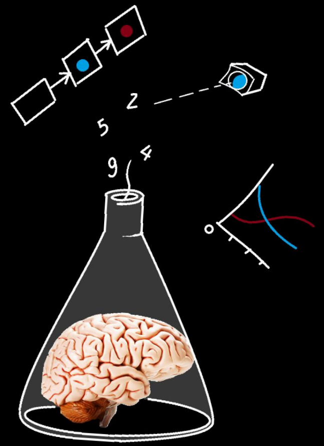


The response matrix: the proportions of hits, misses, false alarms and correct rejections depend on:

- your threshold
- the distance between signal and noise distributions

		State of the world	
		Signal	Noise
Response	Yes	Hit	False alarm
	No	Miss	Correct rejection





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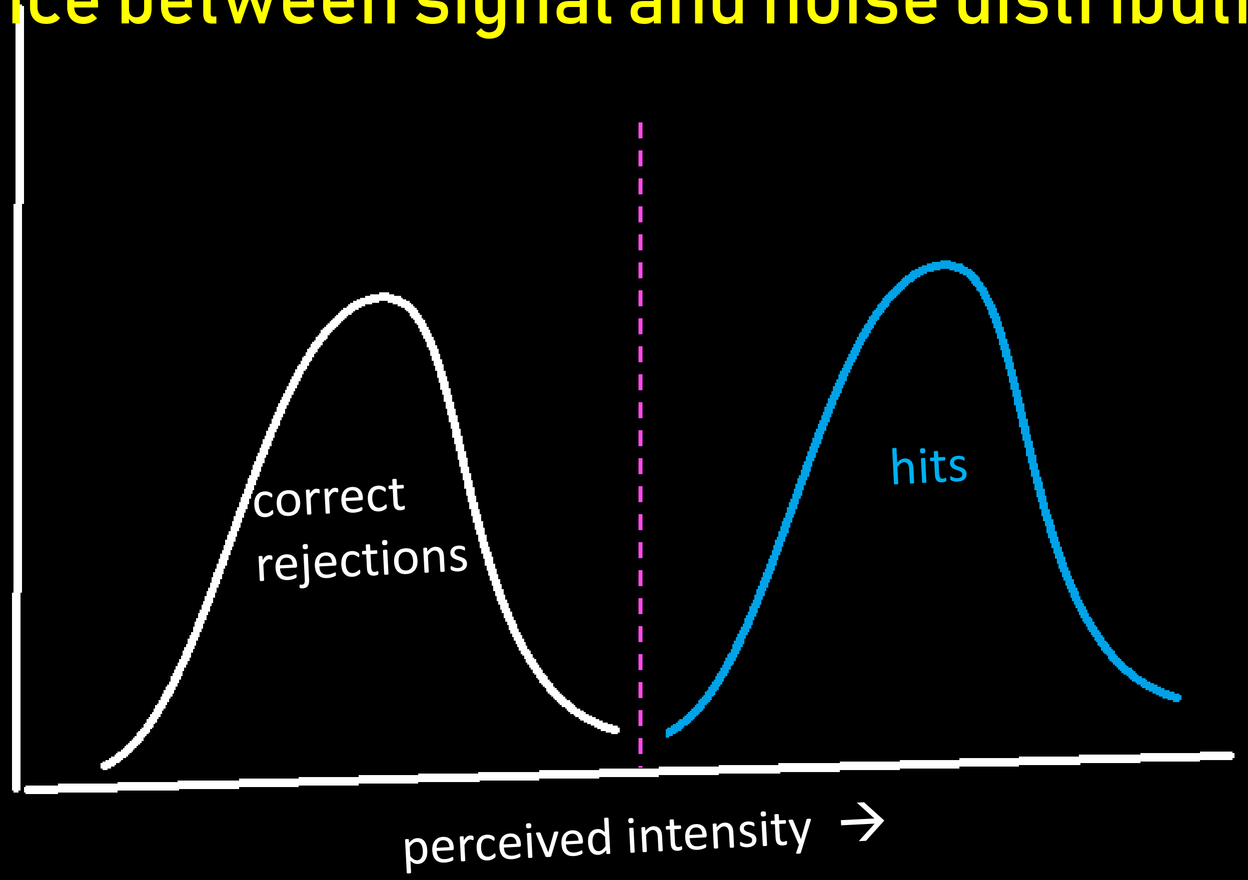
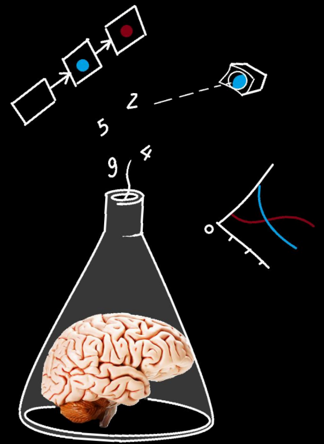
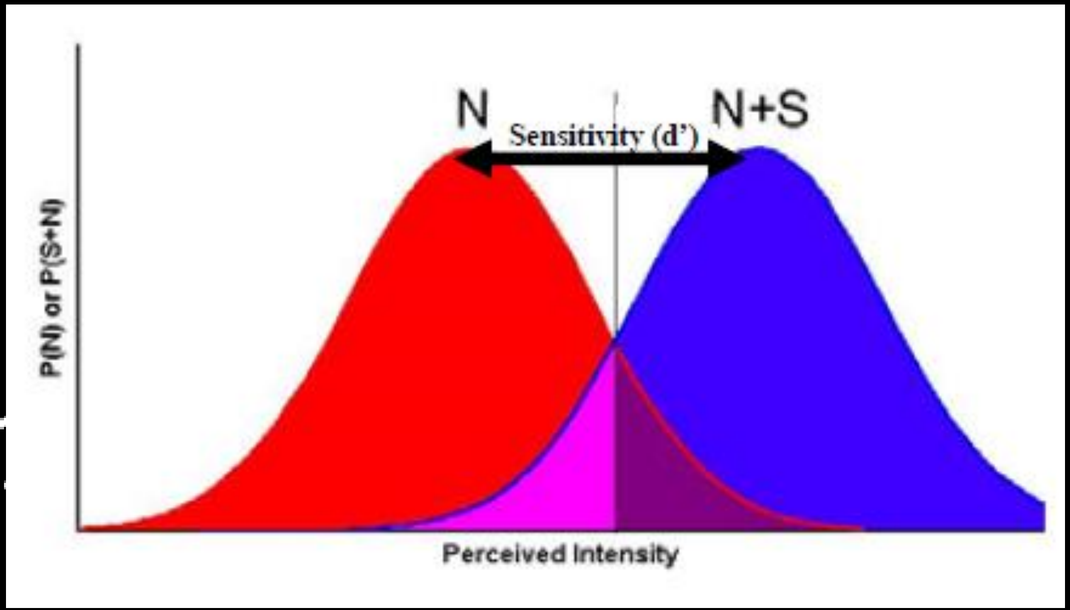




