The eye and the brain: Two approaches to study human behaviour.

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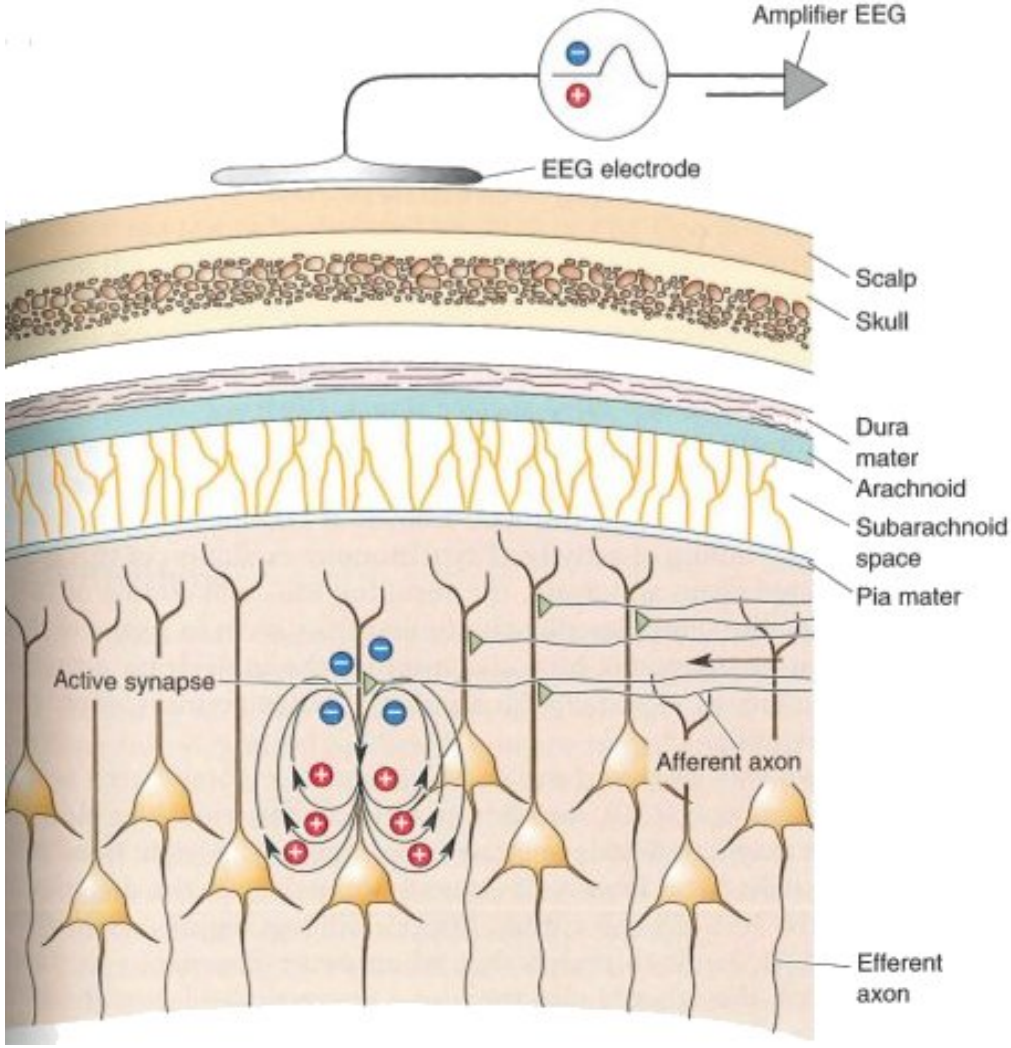
Electroencephalography - SPONTANEOUS

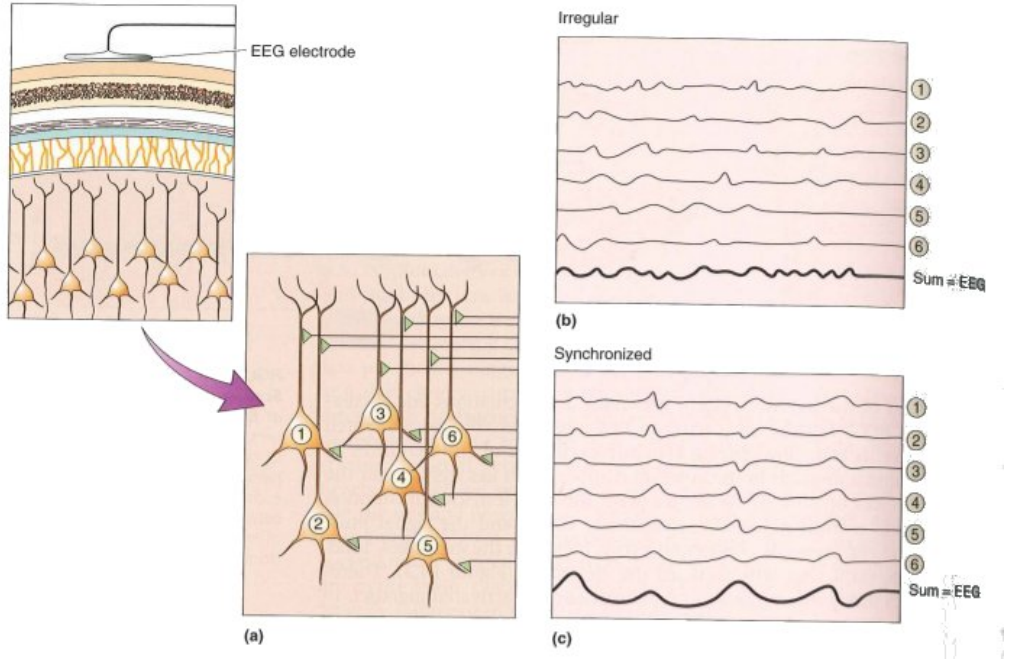
Brain cells (**neurons**) communicate through electrical signals. Electroencephalography (EEG) measures spontaneous brain activity.

From where do EEG come? - Sources



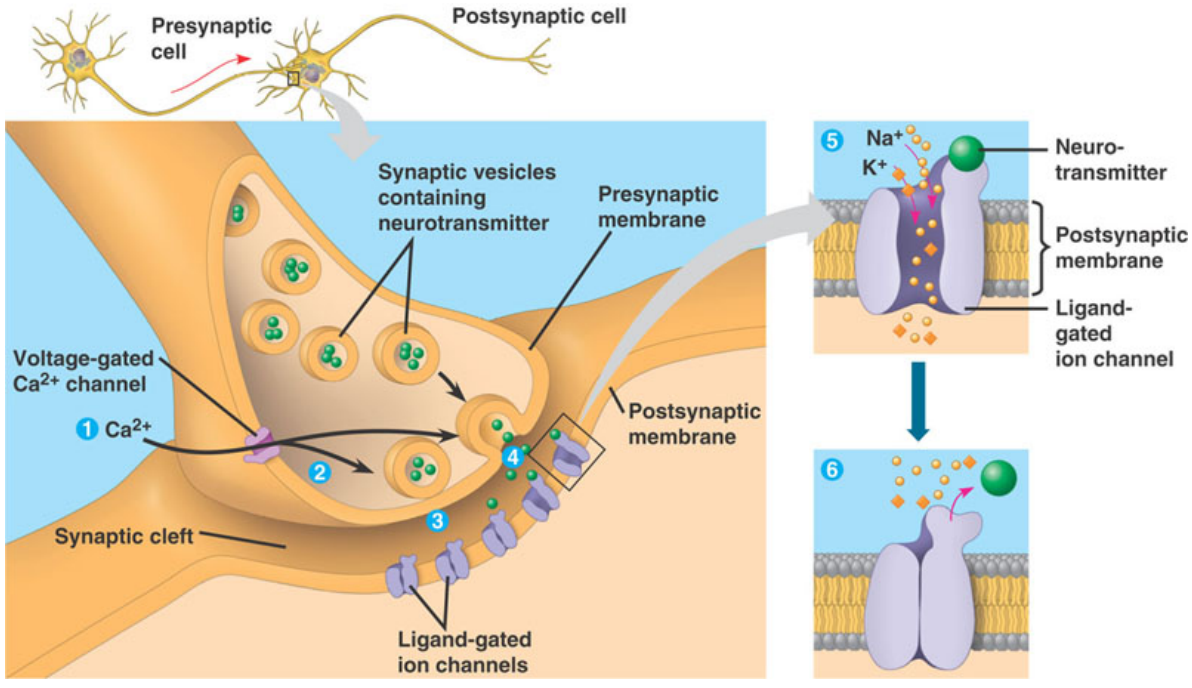
Electroencephalography measures *local field potentials*.

From where do EEG come? - Sources



Local field potentials are postsynaptic potentials generated by a *large* group of neurons.

From where do EEG come? - Sources



Postsynaptic potentials are the voltages generated by the binding of neurotransmitter to the receptors on the membrane of the postsynaptic cell.

EEG measurement in one picture

How is EEG measured?

How is EEG measured?

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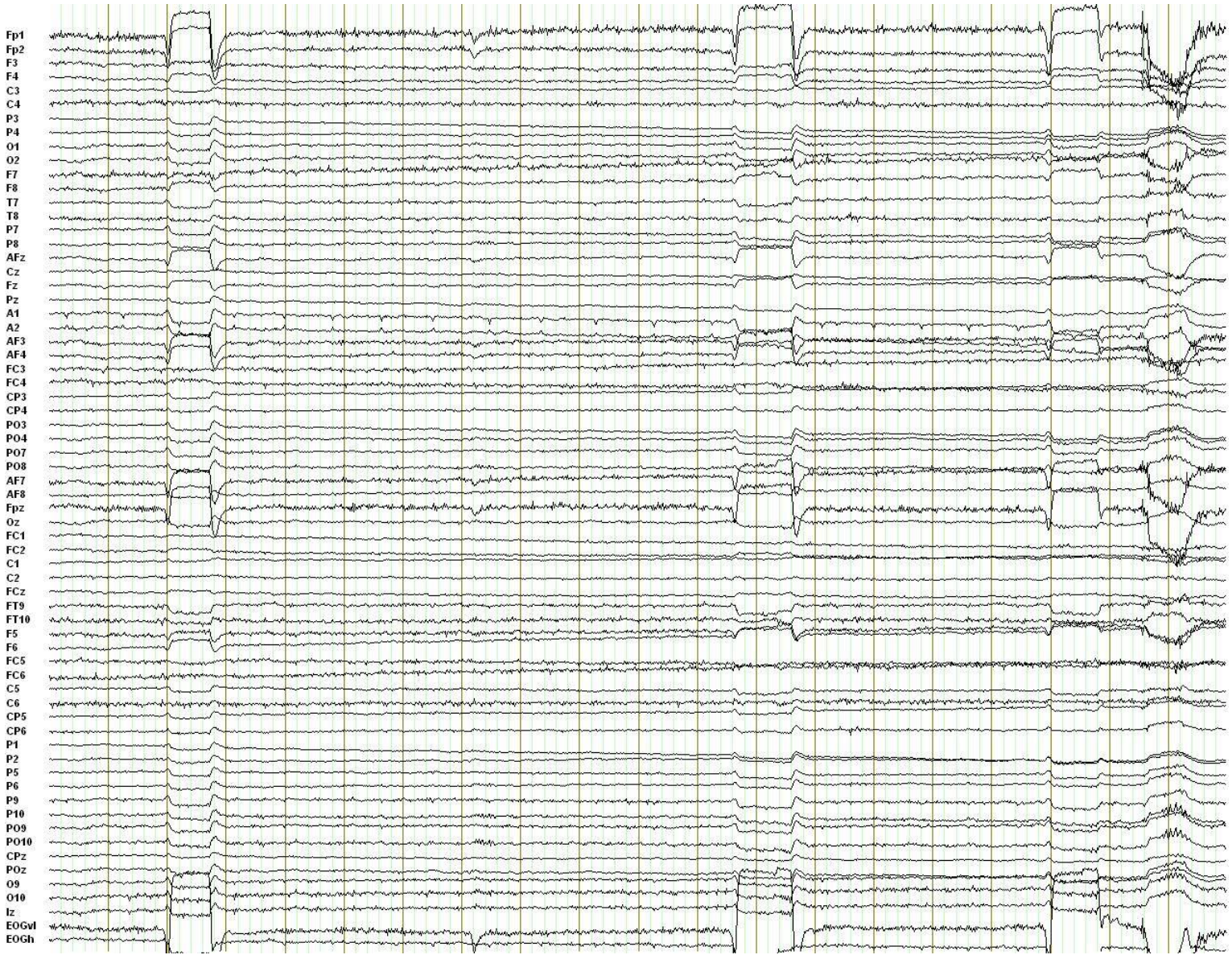
How is EEG measured?

