₁ Re-analysing the data from Moffatt et al. (2020): A textbook illustration of the absence of

₂ evidence fallacy

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9   Abstract

10   Moffatt et al. (2020) reported the results of an experiment (N = 26 in the final sample)

11   comparing the facial (surface) electromyographic correlates of mental rumination and

12   distraction, following an experimentally induced stressor. Based on the absence of

13   significant difference in the perioral muscular activity between the rumination and

14   distraction conditions, Moffatt et al. (2020) concluded that (the *self-reported*) inner

15   experience was unrelated to peripheral muscular activity as assessed using surface

16   electromyography. We suggest this conclusion is hasty and based on waggly evidence.

17   Indeed, concluding on the absence of an effect based on a low-powered statistical test is

18   strongly problematic/uninformative. Moreover, the relation between self-reports and

19   physiological measures was not *directly* assessed, but only indirectly inferred from

20   differences (or absence thereof) in group means. Given the ample inter-individual

21   variability in these measures (as suggested through our reanalysis), we think inferring the

22   individual-level relation between self-reports and physiological measures from group means

23   is inappropriate. Given these limitations, we conclude that it is unclear whether the target

24   article adds to the current/extent knowledge and we suggest ways forward, both from a

25   theoretical and from a methodological perspective. Complete source code, reproducible

26   analyses, and figures are available at

27   https://github.com/lnalborczyk/inner_experience_EMG.

28   *Keywords:* NHST, Bayesian, fallacy, reanalysis, inner speech, rumination,

29   electromyography

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31 evidence fallacy

32 Wordcount (excluding abstract, references, tables, and figures): 1527

Introduction

The activity of silently talking to oneself or "inner speech" is a foundational ability… despite its multiple adaptive functions in everyday life, inner speech can go awry and leads to sustained negative… These inner speech "dysfunctions" (for reviews, see Alderson-Day & Fernyhough, 2015; Lœvenbruck et al., 2018; Perrone-Bertolotti et al., 2014)…

Given the predominantly verbal nature of rumination [], we previously proposed to study rumination as other forms of inner speech have been studied in the past, namely using surface electromyography and motor interference protocols (e.g., Nalborczyk et al., 2017; Nalborczyk, 2019; Nalborczyk, Perrone-Bertolotti, et al., 2020; Nalborczyk, Grandchamp, et al., 2020)…

Moffatt et al. (2020), Grandchamp et al. (2019), Wilkinson and Fernyhough (2017), Nalborczyk, Batailler, et al. (2019)…

The main conclusion from Moffatt et al. (2020) is that inner experience between induced rumination and distraction differs "without a change in electromyographic correlates of inner speech". In other words, their conclusion is that inner experience is unrelated (or loosely related) to the electromyographic correlates of inner speech, which are thought to be represented mostly by the EMG amplitude recorded over the OOI and OOS muscles. However, for this in-sample observation to be of interest in an out-of-sample context (i.e., to be informative of other non-observed individuals, or said otherwise, to brings information about the population), this absence of difference has to be based on sufficiently powered sample size (given the target effect size) and on reliable measures… Moreover, a simple visual exploration of the data reveals important variability between individuals in the main effect of interest. That is, some participants had higher perioral (OOS and OOI) muscular activity in the rumination condition than in the distraction condition, and some other participants showed the reverse pattern. This suggests

58 unexplored variation in the determinants of this effects (e.g., the content of the inner

59 experience). Indeed, the relation between the inner experience and the physiological

60 correlates of inner speech production was only inferred from group means. However, given

61 the previous point, this appears highly problematic. We explore each of these limitations

