Similarity vs. Association in neural oscillatory data: expectations, hints and applications

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Goals

- Assessing the **biological plausibility** of the distinction between similarity and association.
- **MVPA-Neural Decoding** from concept to relation-wise classification.
- **Brain computer interface** for communication based on semantic relations.

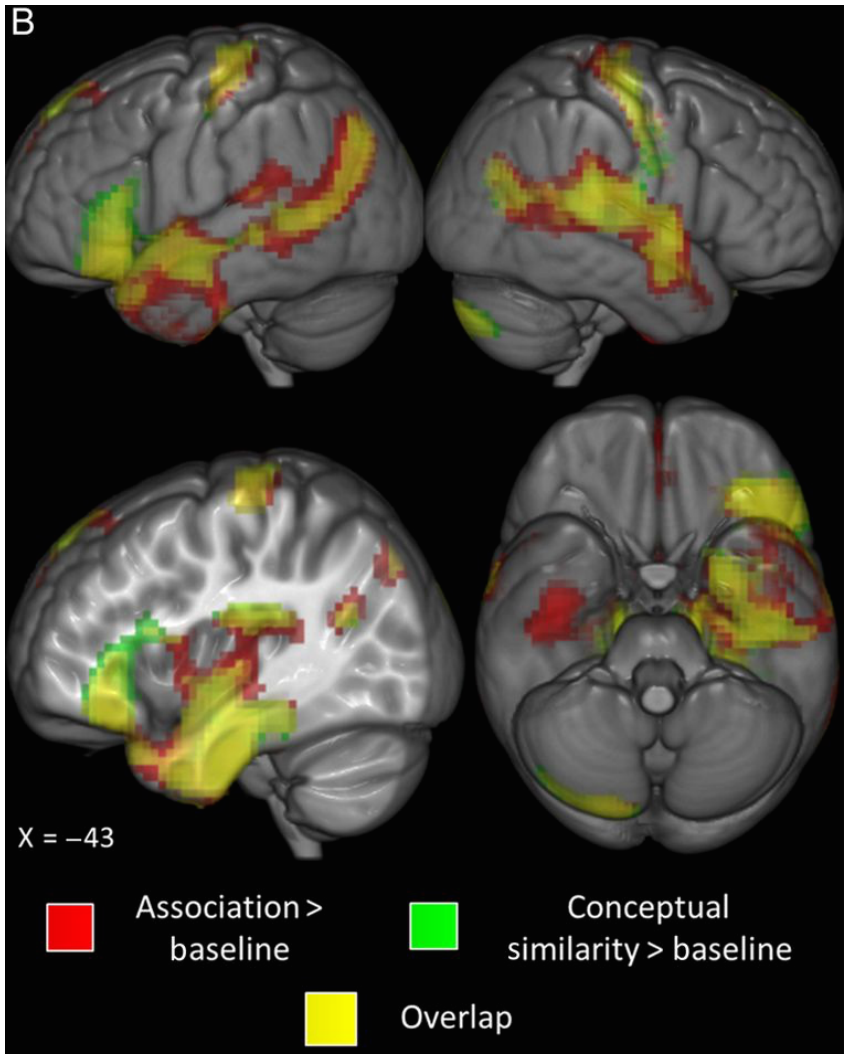
Association vs. Similarity

...a working definition...

- **Association**: function of co-occurence in space, time or language [*car,petrol*],
- **Similarity**: function of overlap of perceptual, functional, conceptual features [*car,bike*],
- **Neither mutually exclusive nor independent.**

Long-term memory:
Association → Episodic Memory
Similarity → Semantic Memory

Association = Similarity (fMRI)



- 96 + 96 prime-probe pairs,
- LSA-based association score (>0.2),
- Associated pairs: score>0.2 & belonging to 2 ≠ categories (eg: living vs. artifacts or tools vs. clothing),
- Similar pairs: score<0.2 & belonging to the same category,
- Tasks: Association & Similarity judgment,
- GLM contrasts: Association judgment > letter matching & Similarity judgment > letter matching.

