Omission related brain responses reflect specific and unspecific action-effect couplings

Dercksen, T.T.[1], Widmann, A.[1,2], Schröger, E. [2], & Wetzel, N.[1,3,4]

[1] Leibniz Institute for Neurobiology, Magdeburg, Germany, [2] University of Leipzig, Germany, [3] Center for Behavioral Brain Sciences Magdeburg, Germany,[4] University of Applied Sciences Magdeburg-Stendal, Germany

Introduction

When a sound is **predicted** but unexpectedly **omitted**, a response is elicited in the brain that can be measured using EEG. This **omission response** fits well within the **predictive coding** theory of perception (Friston & Kiebel, 2009). Predictive coding hypothesizes that, as a **prediction** about an upcoming stimulus is sent **down** the cortical hierarchy, the **absence** of a predicted stimulus should result in a **prediction error** sent **back up** in response (see figure below for a schematic representation of predictive coding). The **omission response** gives convincing empirical support in favor of **predictive coding**, as effects cannot be explained straightforwardly outside of prediction, for instance by **adaptation** effects (May & Tiitinen, 2010). Previous studies (SanMiguel et al., 2013) observed an omission response when the **identity** of the upcoming sound was **known**, but **no** omission response when sound identity was **unknown**. Given the importance of omission studies in the context of predictive coding, we **replicated** this study using **double the amount of participants** (N = 30), and used **principal component analysis** (PCA) to extract components.

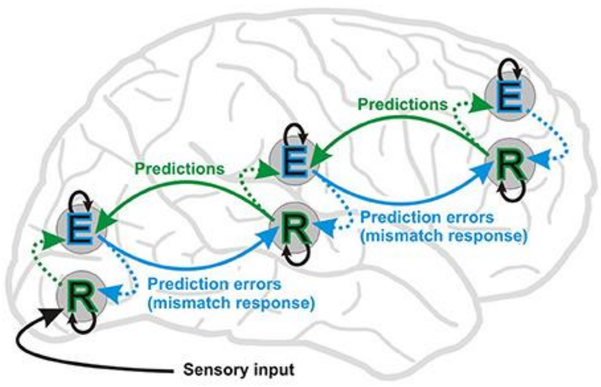

Figure 1: Stefanics et al. (2014). Schematic representation of predictive coding.

Methods

- 30 subjects
- Task: press a button every 600 – 1200 ms
- In 88% of trials a sound was presented when pressing the button
- In 12% of trials a sound was omitted when pressing the button
- In one condition (SO) a single sound was always presented with a button press
- In the other condition (RO) the sound changed randomly with every button press
- A motor control condition (M) was used to subtract motor activity related to pressing the button, in this condition no sounds were presented with the button press
- To measure brain activity, EEG was recorded to compute event-related-potentials (ERPs)
- Subsequently, PCA was applied to omission ERPs. This factor-analytic method uses eigenvalue decomposition to extract linear combinations of variables to account for patterns of covariance in the data, presumably reflecting ERP components