EEG recording: Active



EEG recording: Relaxed

Electroencephalography - EVOKED/INDUCED

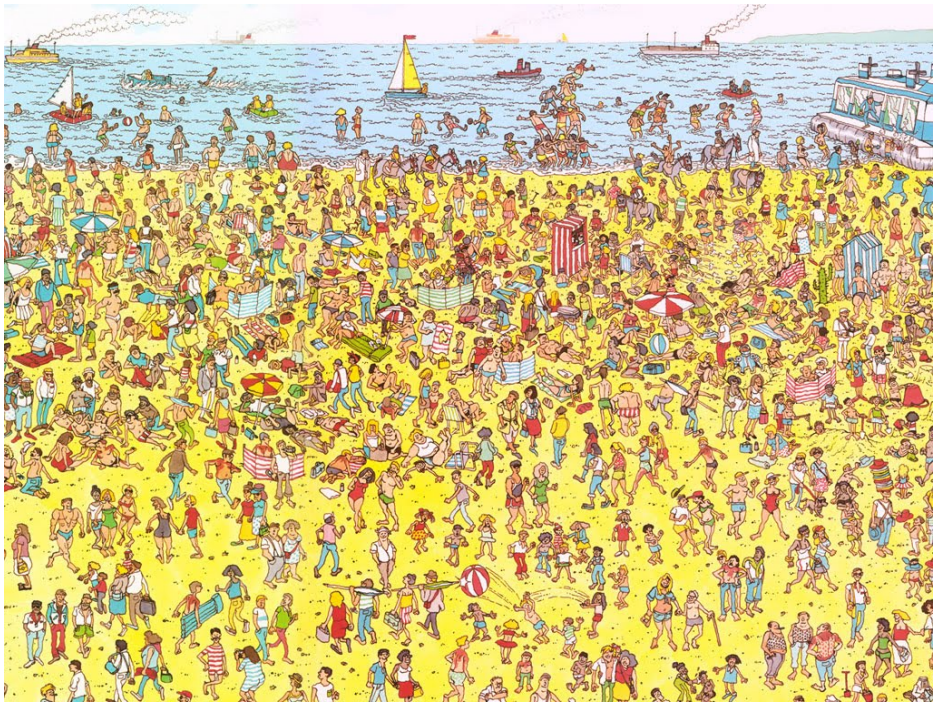
Brain cells (**neurons**) communicate through electrical signals.
Electroencephalography (EEG) measures spontaneous brain activity.
If there is a stimulation brain activity changes:
EP = **Evoked potential** - sensorial ERP (earlier) - stimulus could be irrelevant to the participants.
ERP = **Event-related potential** - cognitive ERP (later) - stimuli are associated with an instruction participants have to follow.

How does it work?

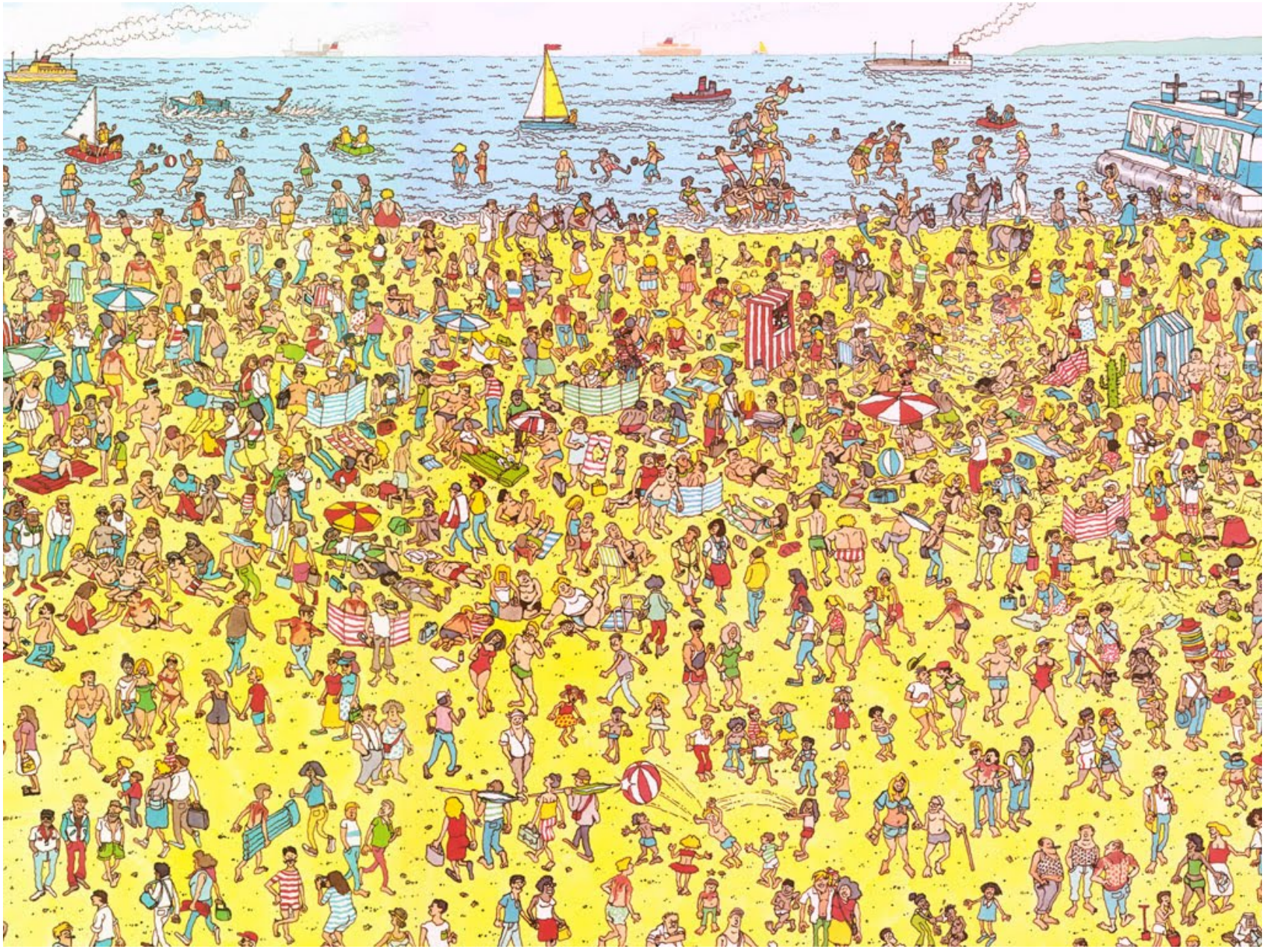
This is Wally

Nice to meet you too!

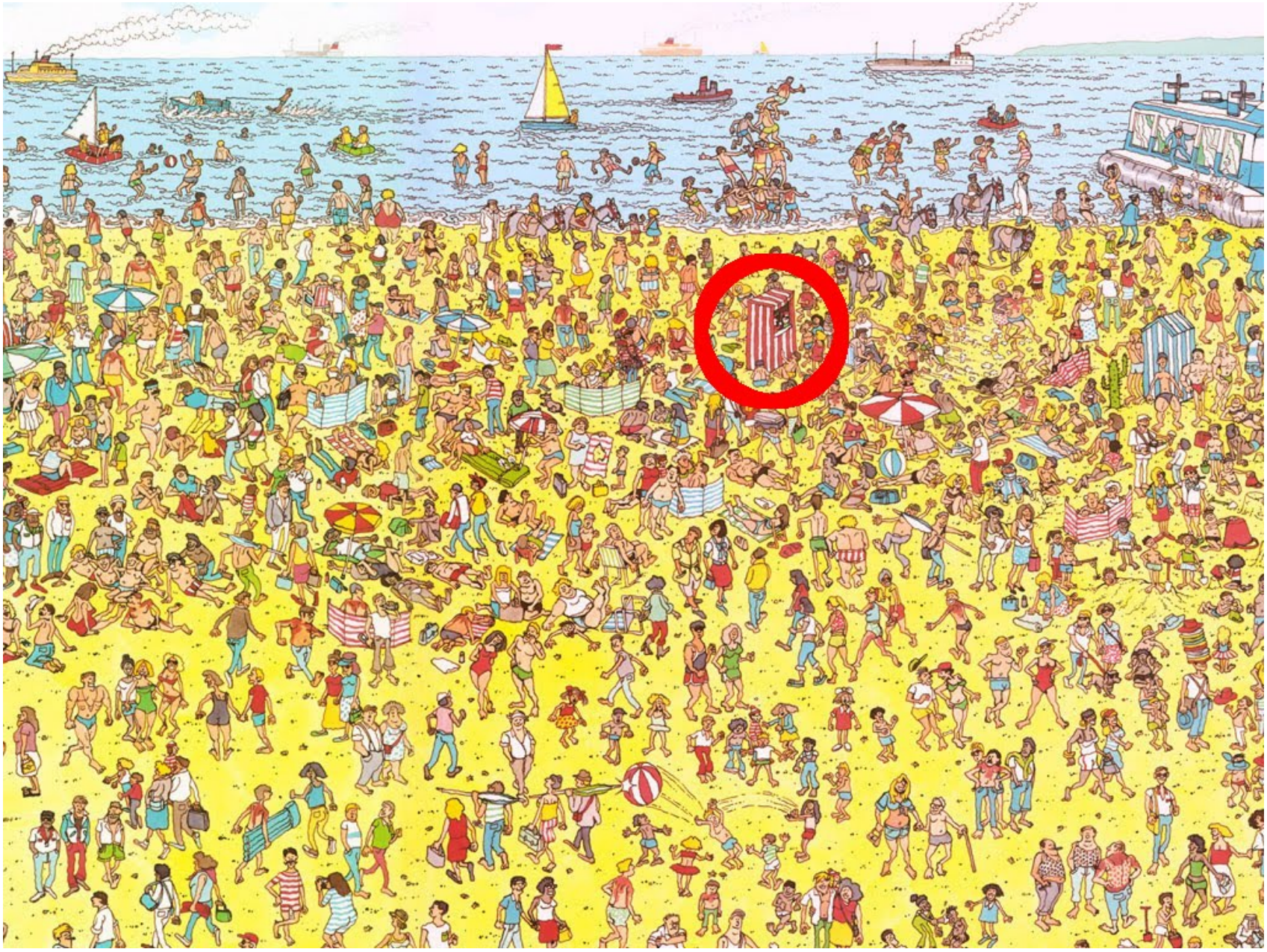
Can you find Wally???