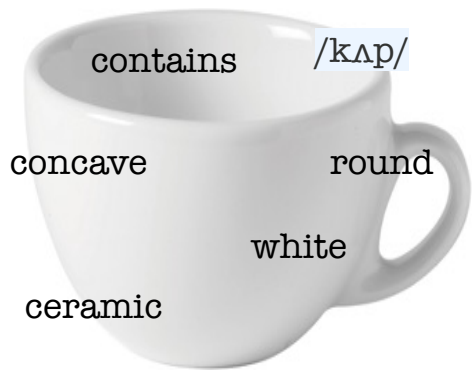
Jackson et al. 2014

Association = Similarity (fMRI)

Jackson et al. 2014 propose a **common mechanism** underlying both Association and Similarity

Cooccurrence of…

Features



Concepts

Association = Similarity (fMRI)

Jackson et al. 2014 assume a binary, orthogonal treatment of Association and Similarity. There are pairs that are:

- Associated pairs that are not Similar,
- Similar pairs that are not Associated.

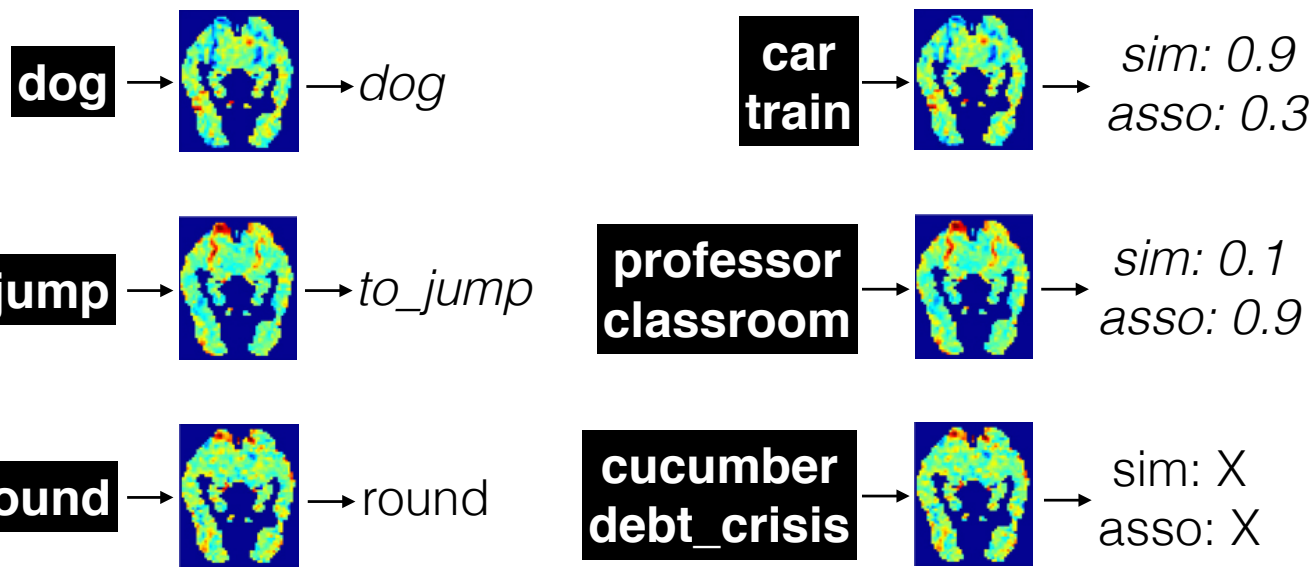
Alternative hypothesis:

- Association and Similarity are distinct dimensions processed in parallel in the same hubs, but at different time or time-frequency slots.