The distance between signal and noise distributions varies among individuals and is called *sensitivity*

(= perceptual skill!)



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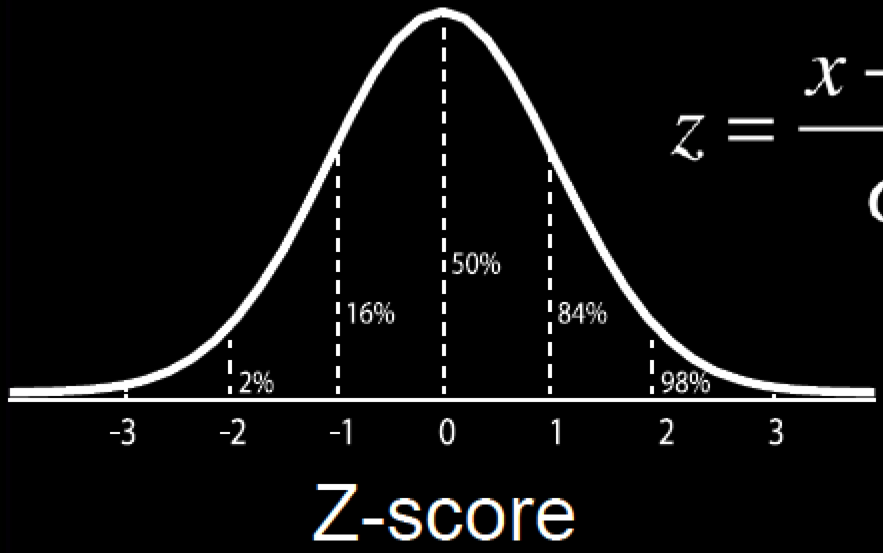
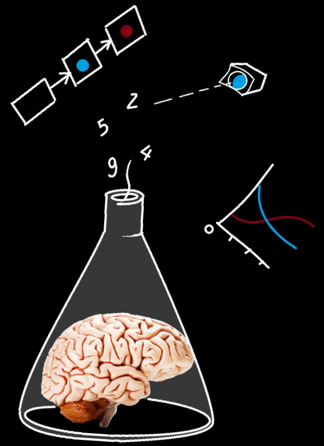
How do we measure this distance?

We cannot measure 'perceived intensity'!

... or can we?



$$z = \frac{x - \mu}{\sigma}$$



Direct relation between proportion observations (rate / probability) and standard deviations (Z-score) = probability expressed as standard deviations

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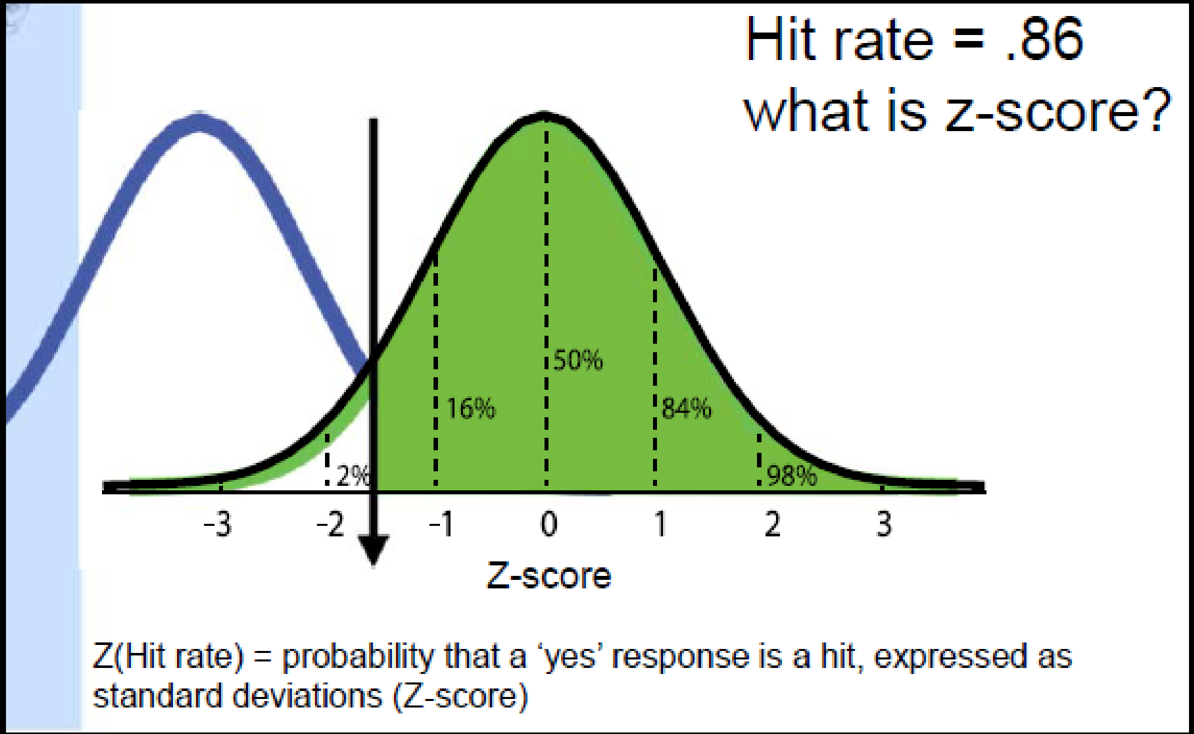