62 and suggests ways forward in the following section.
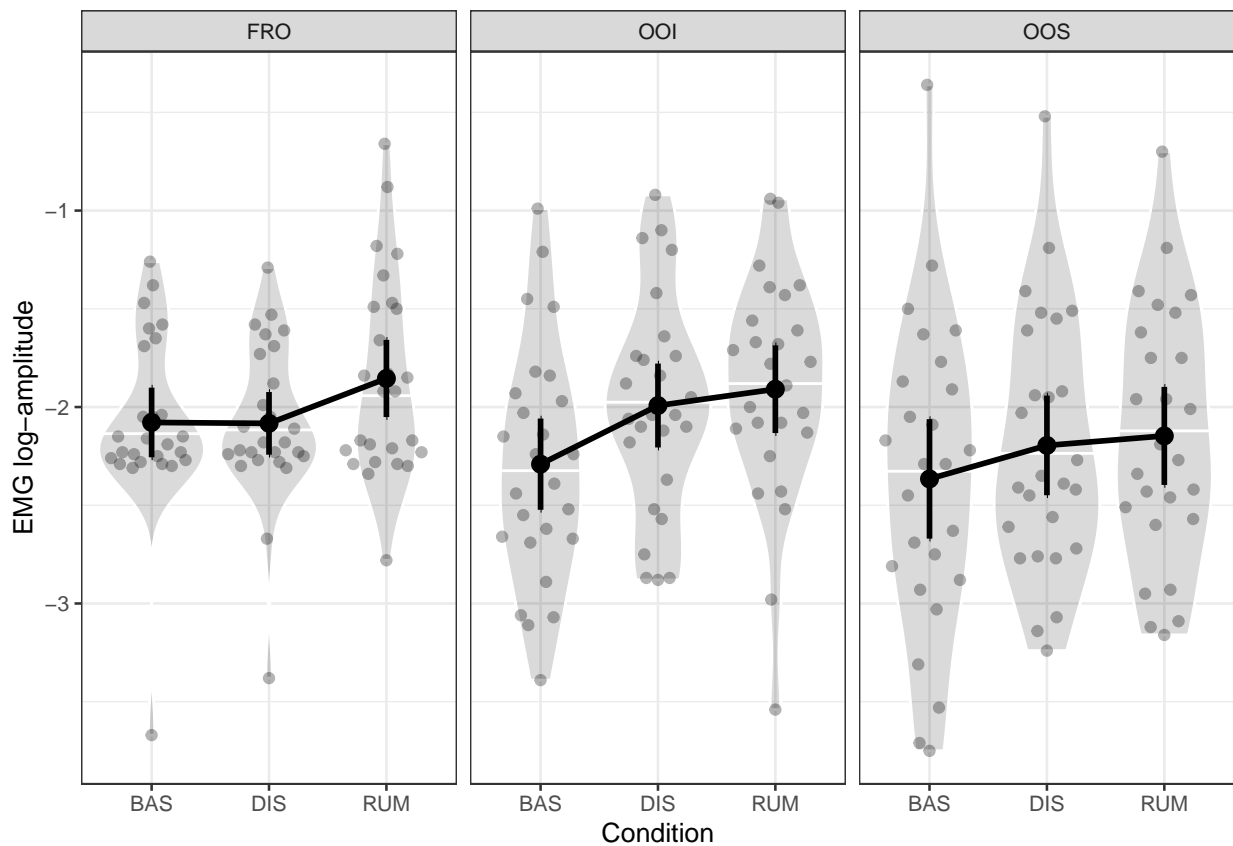
63 **Exploring the data**

Figure 1. Average log-EMG amplitude by muscle and condition. The black dots and intervals represent the by-group average and 95% confidence interval (N = 26). The horizontal white line in the violin plot represents the median. The grey dots represent the individual-level average natural logarithm of the EMG amplitude by muscle and condition.

64   ...

Concluding on the null from low-powered studies

⁶⁶   There is an infamous tradition of running uninformative null-hypothesis significance

⁶⁷ tests in Psychology (e.g., Meehl, 1997, 1978, 1990a, 1990b, 1967). By "uninformative", we

⁶⁸ mean that some null-hypothesis significance tests are often *not* diagnostic with regards to

⁶⁹ the substantive question of interest...

⁷⁰   As highlighted by many authors (e.g., **???**), concluding on an absence of difference

⁷¹ based on not obtaining evidence for the difference is the continuous extension of the logical

⁷² fallacy of the... The argument from ignorance, such as "Science has found no proof of

⁷³ intelligent life nearby us in space, therefore intelligent life does not exist nearby us in

⁷⁴ space."... the absence of evidence fallacy or fallacy of acceptance...

⁷⁵   This problem is tackled in modern usages of null-hypothesis significance test by

⁷⁶ ensuring that the test has good *severity* (e.g., Mayo & Spanos, 2006; Mayo, 2018). In

⁷⁷ general terms, we have evidence for a claim to the extent that it survives a stringent

⁷⁸ scrutiny, that is if it survives *severe tests*. In other words, some claim (e.g., $\theta = 0$) is said

⁷⁹ to be *severely tested*) if it had great chances of being falsified, was the claim false. More

⁸⁰ formally, we can define $\text{SEV}(T, x0, H)$, the severity with which claim H passes test T with

⁸¹ outcome $x0$, and $\text{SEV}(\mu > \mu_1) = \Pr(d(X) \leq d(x0); \mu = \mu_1)$ (Mayo, 2018; Mayo & Spanos,

⁸² 2006)...To put it simply... https://www.analytics-toolkit.com/glossary/severity/...