Decoding *semantic relations* from the brain

Concept-wise (Haxby):
given a stimulus —> observe activity —> guess label

Relation-wise:
given a pair of words —> observe activity —> return a binary, graded or categorial value in terms of semantic relation between within the pair



Association in EEG: ERP & Decoding

Prime		Probe
Unrelated		
tang (pliers)	-	opbrengst (yield)
berg (mountain)	-	drankje (small drink)
eland (moose)	-	eerbied (respect)
rog (ray)	-	maaier (mower)
gesp (buckle)	-	reflectie (reflection)
specht (woodpecker)	-	verpleger (male nurse)
Related		
mier (ant)	-	klein (small)
tram (tram)	-	spoor (track)
racket (racket)	-	tennis (tennis)
naald (needle)	-	draad (thread)
inktvis (squid)	-	tentakel (tentacle)
slurf (trunk)	-	olifant (elephant)

Table 4.2: Examples of stimuli used in the experiment. Taken from the related and unrelated sets.

De Deyne and Storms 2008

Geuze, Farquhar and Desain 2014

Association in EEG: ERP & Decoding

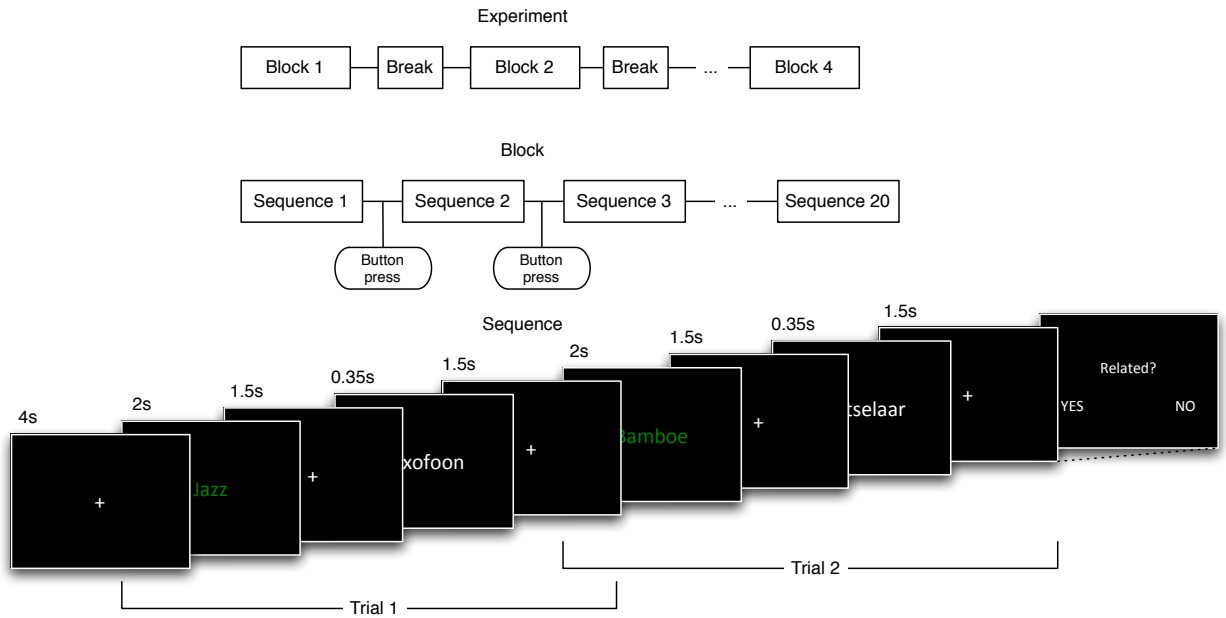


Figure 4.2: **Schematic overview the experimental design.** From global in time (top), to local in time (bottom).