Find Wally



Find Wally



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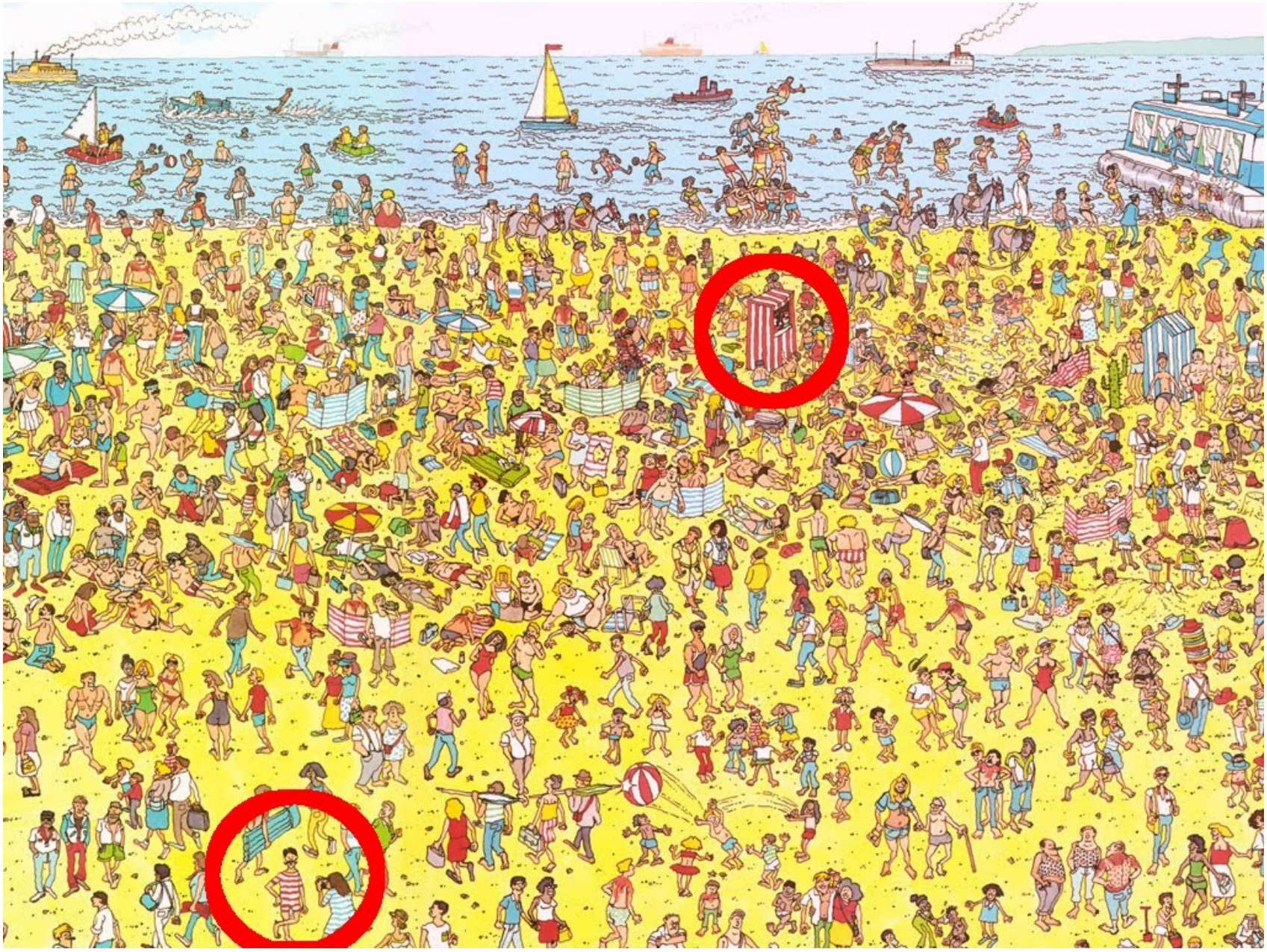
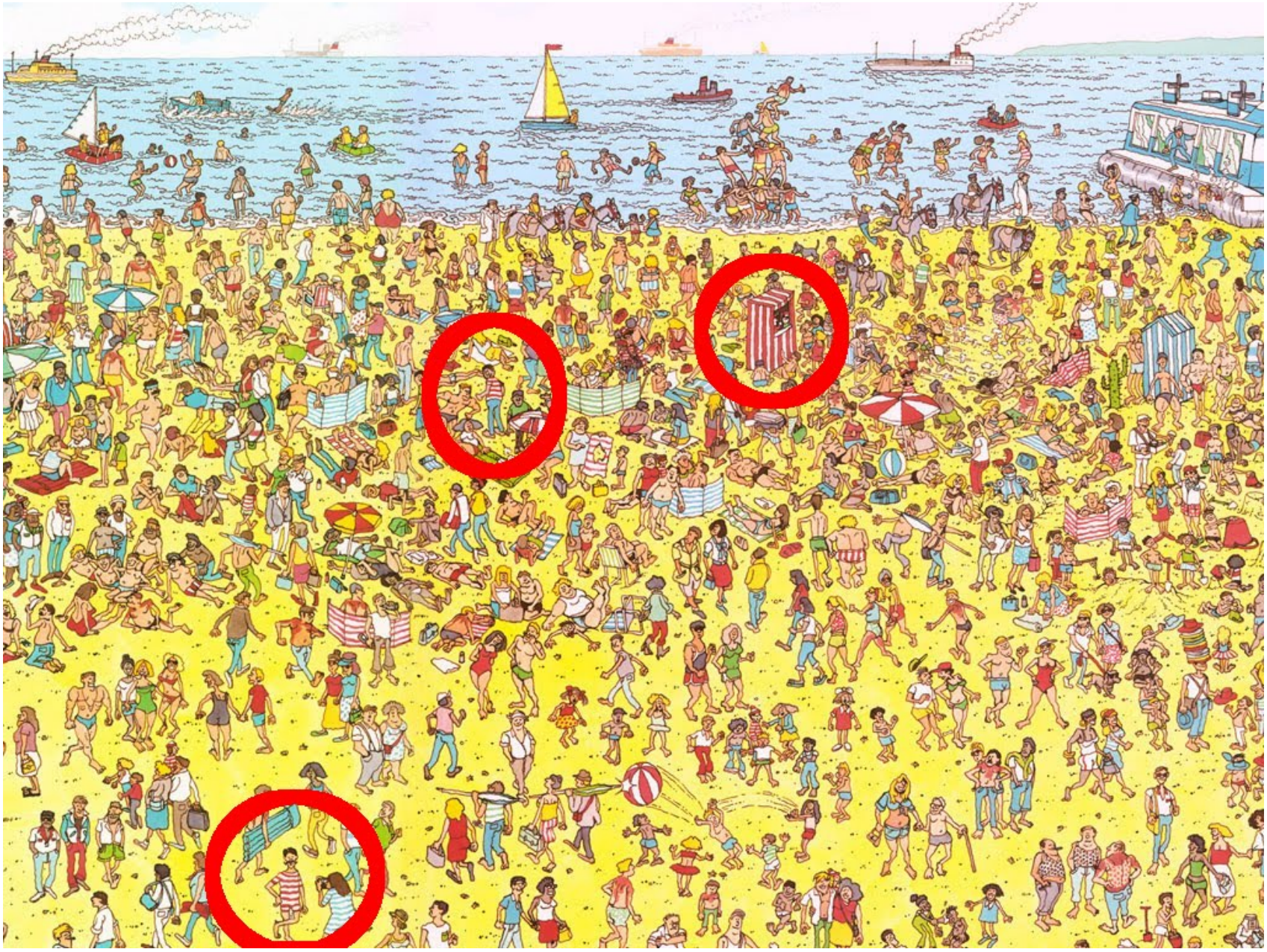
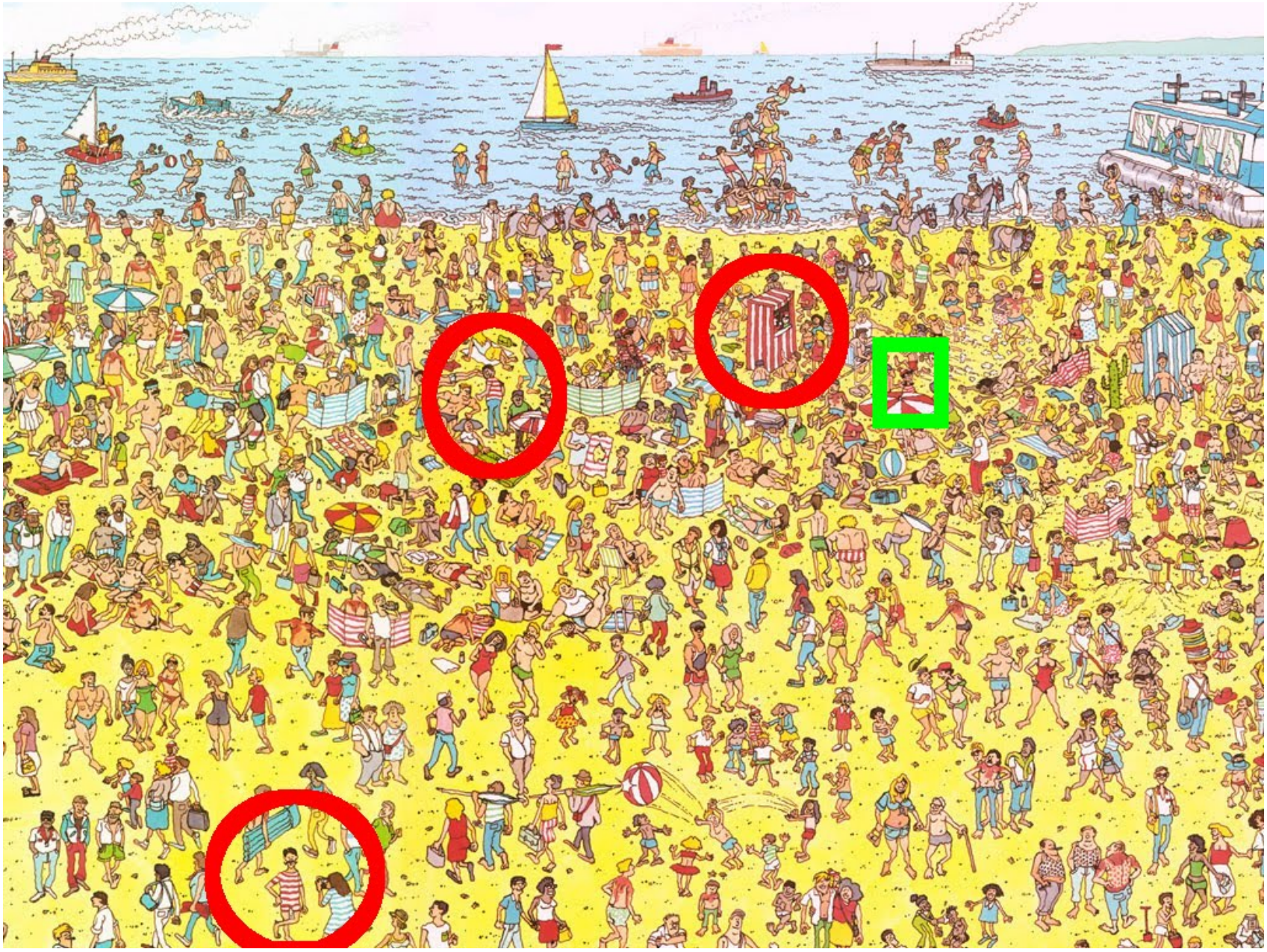