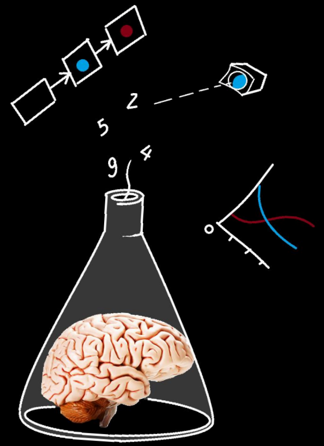

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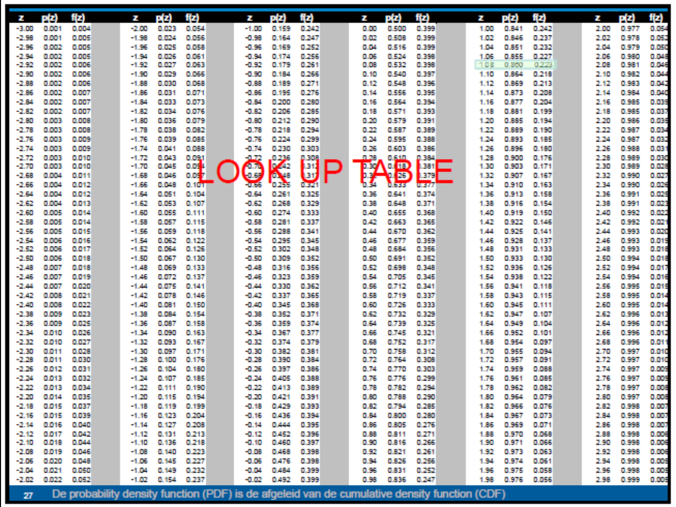
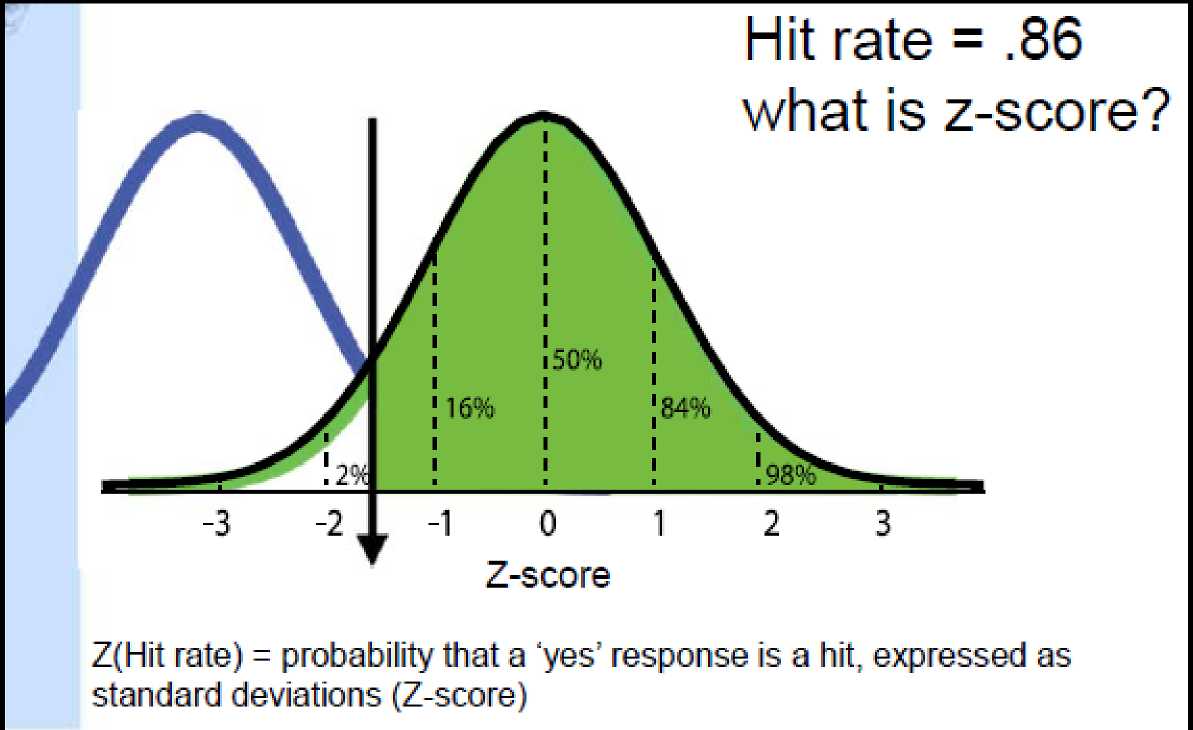
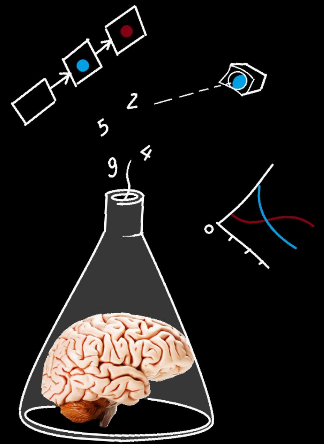