Geuze, Farquhar and Desain 2014

Association in EEG: ERP & Decoding

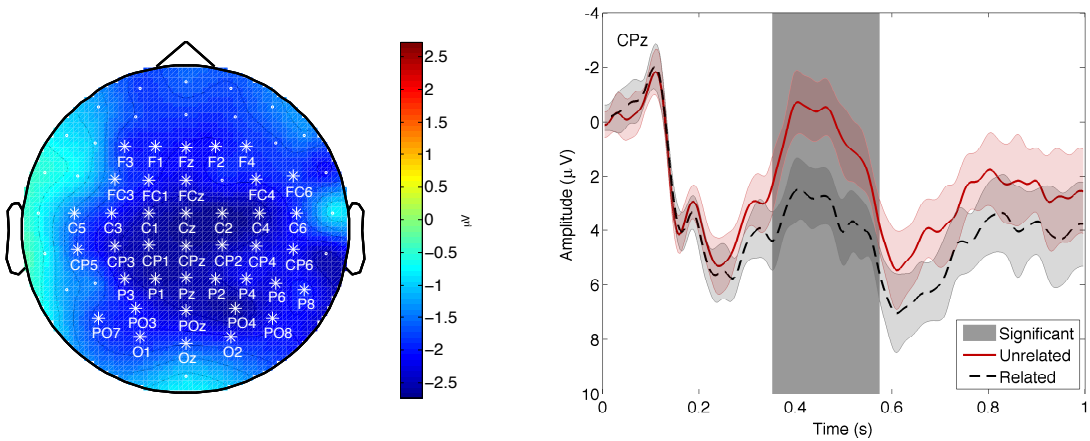


Figure 4.3: **Grand average results for the negative component.** Left panel: A topographic representation of the negative component between 330-600ms. The marked channels show a significant difference between related and unrelated probe responses. Right panel: ERP waveforms for channel Cz for related (black, dashed) and unrelated (red, solid). The area around each line represents the standard deviation, corrected for a within subject design (Field et al. 2012, p. 361–366). Channel Cz has been chosen as an example channel, as other significant channels are similar. Areas marked in grey show a significant difference.

Geuze, Farquhar and Desain 2014

Association in EEG: ERP & Decoding

Figure 4.4: Classification accuracies for the individually trained classifier and the classifier trained across subjects. Accuracies are mean accuracies of test set performance over ten folds. (* $0.001 < p < 0.05$, ** $p < 0.001$).

Geuze, Farquhar and Desain 2014

Association vs. Similarity in EEG: trial clustering

- Exploratory approach,
- Trial: 5,35s of brain activity associated with a <prime,probe> pair,
- Pairs assigned an Association and Similarity score,
- Clustering on the time-series,
- Average Asso & Sim score per cluster.

Average scores significantly different between clusters?

Cluster on neural processing data, see if matches with significant differences in semantic scores.

Preliminary Results

DETREND --> DOWNSAMPLE --> BANDF(**12-30Hz**) --> MAST

	Asso	PathSim	W&Psim	L&Csim
C1:	0.0563	0.1737	0.4009	0.4487
C2:	0.0538	0.1488	0.3427	0.3465
h:	0	**1**	**1**	**1**
p:	0.7585	0.0851	0.0183	0.0530