Find Wally



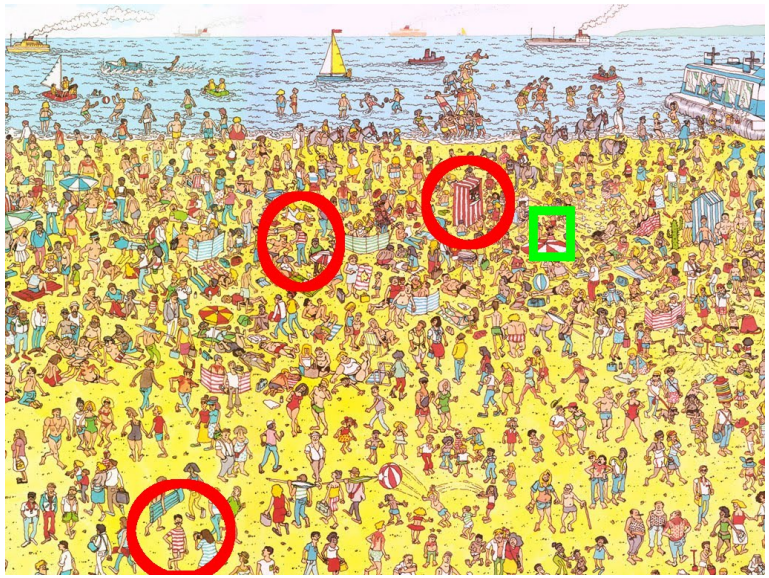
Find Wally



Find Wally - a ‘potential searching strategy’

Sequential steps that might be implemented to find Wally:

1. look for a **red-white striped** pattern
2. look for a **man wearing** a red-white striped **vest**
3. look for a man wearing a red-white striped vest **and blue trousers**
4. look for a man wearing a red-white striped vest and blue trousers **and a hat**



Find Wally

Two topics could be addressed when such strategy is followed:

Depth of search, is it incremental?

Adding elements to consider when analysing a scene increases working memory load.

Engagement or disengagement of attention

Every time that a target-like object is found we need to determine if it is the right one, otherwise discard it, and search for a new one.

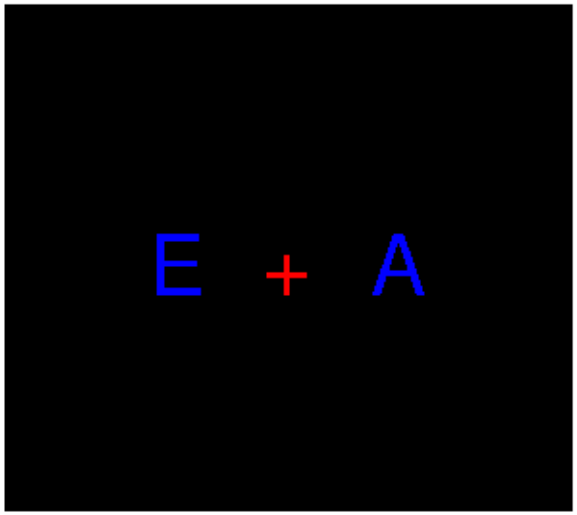
We chose engagement and disengagement of attention.

An example of ERP research

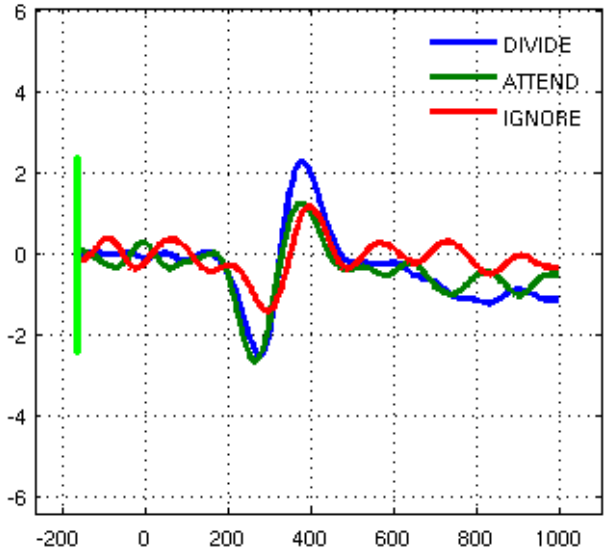
To be tested with EEG the task has to be stripped off. It must be very simple, address the mechanisms in its simplest form. Remove most confounds.
Eye movements have to be minimized, to control for artifact.
Participants searched the digit ‘5’ which was embedded among letters (e.g., ‘A’, ‘B’, ‘C’, ‘D’, ‘E’, . . . , ‘P’).
To make the study more interesting we included a divide-attention condition, to try to understand how people can direct attention toward two locations simultaneously.
Click here to see a trial example.

. . . and how does it look?

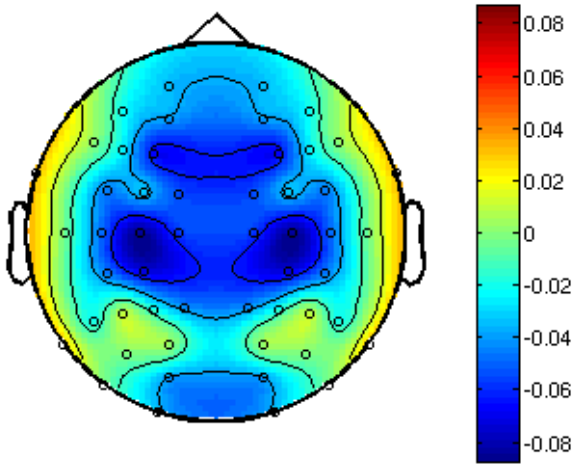
Extract of experimental paradigm



Event-related brain potential waveform



Current source density map



The time-couse of search processing

A searching strategy can be implement as: Are there neurocorrelates for this strategy?

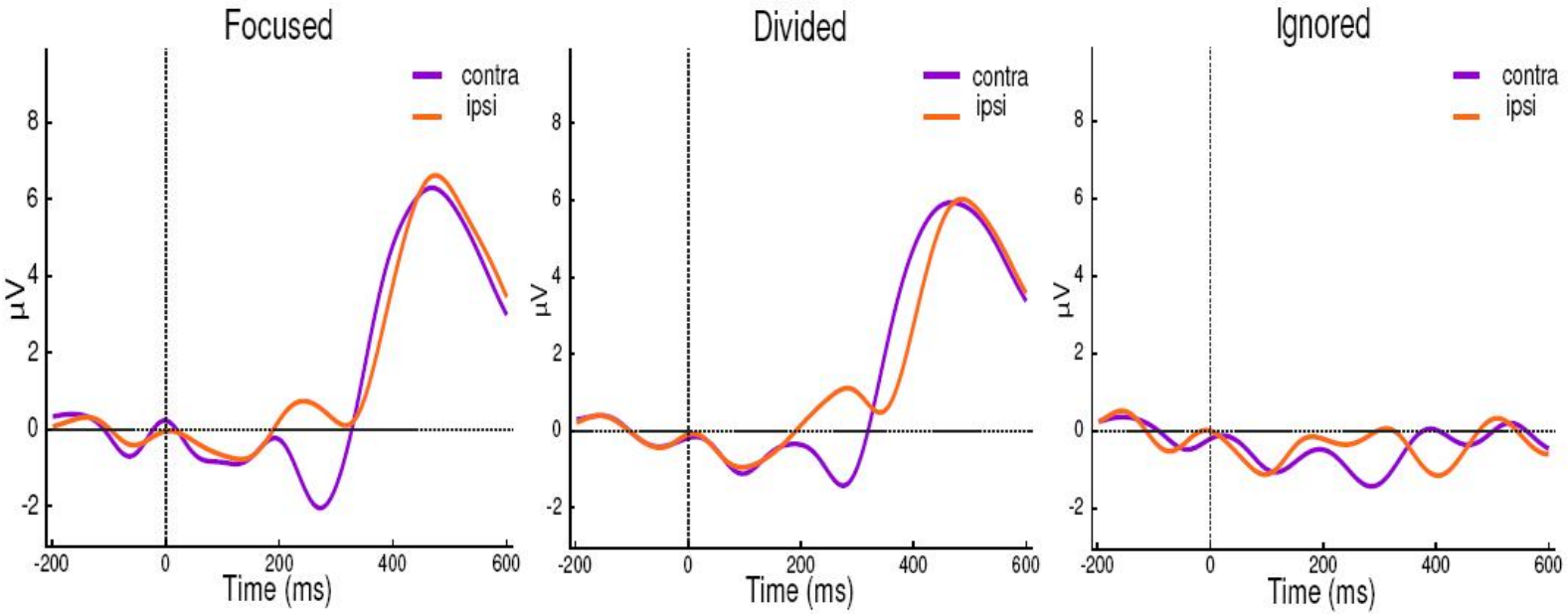
1. Find a potential target -N2pc
2. Is the current object the actual target? - P300
3. Release the object and search another - P4pc
4. restart the search

Is this model correct?

▸ testModel?