1.08



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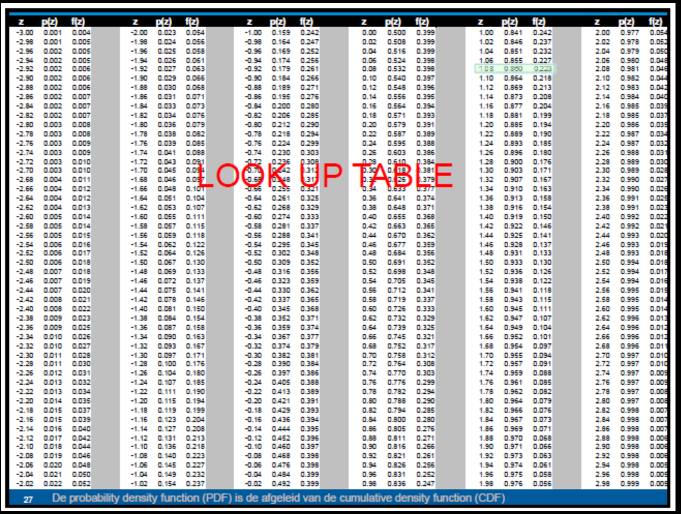

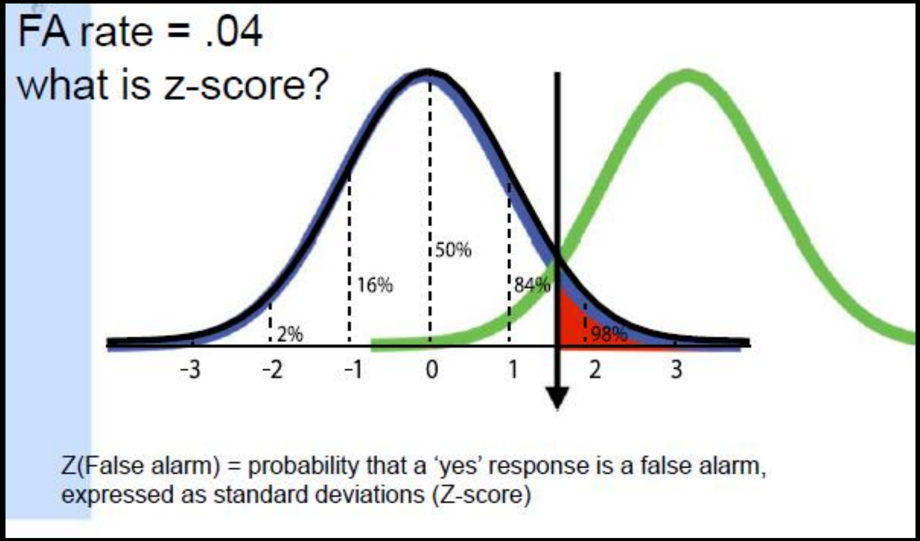

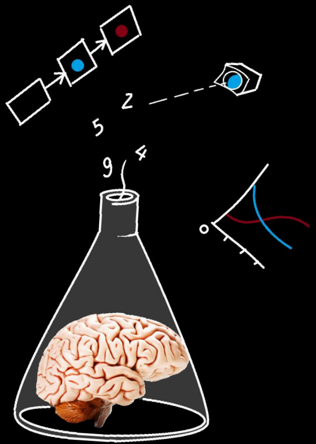

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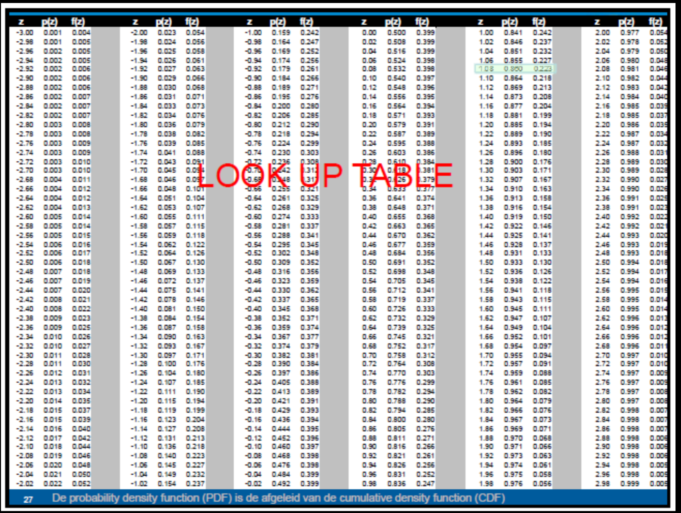