⁸³   Anticipating the critics on the power of their study (a critic that was probably raised

⁸⁴ during peer review), Moffatt et al. (2020) report the results of a (possibly ran a posteriori)

⁸⁵ power analysis using the effect size reported in Nalborczyk et al. (2017) of $d = 0.72$, which

⁸⁶ is highly optimistic estimate of the substantive effect of interest in the target article (i.e.,

⁸⁷ the difference in EMG amplitude between the rumination and distraction conditions) as

⁸⁸ this effects represents the standardised mean difference *between a rest period and a*

⁸⁹ *rumination one* (Nalborczyk et al., 2017)...

```r
# How many participants do we need for a target statistical power of 0.8?
library(pwr)
pwr.t.test(
  d = 0.72, sig.level = 0.05, power = 0.8,
  type = "one.sample", alternative = "two.sided"
  )
```

```
## 
##      One-sample t test power calculation
## 
##              n = 17.16004
##              d = 0.72
##      sig.level = 0.05
##          power = 0.8
##    alternative = two.sided
```

We suggest the (a priori) power of the study ran by Moffatt et al. (2020) was was much lower than suggested by the authors. Indeed, we may speculate that the effect (i.e., the standardised mean difference in EMG amplitude) between the rumination and distraction condition may be much weaker than the effect (i.e., the standardised mean difference in EMG amplitude) between the rumination and the rest conditions. If we assume that the former is half the size of the latter (which seems reasonable given the distribution of effects sizes in Experimental Psychology, e.g., Szucs & Ioannidis, 2017), therefore the a priori power of the main statistical test from Moffatt et al. (2020) is around 0.44, meaning that they had less than 1 chance over two to find a significant effect, given the effect in the population is actually 0.36. Because this is less than the chance of obtaining a head in a coin flip, we feel these resources may have been better invested.

```
# A priori power for n = 26 (per condition) and d = 0.36
pwr.t.test(
  n = 26, d = 0.72 / 2, sig.level = 0.05,
  type = "one.sample", alternative = "two.sided"
  )
```

```
109  ##
110  ##        One-sample t test power calculation
111  ##
112  ##                n = 26
113  ##                d = 0.36
114  ##        sig.level = 0.05
115  ##            power = 0.4228455
116  ##      alternative = two.sided
```

Anticipating again the legitimate critique that the absence of a significant difference is not *necessarily* "significant" evidence of the absence of the effect, Moffatt et al. (2020) report the following Bayes factor analysis:

"[…] therefore it is possible that the sample size of the present study lacked sufficient power to detect the effect of rumination on muscle activity. In order to test this, a Bayesian paired samples t-test was conducted for the peak log values of muscle activity between the rumination and distraction conditions. This revealed strong evidence in favour of the alternative hypothesis for the FRO muscle ($B_{10} = 18.79$), and moderate evidence in favour of the null hypothesis for the OOS ($B_{10} = 0.232$) and OOI ($B_{10} = 0.278$) muscles, according to current guidelines for interpreting Bayes factors [43]."

While we appreciate the effort, the current approach poses new problems. First,

129 contrary to what the authors suggest, computing a BF (i.e., comparing two models) does

130 not solve at all the problem of low power. Second, no details are given with regards to the

131 exact models that were compared. Second... Third, and most importantly, the BFs indicate

132 moderate evidence in favour of the null for the OOI and OOS muscles. More precisely,

133 these BFs indicated that the (observed) data are $1/0.232 \approx 4.31$ times more likely under

134 the null than under the alternative hypothesis for the OOS and $1/0.278 \approx 3.6$ times more

135 likely under the null than under the alternative hypothesis for the OOI. In other words, the

136 evidence is favour of the null is relatively weak and sensitivity analyses (i.e., reporting the

137 BF with different prior scales) may unsurprisingly results in various BFs... For instance...

138 Finally and most importantly, the power...

```r
library(BayesFactor)

ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], paired
```