The results of the experiment

results



gotoDiscussion

The time-course of search processing

A searching strategy can be implement as: Are there neurocorrelates for this strategy?

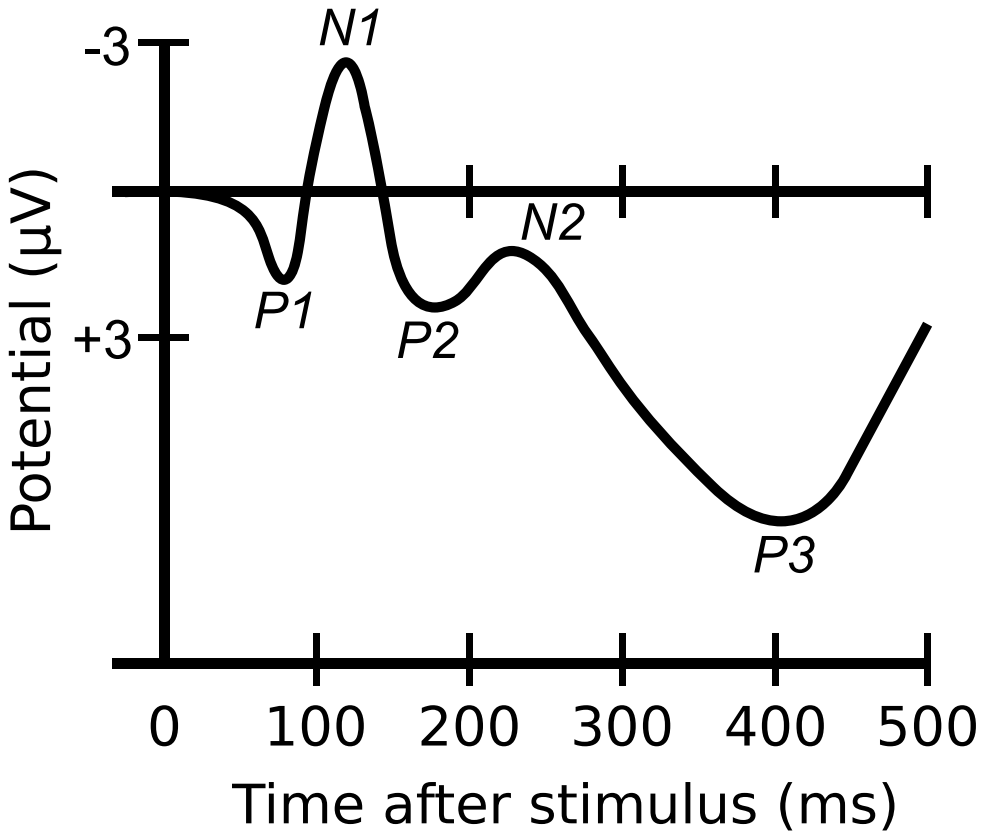
1. Find a potential target - N2pc
2. Release the object and search another - P4pc
3. Is the current object the actual target? - P300
4. restart the search

Is this model correct?
No. Disengagement happens before, or in parallel with, the processing of the potential target.
Or, the P4pc component of the ERPs does not reflect attentional disengagement.

Event-related potentials - recap

Cognitive neuroscientists want to know how behaviour is implemented in the brain.
A computer presents stimuli while EEG is measured.
Information about the stimulus display are sent to the EEG computer.
Using that information we can identify traces of EEG during which the stimuli were presented.
Those EEG traces are cut into intervals containing brain activity evoked by the stimuli.
EEG epochs are then averaged together -> ERP.

How do ERPs look like?

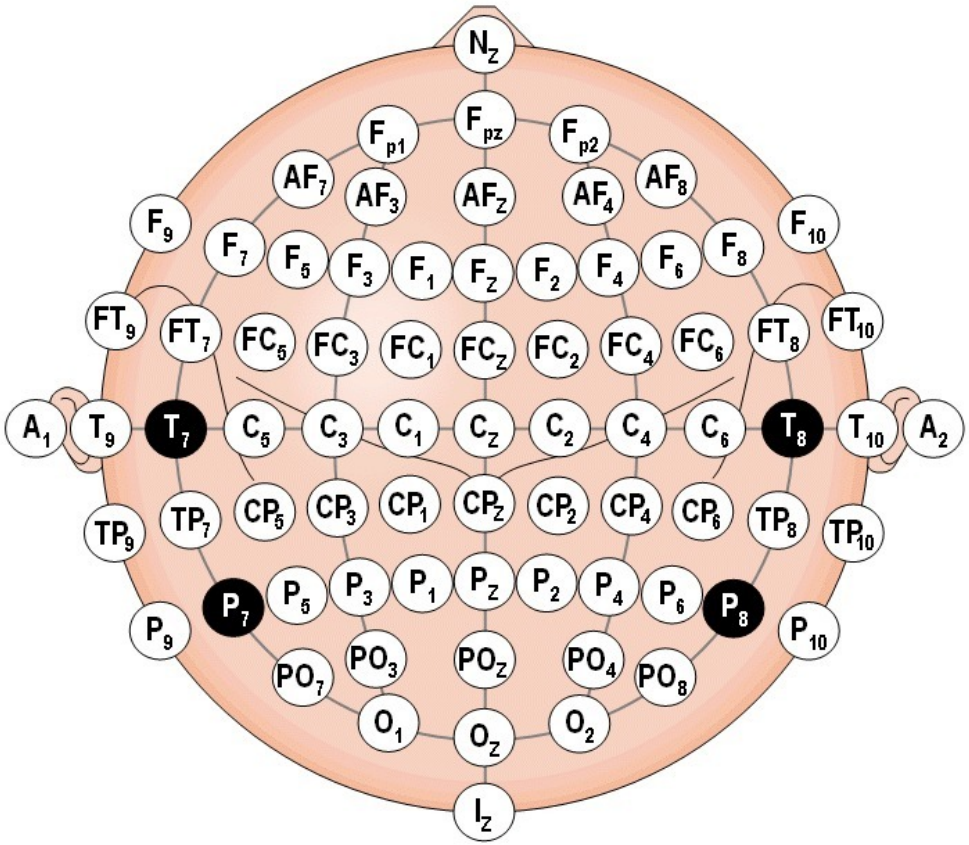


Average of oscillatory brain responses characterized by:

1. Polarity
2. Onset/Order
3. Topography

might reflect the cognitive process evoking them (e.g.: CNV, ERN, ELAN).

Topography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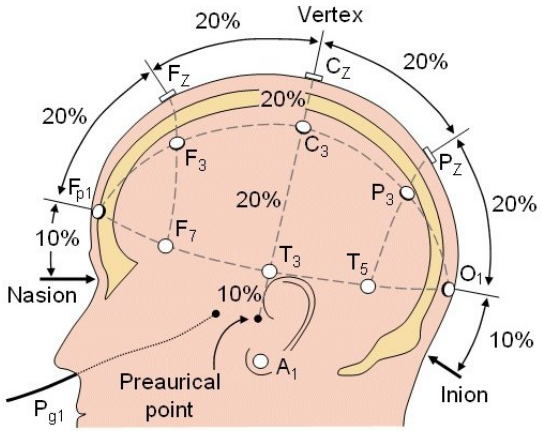
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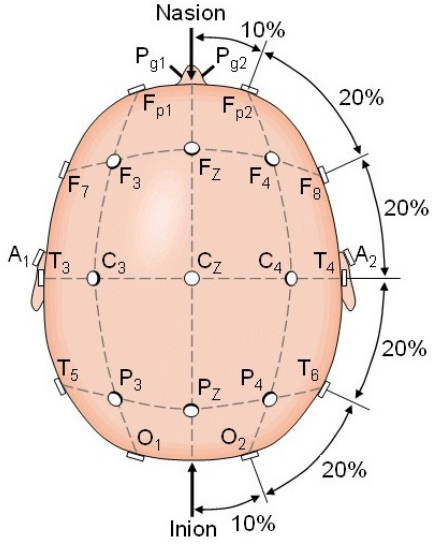
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ERP components

ERP	onset (ms)		topography (cortex)	functionality
C1	6	90	striate	visual processing
P1	8	120	extrastriate	visual processing + attention
N1-a	8	120	fronto-central	auditory processing + attention
ELAN	10	300	frontal (left)	violation of word-category or phrase structure
N1-v	15	200	occipito-parietal/temporal	visual processing + attention
N170	13	200	occipito-temporal (right)	processing of faces
P2	15	275	centro-front parieto-occip	comparison with internal representation
MMN/N2a	15	250	primary auditory/visual	detection of change (oddball)
N2b	20	350	anterior	response inhibition/conflict, error monitoring
N2c	20	300	posterior	degree of attention allocated to stimulus
N2pc	20	300	posterior-contralateral	attention allocation
P300/P3b	30	600	parietal	stimulus evaluation and categorization
P3a	25	280	fronto-central	attention engagement, processing of novelty
N400	25	500	centro-parietal	semantic processing
P4pc	35	450	posterior-contralateral	attention deallocation
P600	50	1200	centro-parietal	syntactic processing
ERP timelocked to responses				
CNV	26	470	vertex	contingency between two stimuli
LRP	26	470	centro-contralateral	response preparation
ERN/Ne	8	150	fronto-central	error processing

Blue (EP), Pink (stimulus processing), Yellow (stimulus categorization), Green (Response related)

There is more to EEG than just ERPs

Event-related potentials are the most simple type of EEG analysis, but are not the only possibility.

Time-frequency analysis. Analyses changes in brain rhythms.

Frequency bands:

Alpha	$8\text{Hz} <$	α	$<$	13Hz	relaxation
Beta	$13\text{Hz} <$	β	$<$	25Hz	active state
Theta	$4\text{Hz} <$	θ	$<$	8Hz	memory updating
Gamma	$25\text{Hz} <$	γ			higher processing
Mu	$8\text{Hz} <$	μ	$<$	13Hz	motor activity
Delta	$4\text{Hz} <$	δ			sleep

...

The Neural Efficiency Hypothesis

Neural efficiency: when executing the same task High-IQ (HIQ) individuals show less brain activation than Low-IQ (LIQ) individuals.
Cerebral activity in HIQ individuals is smaller and/or more localized than in LIQ individuals.
Neural efficiency reflects:

1. a more focused use of specific, task-relevant, areas
2. the nonuse of brain areas irrelevant for good task performance.

What induces differences in brain activity?

1. Do the execution of the same tasks requires more cognitive resources in LIQ individuals than in HIQ individuals?
2. Do HIQ and LIQ individuals resolve the task in different ways? Do HIQ individuals adopt a more efficient strategy (more economic resource management)?

Two groups of different IQ must execute the same task in the same way.