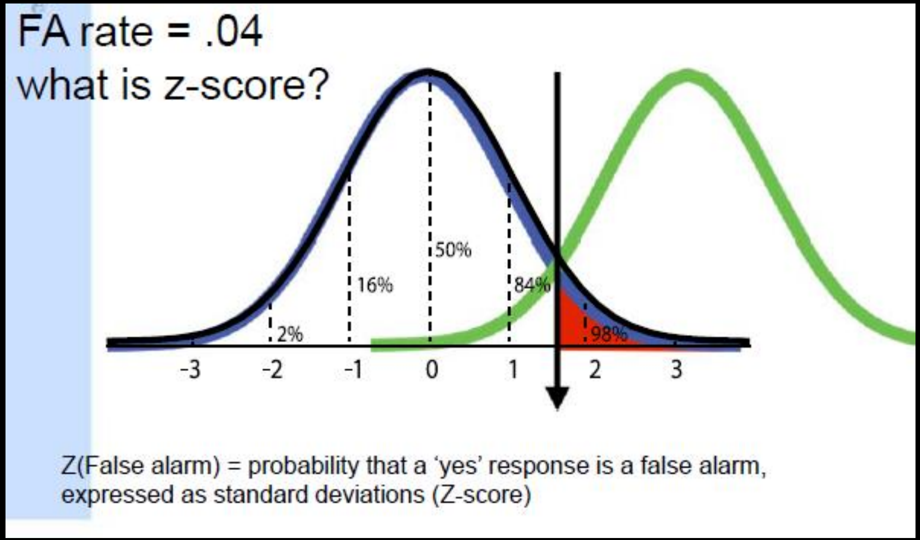
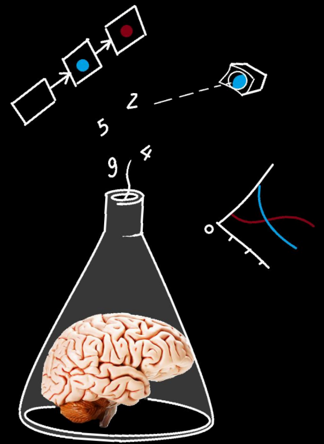




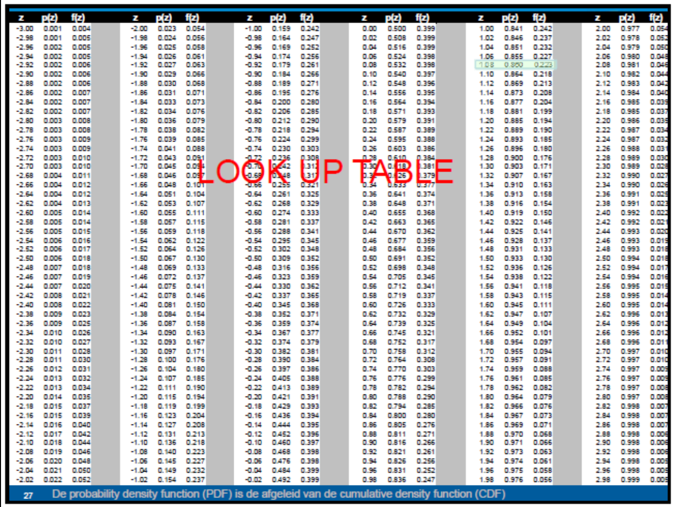
-1.75

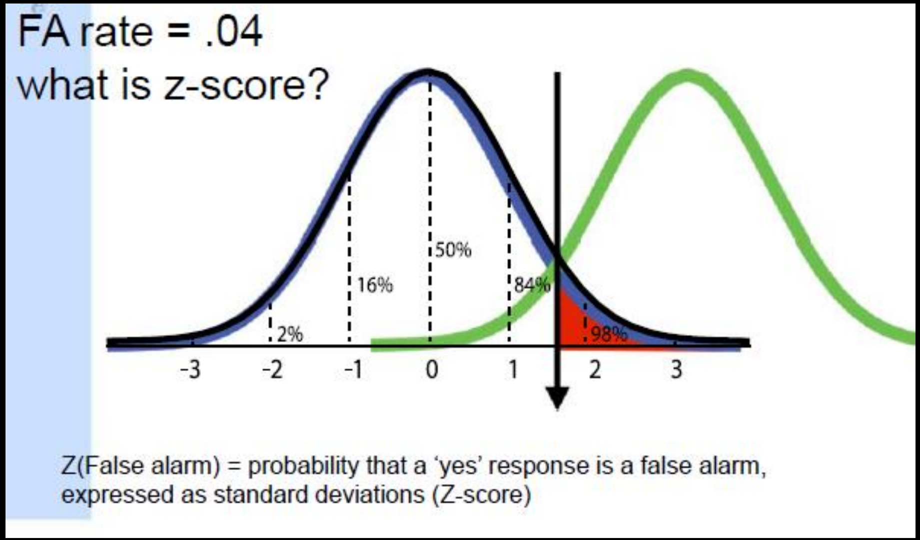


The distance between signal and noise distributions varies among individuals and is called *sensitivity*

(= perceptual skill!)