139 ## Bayes factor analysis

140 ## --------------

141 ## [1] Alt., r=0.707 : 0.2796158 ±0.03%

142 ##

143 ## Against denominator:

144 ##   Null, mu = 0

145 ## ---

146 ## Bayes factor type: BFoneSample, JZS

```r
ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], paired
```

147 ## Bayes factor analysis

148 ## --------------

149 ## [1] Alt., r=1 : 0.2072665 ±0.06%

150 ##

```
151  ## Against denominator:

152  ##    Null, mu = 0

153  ## ---

154  ## Bayes factor type: BFoneSample, JZS
```

```r
ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], paired
```

```
155  ## Bayes factor analysis

156  ## --------------

157  ## [1] Alt., r=1.414 : 0.1505836 ±0%

158  ##

159  ## Against denominator:

160  ##    Null, mu = 0

161  ## ---

162  ## Bayes factor type: BFoneSample, JZS
```

```r
# ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], pa
# ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], pa
# ttestBF(x = df2$OOI[df2$condition == "RUM"], y = df2$OOI[df2$condition == "DIS"], pa
```

163   We fitted a multivariate Bayesian regression model on these data... then we generated

164 new datasets from the posterior predictive distribution... and computed the Bayes factor in

165 favour of the alternative hypothesis (BF_{10}) for varying sample sizes from 20 to 200

166 participants (by increments of 10 participants) with 10 simulations (i.e., 1000 simulated

167 datasets) for each sample size...

168   As shown in Figure 2, the BF in favour of the alternative hypothesis is growing

169 proportionally with the sample size...

170   We should keep in mind the limitations of this analysis, which uses simulated
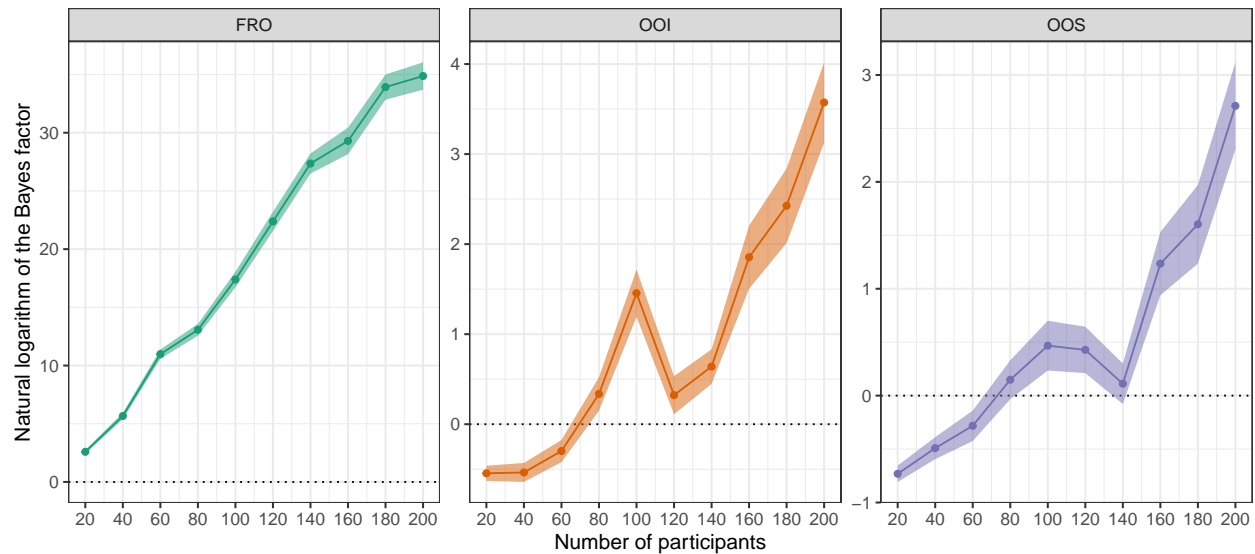
Figure 2. Average natural logarithm of the Bayes factor in favour of the alternative hypothesis (BF10), along with its standard error, computed over 1000 datasets of increasing size simulated from the posterior predictive distribution of the varying-intercept multivariate Bayesian regresion model.

171 datasets form the posterior distribution estimated from… which corresponds more or less to

172 the Bayesian analogue of the post-hoc frequentist power analysis, which has been much

173 criticised (e.g., Lakens, 2014). However, the present analysis differs from this kind of

174 analysis by relying on the posterior distribution… and because we do not aim to reach a

175 dichotomic (e.g., accept/reject) goal but rather to see how the BF amplitude evolves with

176 varying sample sizes.