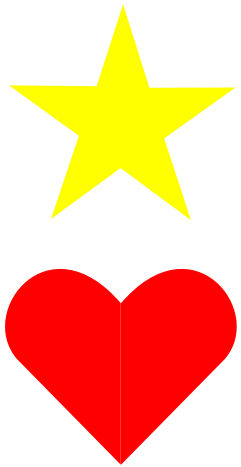
The experiment

1. Choose a task previously used to study individuals differences in intelligence.
2. Systematic control of the strategies used by the participants.
3. Measure the electroencephalogram to quantify differences at the neurophysiological level.

The task

Sentence-picture matching task.

"The heart is above the start"



Two strategies to solve it:

linguistic

Read the sentence and proceed to the comparison.

imagery

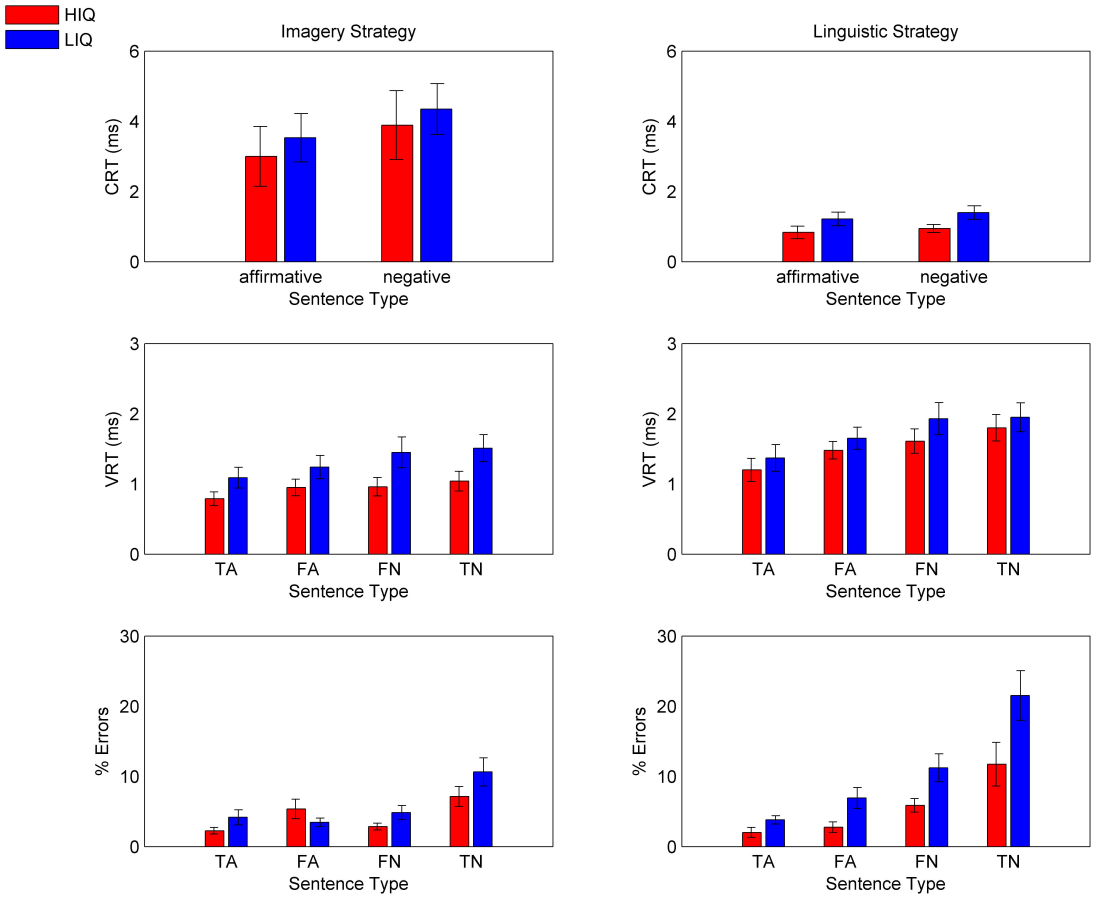
Create an image representing the sentence before proceeding to the comparison.

Measurement of brain activity

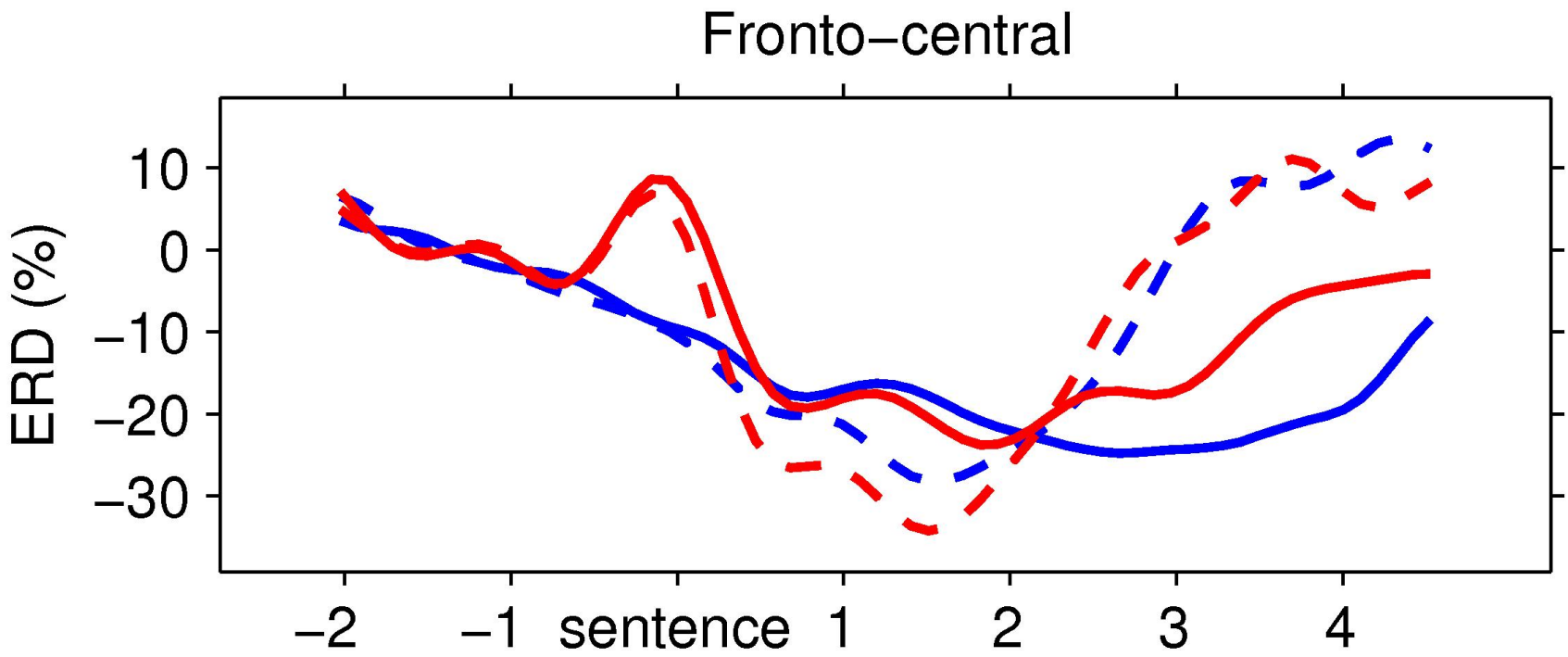
Amplitude of the **alpha** rhythm is smaller in situations with a high cognitive load than in less demanding situations.

Behavioural Results

Did participants use the two strategies correctly?



EEG Results

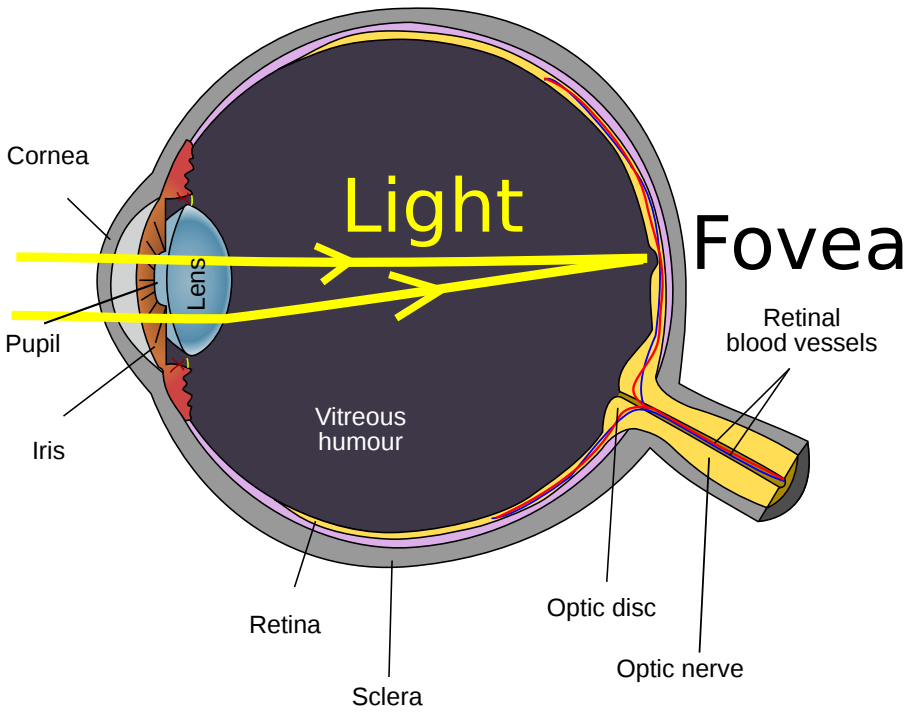


High IQ individuals (red lines)
Low IQ individuals (blue lines)
Imagery strategy (continuous lines)
Linguistic strategy (dashed lines)

Conclusions

HIQ individuals are faster and more accurate than LIQ individuals in the SVT.
The two groups showed similar levels of activities when executing the task in the same way.
However, activity was significantly reduced (synchronized) in HIQ individuals in the interval preceeding the beginning of the trial.
It is important to have an idea of what a person might be doing when one wants to infeer what the person might be doing.
Our results do NOT support the claim that HIQ individuals use less brain, but if neural efficiency means adapting behaviour to maximize performance that is efficient brain management!

The eye



Human visual field is $\approx 200°$
Fovea: central region of the retina.
Visual acuity is highest within $1°$ and decreases sharply after $5°$ from the center of the fovea.
Photoreceptors in the fovea allow a clear perception.
Photoreceptors outside the fovea allow analysis at a lower resolution.
Inspection of the visual field requires multiple eye movements which foveate objects of interest.

Eye tracking methodology

Contact

Scleral contact lens (physiology of eye movement) - Pros: very high resolution and sensitivity. Cons: invasive.

Optical

Video-based corneal reflection eye-trackers. Measure the change in infrared light reflected by the cornea when the eyes move. Pros: Fairly high resolution, non-invasive.

EOG

Electrooculogram measures voltage changes between cornea and fundus when the oculomotor muscles contract. Pros: relatively inexpensive, allows detection of movements also in the dark. Cons: difficult distinction among different size of saccades.

Eye tracking setups

Head-mounted

Chin/head rest.