Sensitivity = z-score for hits minus z-score for false alarms : 1.08 – -1.75 = 2.83





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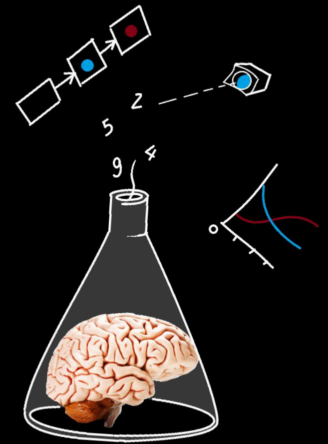
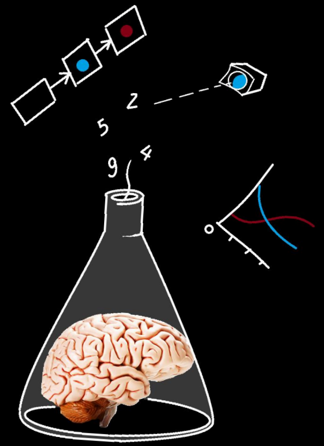


The distance between signal and noise distributions varies among individuals and is called *sensitivity*

(= perceptual skill!)

All that we need to measure sensitivity are the proportions

		State of the world	
		Signal	Noise
Response	Yes	P(Hit) 0.66	P(False alarm) 0.14
	No	P(Miss) 0.34	P(Correct rejection) 0.86

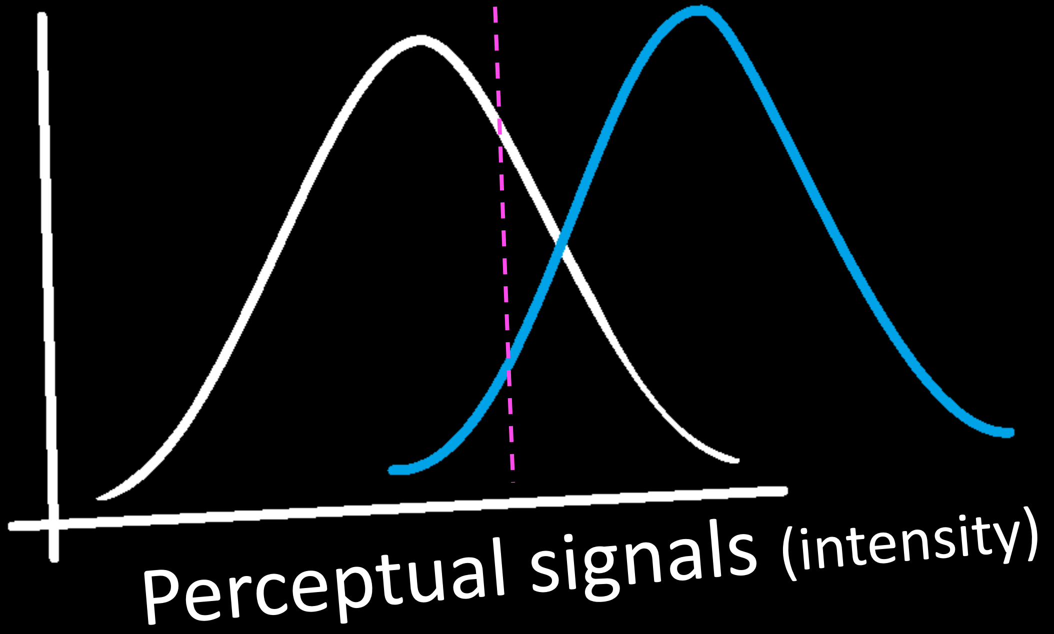


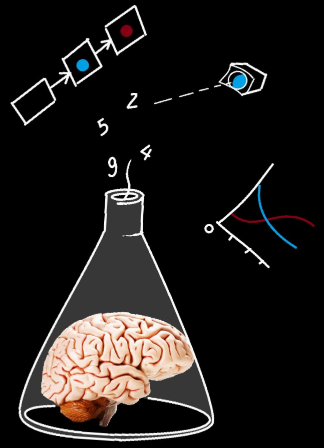
The distance between signal and noise distributions varies among individuals and is called *sensitivity*

(= perceptual skill!)

Not affected by response threshold (criterion) !

z(hits) – z(false alarms) remains same



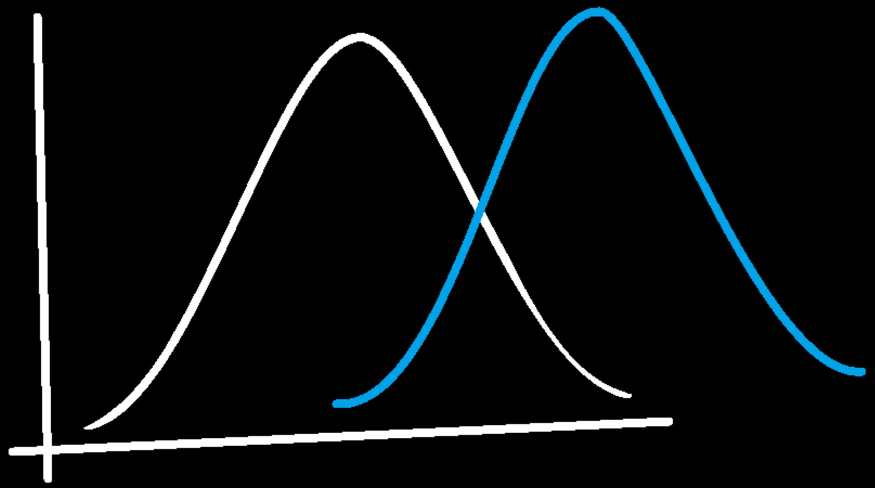


Staircase procedures

What if we want to measure performance irrespective of these subjective perceptual processes?