177 **Manipulating rumination within-subject**

178   In Nalborczyk, Banjac, et al. (2020), we manipulated the modality of rumination

179 (whether it is verbal or non-verbal) in a between-subject manner to avoid order effects… In

180 contrast to this approach, Moffatt et al. (2020) asked participants to ruminate and then

181 distract themselves (or reciprocally), after an induced stressor (an induced failure)…
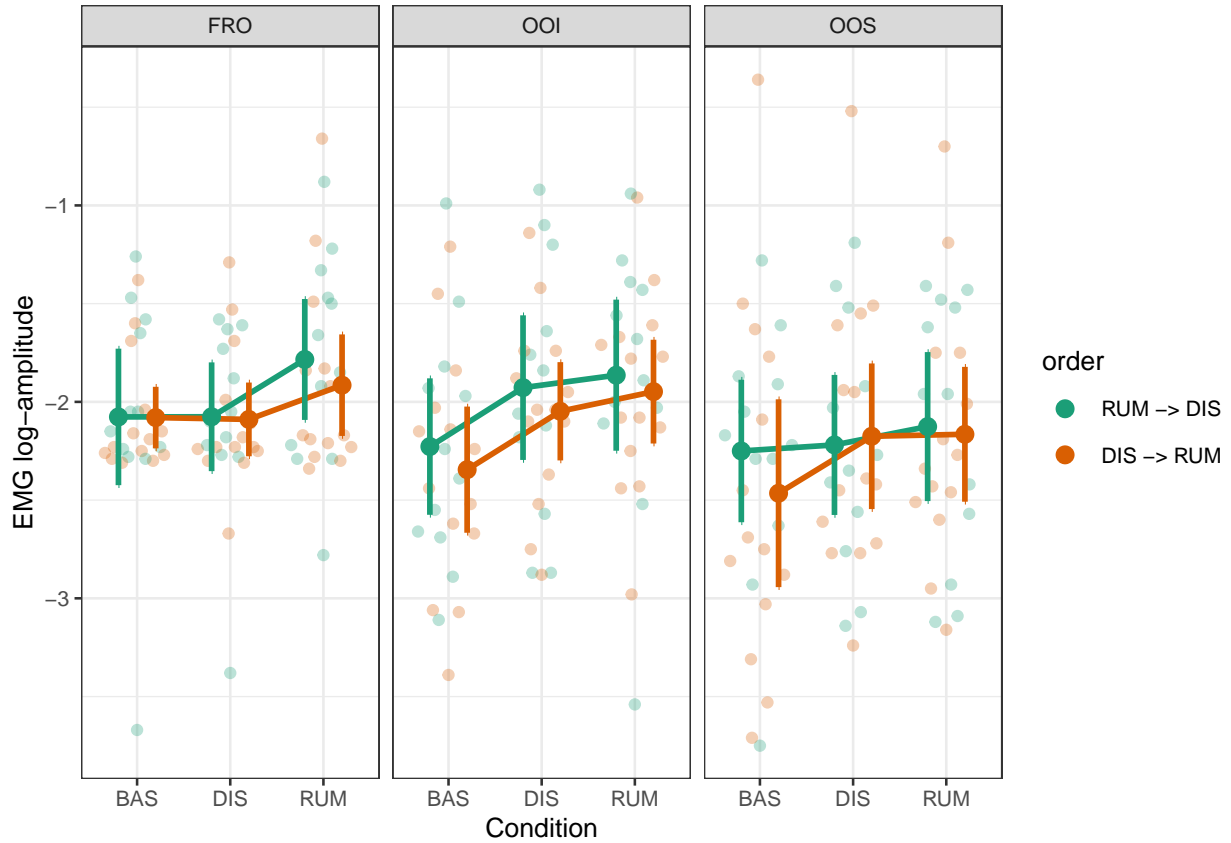
Figure 3. Average log-EMG amplitude by muscle and condition. The black dots and intervals represent the by-group average and 95% confidence interval (N = 26). The horizontal white line in the violin plot represents the median. The grey dots represent the individual-level average natural logarithm of the EMG amplitude by muscle and condition.