Remote eye-tracker

wearable eye-tracker

Eye movements I

Eye movements are controlled by 6 (extraocular) muscles.
Saccades: Rapid, “jump-and-rest” foveations of objects occuring while scanning or reading. Saccades are fast, they are an efficient way to search and explore the visual field. Saccades are controlled by the frontal lobe.
Rapid eye movement (REM): sleep stage characterized by rapid eye movements.
Microsaccades: Small saccades (0.2°) occuring during thorough observation. They ensure input continuity to photoreceptors that would otherwise stop responding.
Smooth pursuit movements: Allow maintaining foveation on moving objects. Characterized by smooth motion without abrupt starts and stops. Slower than saccades.

Eye movements II

Express saccades: Saccades that are half the duration of a saccade. They generate from a neuronal mechanism that bypasses time-consuming circuits and activate the eye muscles more directly than saccades.
Optokinetic reflex: Saccade to the original point of fixation after smooth pursuit.
Vestibulo-ocular reflex: Eyes movement in the direction opposite to the head movement to keep the retinal image stable.
Vergence movement: Simultaneous movement of both eyes to adjust the focus to objects that are close or far (convergence and divergence).
Pupil constriction: Constriction of the pupil size to accomodate focus on nearby objects (pupil dilation is also linked to mental effort).

Saccades and Fixations

Saccades are ballistic movements happening every $\approx$ 200 ms.
They are ballistic because their top velocity is proportional to their amplitude. Allows distinction of saccades from other eye movements.
During saccades there is no visual input. Visual input is acquired during *fixation*.
Fixations keep the eye steady in one location creating a stable image.
Saccades can be:

- **stimulus-driven** saccades are initiated by sensory events such as abrupt-onset stimuli.
- **goal-driven** saccades are initiated on the basis of an observer's goal and intetions.

There is a strong link between saccades and attention.
Saccades can be defined in term of amplitude and speed.
Fixation are defined in terms of duration.

Eye tracker in advertisement

Eye tracking technologies is becoming more and more dominant in advertising.
Companies study visual behaviour to understand what guides/attracts the eye.
Some of the topics studied cover:

- products positioning (supermarket)
- magazine advertisements
- websites structure

From gaze behaviour company try to understand:

- what people like (look at) the most
- where products should be placed
- what should be around the product
- if they can manipulate choice unconsciously

An example

There is a difference between these figures. The right one encouraged the buyer more than the left one. . .
Why? A closer look. . .

Heat map – distribution of fixations

Do perfectionists have better eye for details?

What is perfectionism?

Perfectionism in the litterature

Perfectionism is a multidimensional personality construct characterized by:

Concern over Mistakes, Doubt about Actions, Parental Expectation, Parental Criticism

Personal Standards, Organization

When related with psychopathology perfectionists are:
- preoccupied with attainment of perfection
- dissatisfied with performance

There is no hypothesis on the cognitive mechanisms underpinning perfectionism!
What about the positive type?

Who is a perfectionist?

Do Perfectionists Have Eye for Details?

Perfectionists aim at flawless performance.
To attain perfection every single detail should be considered, analyzed and taken care of.
Are perfectionists better in analyzing details?
If perfectionists are better than non-perfectionists in analyzing details they should perform better in a task that requires a very fine analysis of details.

Experiment 1

Aim: Find a fun way to test if perfectionists have eye for details.
Compare performance of perfectionists and non-perfectionists in a task that require scrupulous analysis of details.
40 picture puzzles – couples of figures with 5 differences, each displayed for 90 seconds.
Random clicking was discouraged awarding 5-seconds penalties.
Participants' accuracy and time to identify the differences were measured and correlated with the participants' perfectionism scores.
An eye-tracker was used to determine if perfectionists' and non-perfectionists' search stragies differ. This step did not work.

Example

Example

Predictions

Core Idea

If perfectionists are better than non perfectionists in focusing on the details then they should be better in finding the differences.

1. Accuracy Perfectionists should find a higher number of differences than non perfectionists
2. Reaction Times Perfectionists should
   - employ less time to find the differences
   - might employ more time when they are afraid of making mistakes

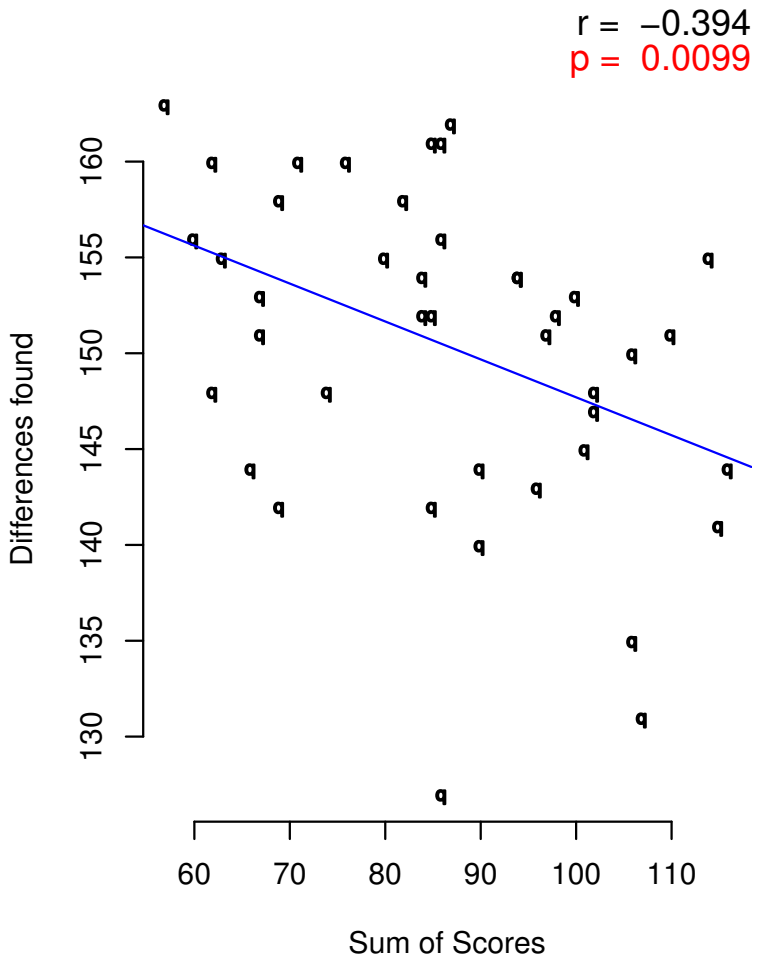
Participants

42 students (25 women) between 18 and 21 years of age participated.
Mean perfectionist scores was 87.02 (max = 57, min = 116, s.d. = 16.21).

Results – Accuracy

Accuracy was defined as the total number of differences that each participant found.
6 figures were excluded from the analysis because the areas of the differences had not be defined precisely and led to too many errors.

Results – Accuracy



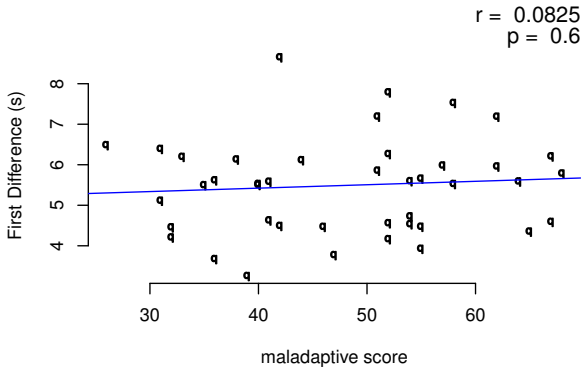
Time to find differences

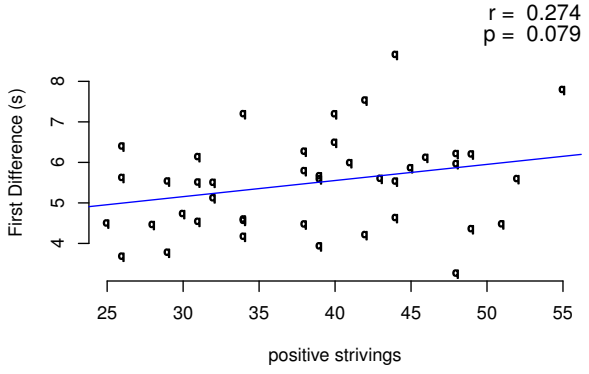
Reaction times were defined as the time required to find the differences.
However, 5 differences for each figures couple and a limited amount of time (i.e., 90 seconds) to find them was not a good combination because it did not allowed a straightforward analysis of the time spent to find a difference: There was too much variability between subjects.

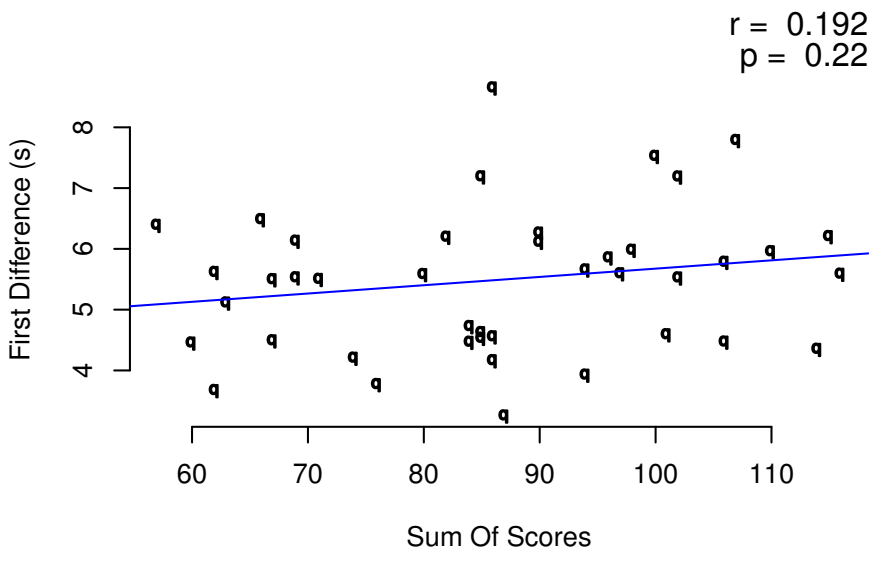
What went wrong?

1. Few differences (53) where found consistently by all participants (without considering order).
2. Limiting the differences search to a fixed amount of time might not have been a good idea.

Time required to find the first difference







. . . other reaction times

	mean	stdev	r	p
totRT	12.731	2.994	0.017	0.9128
maxRT	17.852	4.352	0.047	0.7665
firstRT	5.419	1.194	0.192	0.2233
sumRT	499.858	121.877	0.047	0.7665

Table: Descriptive statistics for different types of Reaction Times and their correlations with the perfectionists scores.

What did we find?

Accuracy

In a set amount of time perfectionists find less differences than non perfectionists in a comparative visual search task.
This is opposite to what we predicted.