e.g., a person is slightly color-blind in our Stroop task

RED BLUE BLUE RED

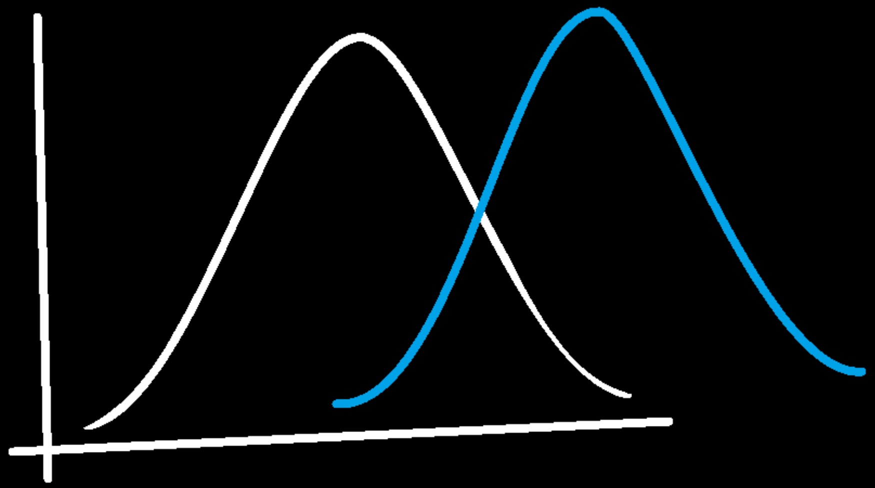


Staircase procedures

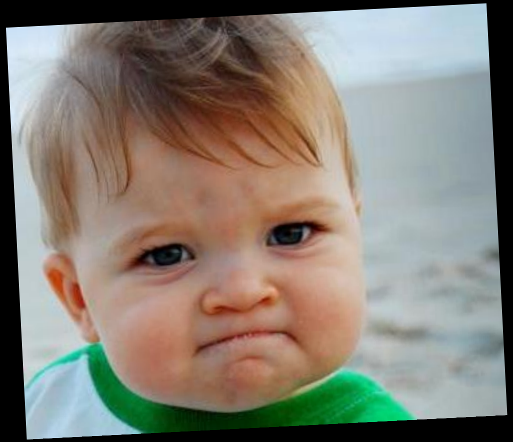
a.k.a.: Controlling the subjective distance between the relevant and the irrelevant

→ adjust stimulus intensity, duration, etc., on the basis of incoming responses

→ so that all subjects perform equally

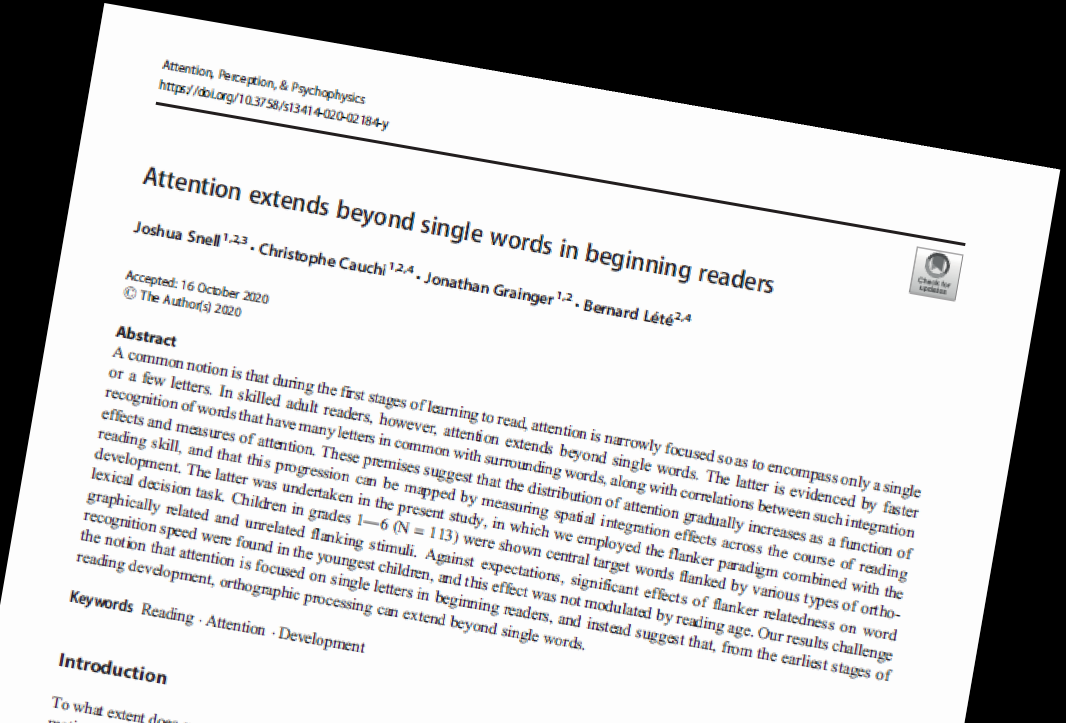


Staircase procedures



"Words are impacted by surrounding words"
"What is the developmental trajectory of this?"