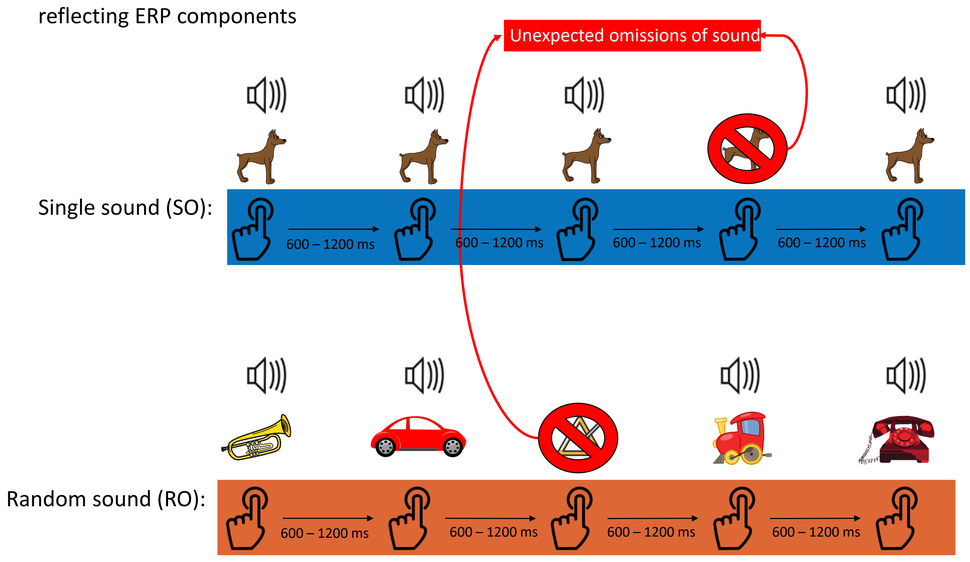

Figure 2: Schematic representation of single sound (SO) and random sound (RO) experimental conditions.

PCA Results

- Omission of sound stimuli in the **single sound** condition resulted in an omission response consisting of an **oN1, oN2, and three oP3 components** (oP3-1, oP3-2, oP3-3)
- Omission of sound in the **random sound** condition resulted in an omission response consisting of an **oN1 and three oP3 components**
- All omission components except for oP3-1 were **stronger** in the **single sound** condition compared to the **random sound** condition