Reaction Times

- Cannot be used to differentiate perfectionists and non-perfectionists
- Can be used but the experimental set-up must be different.

Why did reaction times not work?

‘Critical’ manipulations

- More than 1 difference per figure.
- Limited search time (90 s.).

Why?

1. To discriminate the two groups depending on the order with which they found the differences.
2. To compare what the two groups could do in the same amount of time.

The differences found were:

- Inconsistent among participants/groups.
- With no ‘general’ order.

P.s.: Infinite search time was left for a follow up study if this pilot would have worked.

What could have cause these results?

ANXIETY?

Perfectionists might have become anxious because:

- They realized they were not finding all the differences.
- The time limit might have affected perfectionists more than non-perfectionists.

TOO MUCH focus on the detail?

Perfectionists were so focused on the details that they did not find differences that were not details.

Which ONE will it be?

Could it be about anxiety?

Anxiety might make the search more frantic and maybe less effective.
Someone hazarded a freezing response, but the data show that participants continued searching for the whole task.
We can ‘partly’ reject this hypothesis, because there was no significant evidence that maladaptive perfectionists perform the task worst than adaptive perfectionists.
Maybe a comparison of two groups in the most difficult and easy figures could give some insights on this.

Is it about TOO MUCH focus on the detail?

What's a detail?
Perfectionists are so focus on details that they cannot disengage from analyzing small parts and forget about 'bigger' parts.
Perfectionists might have not been able to change their mind set from local to global processing.
What does not fit with this theory:

- Is a detail just a small object, part of another object?
- Is a 'big' object/difference enough to be considered a global difference?
- It is very difficult to test it with our set-up because of the presence of more than one difference per figure

Questions left open

Anxiety

- Administer an anxiety questionnaire before and after the experiment.

Focus on the detail

- Use objects that have all the same dimensions and are small (details?).
- Establish that analysis of detail(s) correlates with local processing.

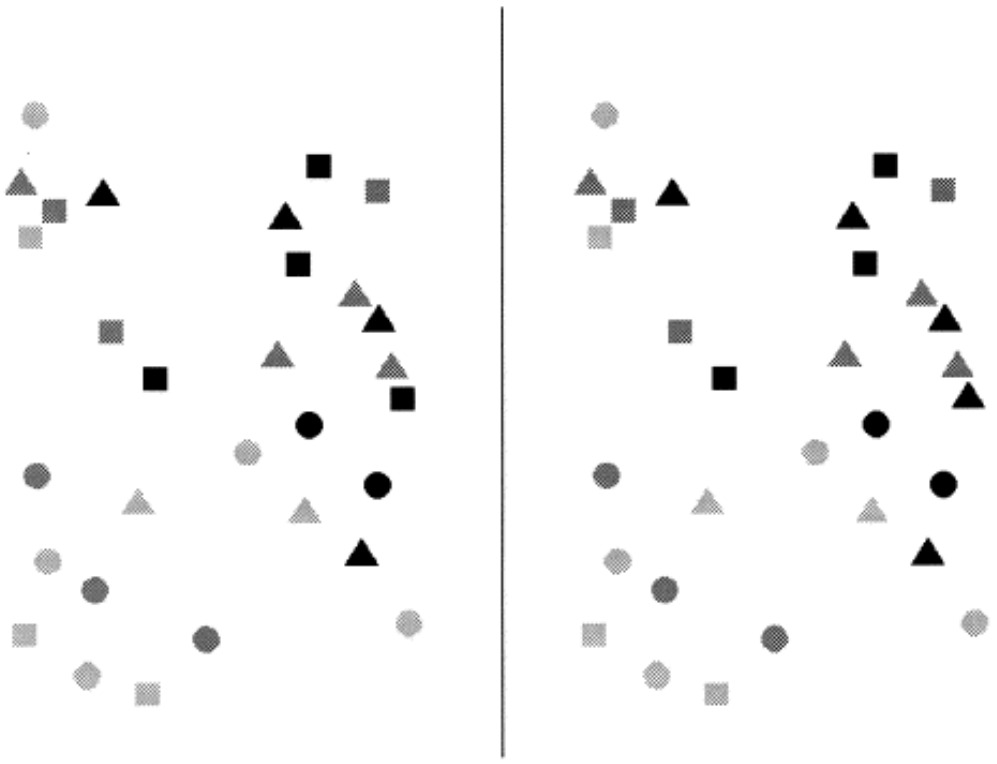
Experiment 2

Comparative visual search task . . . again
The task primes focus on the details (maybe local processing)

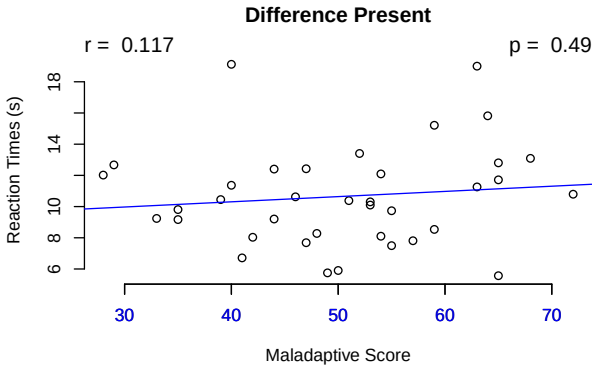
New setup

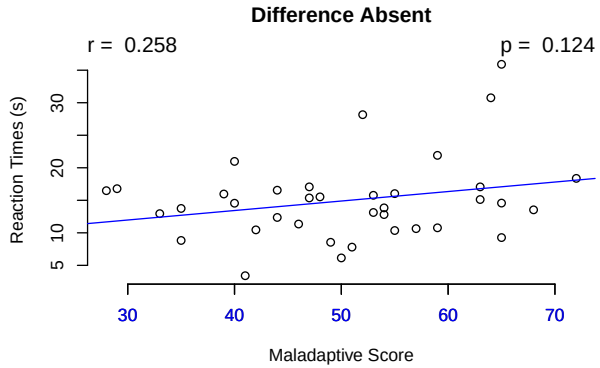
- All objects subtend the same ‘small’ area
- Only one difference per figure
- Unlimited search time
- Inclusion of a trials with NO difference. Will perfectionists give up (disengage from the search task) later than non perfectionist?

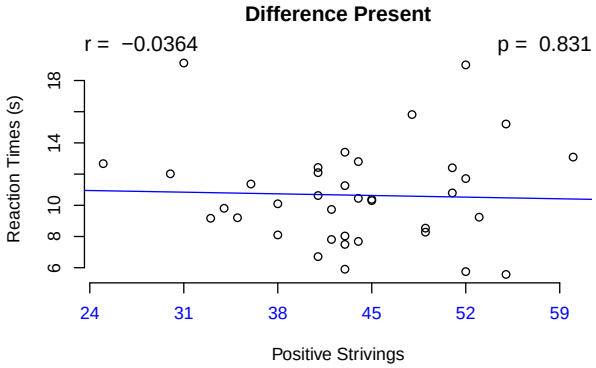
Example of stimulus display

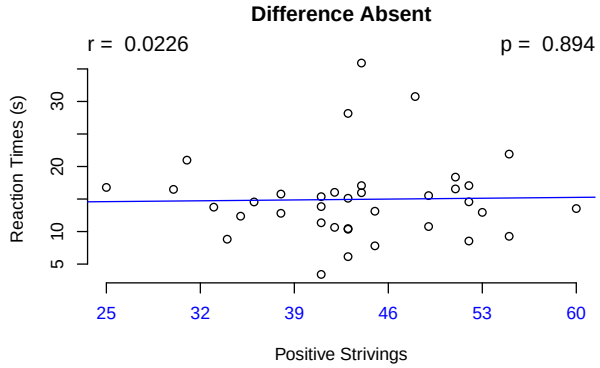


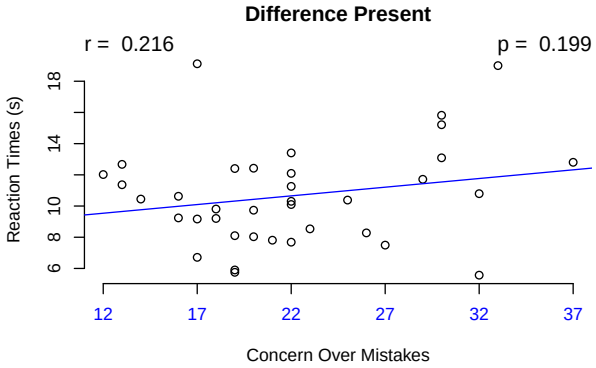
Results

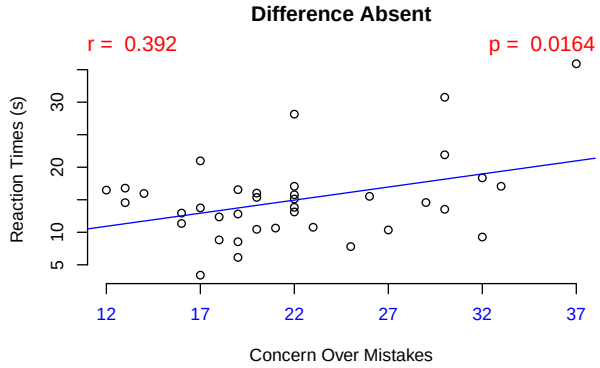

Difference Present
r = 0.117
p = 0.49
Reaction Times (s)
6
8
10
14
18
30
40
50
60
70
Maladaptive Score


Difference Absent
r = 0.258
p = 0.124
Reaction Times (s)
5
10
20
30
30
40
50
60
70
Maladaptive Score


Difference Present
r = −0.0364
p = 0.831
Reaction Times (s)
6
8
10
14
18
24
31
38
45
52
59
Positive Strivings


Difference Absent
r = 0.0226
p = 0.894
Reaction Times (s)
5
10
20
30
25
32
39
46
53
60
Positive Strivings


Difference Present
r = 0.216
p = 0.199
Reaction Times (s)
6
8
10
14
18
12
17
22
27
32
37
Concern Over Mistakes


Difference Absent
r = 0.392
p = 0.0164
Reaction Times (s)
5
10
20
30
12
17
22
27
32
37
Concern Over Mistakes

Results

The relationship between perfectionist and local processing is still unsupported.
The link between local processing and analysis of details is also unproven.
However, we did find behavioral evidence supporting preoccupation with errors.

What's next?

Determine what is the mechanism behind preoccupation with error.
Is it because perfectionists do more double checking than non-perfectionists?
Double checking is measurable through gaze analysis if after determining that there is a difference in the figures:

1. perfectionists switch between the two figures more times than non-perfectionists
2. perfectionists take longer than non-perfectionist to click on the difference

and for now . . . that's all folks

We only have 4 participants per group.
Any statistics testing will be pointless
so . . . if you'd like to know what happens:

1. invite me again next year
2. come to visit the rainy Groningen
3. write me an e-mail in a year p.toffanin@rug.nl
4. or keep an eye on my webpage
   `http://paolo.mp-concepts.net`

Thank you for the attention!!