About the order effects, Moffatt et al. (2020) say:

"Unless otherwise reported, the inclusion of order in which the conditions were completed as a between-subjects variable as part of a mixed-design ANOVA produced no significant main effects or interactions involving order."

Unfortunately, the same line of reasoning applies for testing the effect of the order, which is even less powered than the test of the main effect of interest, rendering it practically uninformative...

189 **Does everyone?**

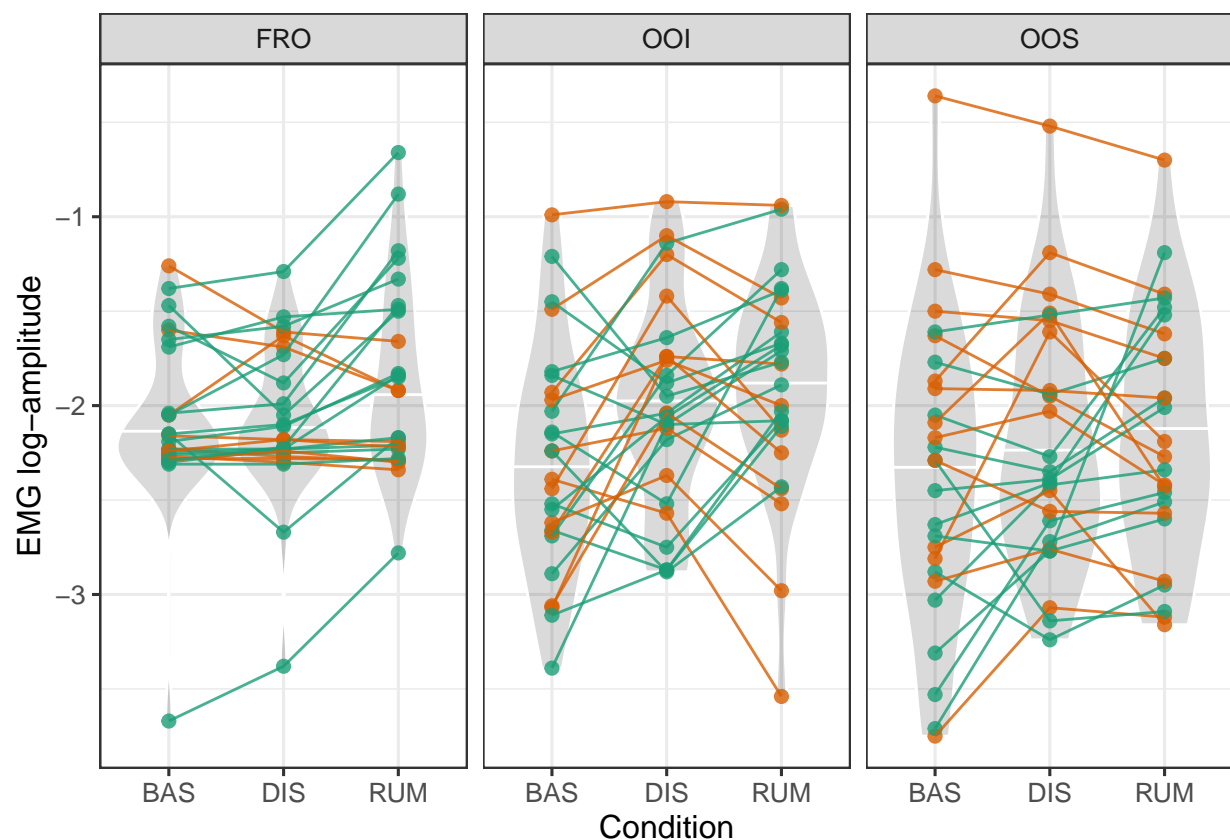190   Haaf and Rouder (2017)...

Figure 4. Inter-individual variability in the main effect of interest (i.e., the difference between the rumination and distraction conditions). Green dots and lines represent the average logarithm of the EMG amplitude of participants that showed a higher EMG amplitude in the rumination condition than in the distraction condition, whereas orange dots and lines represent the average logarithm of the EMG amplitude of participants that showed a higher EMG amplitude in the distraction condition than in the rumination condition.

191   Huge inter-individual variability... which leads to the next point, what is the relation

192 between self-reports and EMG?

Relation between self-report and EMG correlates

...

Discussion and conclusions

Baseline-standardisation...

Supplementary materials

Reproducible code and figures are available at
https://github.com/lnalborczyk/inner_experience_EMG.

Acknowledgements

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