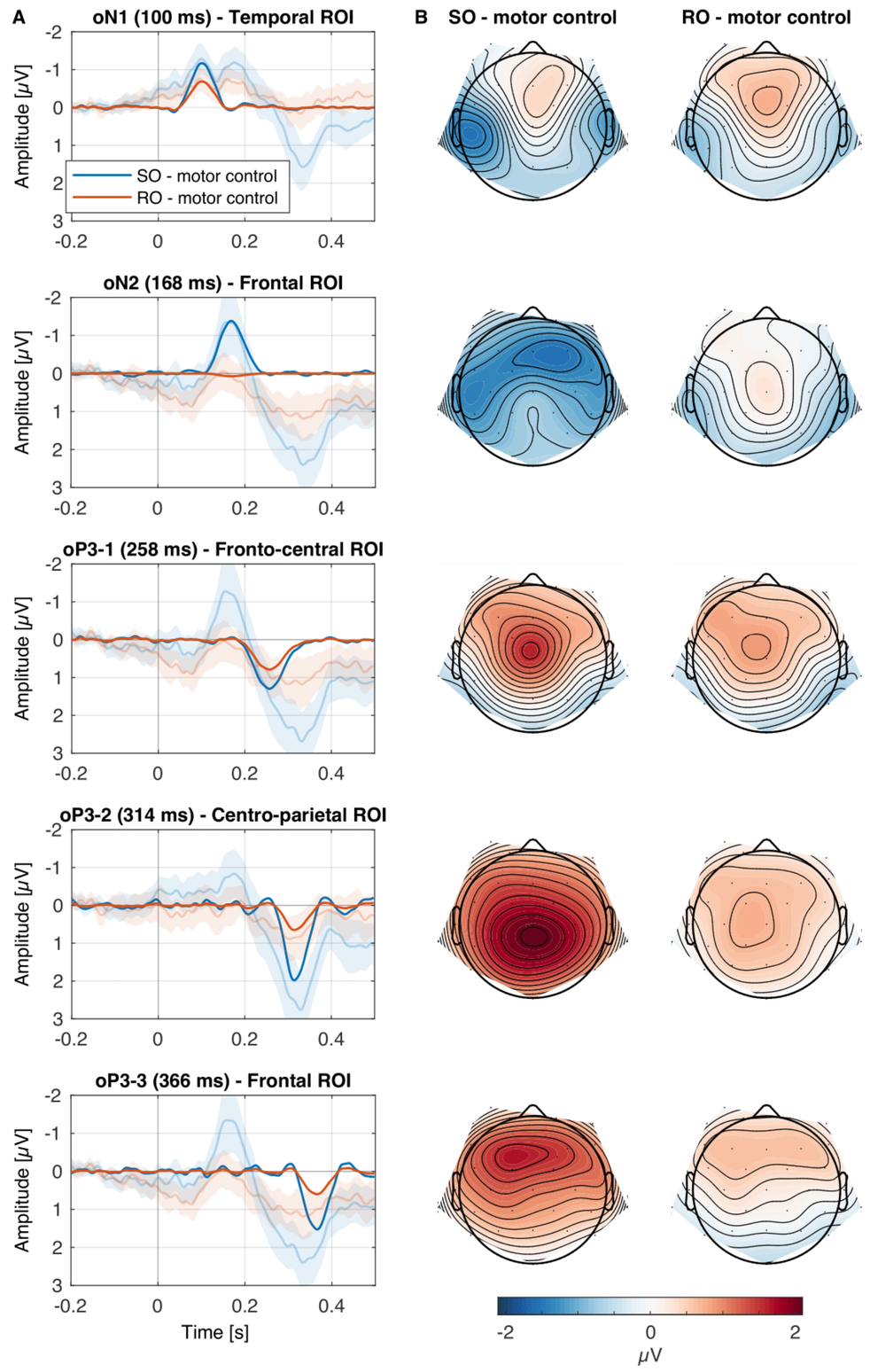

Figure 3: reconstructed PCA component difference waveforms (oN1, oN2, and the three oP3-subcomponents), grand-average difference waves, and topographies. Panel A shows reconstructed PCA components (opaque lines) for omissions in the single sound condition (SO, blue) and random sound condition (RO, orange), where in both conditions motor activity was subtracted. Corresponding ERPs are plotted transparently in the background. Panel B shows topographies of the PCA components for SO and RO conditions.

Statistical Tests

Component	Contrast	d	BF_{10}	t	p
oN1	SO vs. M	-1.07	8104	-5.86	<.001
	RO vs. M	-0.74	87.3	-4.06	<.001
	SO vs. RO	-0.56	8.46	-3.06	.005
oN2	SO vs. M	-0.59	13.1	-3.26	.003
	RO vs. M	0.06	0.20	0.31	.762
	SO vs. RO	-0.8	180	-4.36	<.001
oP3-1	SO vs. M	0.67	34.3	3.67	<.001
	RO vs. M	0.64	21.9	3.48	.002
	SO vs. RO	0.32	0.76	1.76	.089
oP3-2	SO vs. M	0.95	1460	5.19	<.001
	RO vs. M	0.59	12.8	3.24	.003
	SO vs. RO	0.79	173	4.34	<.001
oP3-3	SO vs. M	1.19	43398	6.53	<.001
	RO vs. M	0.77	120	4.19	<.001
	SO vs. RO	0.76	115	4.18	<.001

Table 1: Summary of the results. SO = single condition omission; RO = random condition omission; M = motor control. SO vs. M and RO vs. M t-tests test for elicitation of the omission components, while SO vs. RO t-tests test for amplitude differences between omission components. BF_{10} is the Bayes factor of the Bayesian t-tests where higher values represent more support for the alternative hypothesis.

Conclusions

- We replicate ERP components **oN1, oN2, oP3** in response to omissions when sound identity is **predictable**
- In line with earlier findings, **higher amplitude** omission components are observed when sound identity is **predictable**, confirming the important role **identity specific** predictions play in perception and learning
- Contrasting earlier findings, omission components **oN1, oP3** are also observed when sound identity is **unpredictable**, suggesting that predictions **do not** necessarily have to be identity specific in order to elicit a prediction error
- Results suggest the existence of both **specific** and **unspecific** predictions along the sound processing hierarchy, where **precision weighting** possibly influences the strength of prediction error

Acknowledgements

This project was funded by the Center for Behavioral Brain Sciences Magdeburg, funded by the European Regional Development Fund (ZS/ 2016/04/78120), and the Leibniz Association (P58/2017).

References

- Friston, K., & Kiebel, S. (2009). *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1211-1221.
- May, P. J., & Tiitinen, H. (2010). Mismatch negativity (MMN), the deviance-elicited auditory deflection, explained. *Psychophysiology*, *47*(1), 66-122.
- SanMiguel, I., Saupe, K., & Schröger, E. (2013). *Frontiers in human neuroscience,* 7, 407.
- Stefanics, G., Kremláček, J., & Czigler, I. (2014). *Frontiers in human neuroscience*, *8*, 666.

Contact details:
Tjerk T. Dercksen
0031617085296
tjerk.dercksen@lin-magdeburg.de
Leibniz Institute for Neurobiology
Brenneckestraße 6, 39118 Magdeburg