DETREND --> DOWNSAMPLE --> BANDF(**4-7Hz**) --> MAST

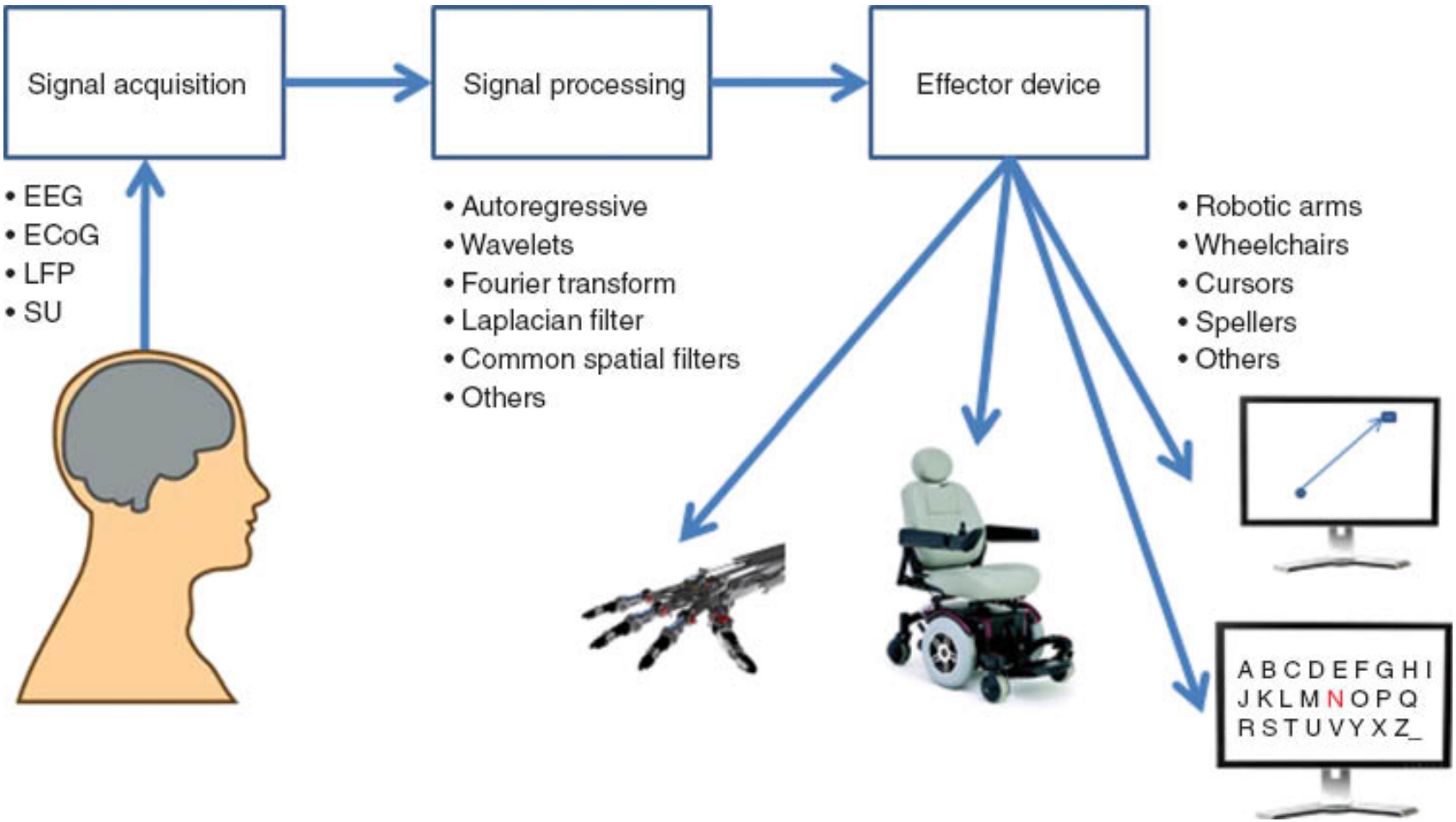
	Asso	PathSim	W&Psim	L&Csim
C1:	0.0607	0.1529	0.3742	0.3734
C2:	0.0353	0.1488	0.3239	0.3274
h:	**1**	0	0	0
p:	0.0873	0.8957	0.2945	0.6362

Results

if that is the case:

- There is a difference between Association & Similarity in terms of neural processing.
- This difference is most probably in the **time-frequency domain**... and reflects work of Klimesch, Schimke and Schwaiger 1994 and of Bastiaansen and Hagoort 2006.
- Would allow a BCI to leverage two dimensions between prime and probe based on two distinct frequency bands/semantic relations.

BCI


Signal acquisition
Signal processing
Effector device
• EEG
• ECoG
• LFP
• SU
• Autoregressive
• Wavelets
• Fourier transform
• Laplacian filter
• Common spatial filters
• Others
• Robotic arms
• Wheelchairs
• Cursors
• Spellers
• Others
A B C D E F G H I
J K L M N O P Q
R S T U V Y X Z _

Semantic BCI

Find the word the subject is thinking about by (**prime**):

- presenting *n* other words (**probes**)
- decoding whether the probe is *associated* with the prime (binary single-trial classification on the same time slot of the N400)

THE END