Standard paradigm: show words for 150 ms
"Uh oh, kids can't even recognize single words in 150 ms"



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Attention extends beyond single words in beginning readers

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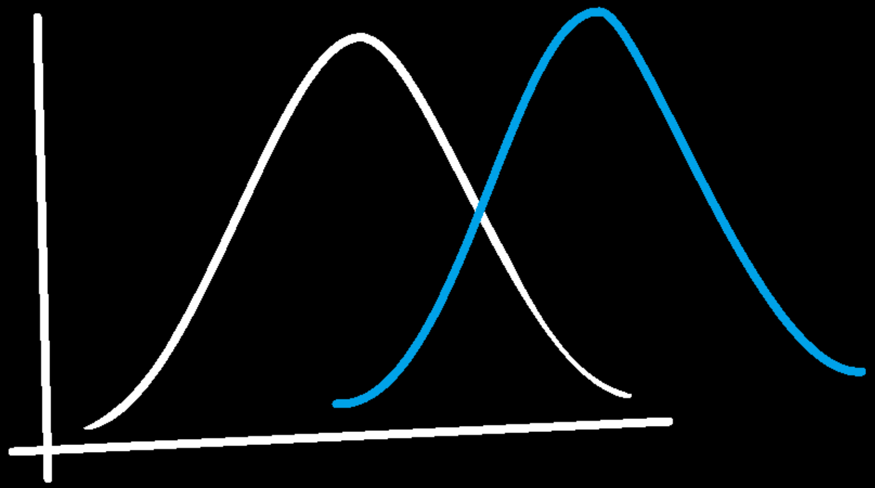
Abstract
A common notion is that during the first stages of learning to read, attention is narrowly focused so as to encompass only a single or a few letters. In skilled adult readers, however, attention extends beyond single words. The latter is evidenced by faster recognition of words that have many letters in common with surrounding words, along with correlations between such integration effects and measures of attention. These premises suggest that the distribution of attention gradually increases as a function of reading skill, and that this progression can be mapped by measuring spatial integration effects across the course of reading development. The latter was undertaken in the present study, in which we employed the flanker paradigm combined with the lexical decision task. Children in grades 1—6 (N = 113) were shown central target words flanked by various types of orthographically related and unrelated flanking stimuli. Against expectations, significant effects of flanker relatedness on word recognition speed were found in the youngest children, and this effect was not modulated by reading age. Our results challenge the notion that attention is focused on single letters in beginning readers, and instead suggest that, from the earliest stages of reading development, orthographic processing can extend beyond single words.

Keywords Reading · Attention · Development

Introduction

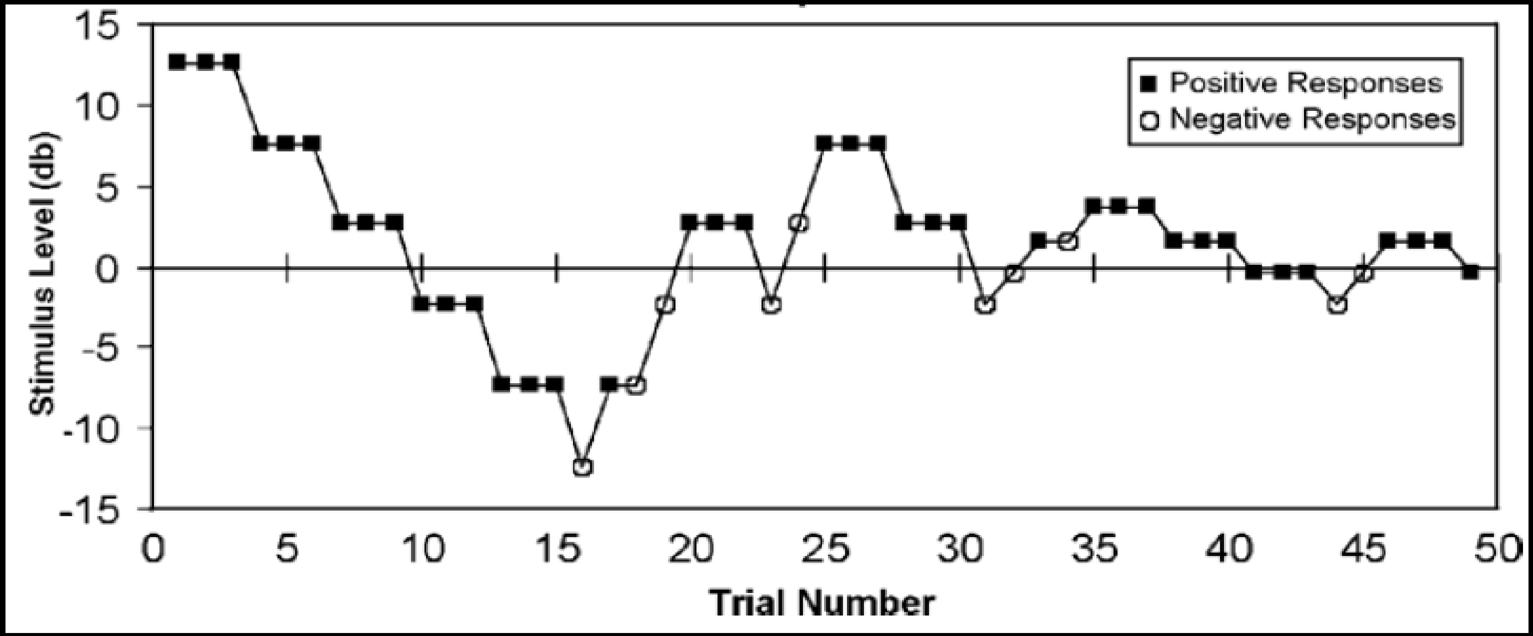
To what extent does

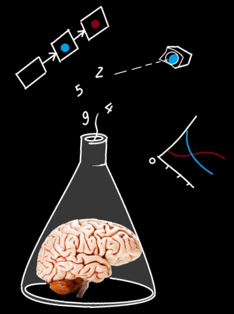


Staircase procedures : example

- After X correct trials, decrease stimulus duration by β
- After Y incorrect trials, increase stimulus duration by β

- After each oscillation, decrease β a bit (until it hits 0)





Next Monday