

1 **Dynamic up- and down-regulation of the default (DMN) and extrinsic (EMN) mode**
2 **networks during alternating task-on and task-off periods**

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23 **Abstract**

24 Using fMRI, Hugdahl et al. (2015) reported the existence of a general-domain cortical
25 network during active task-processing which was non-specific to the cognitive task being
26 processed. They labelled this network the extrinsic mode network (EMN). The EMN would
27 be predicted to be negatively, or anti-correlated with the classic default mode network
28 (DMN), typically observed during periods of rest, such that while the EMN should be down-
29 regulated and the DMN up-regulated in the absence of demands for task-processing, the
30 reverse should occur when demands change from resting to task-processing. This would
31 require alternating periods of task-processing and resting, and analyzing data continuously
32 when demands change from active to passive periods and vice versa. We were particularly
33 interested in how the networks interact in the critical transition points between conditions. For
34 this purpose we used an auditory task with multiple cognitive demands in a standard fMRI
35 block-design. Task-present (ON) blocks were alternated with an equal number of task-absent,
36 or rest (OFF) blocks to capture network dynamics across time and changing environmental
37 demands. To achieve this, we specified the onset of each block, and used a finite-impulse
38 response function (FIR) as basis function for estimation of the fMRI-BOLD response. During
39 active (ON) blocks, the results showed an initial rapid onset of activity in the EMN network,
40 which remained throughout the period, and faded away during the first scan of the OFF-block.
41 During OFF blocks, activity in the DMN network showed an initial time-lag where neither the
42 EMN nor the DMN was active, after which the DMN was up-regulated. Studying network
43 dynamics in alternating passive and active periods may provide new insights into brain
44 network interaction and regulation.

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49 **Introduction**

50 Applying an inclusive conjunction analysis to fMRI data from nine different studies with a
51 total of 187 subjects, and comprising nine different cognitive tasks, Hugdahl et al. [1] found a
52 generalized cortical network that was independent of the specifics of the individual task and
53 cognitive processes. The authors labelled this the Extrinsic Mode Network (EMN), as a task
54 non-specific network, with a fronto-temporo-parietal distribution, including the inferior and
55 middle frontal gyri, inferior parietal lobule, supplementary motor area, and the inferior
56 temporal gyrus. The EMN thus has a spatial architecture overlapping with what Fedorenko et
57 al. [2] labelled the "cognitive flexibility network", and Duncan [3] labelled the "multiple
58 demand network" (see also [4]). Common for all these networks is that they are suggested to
59 be general-domain networks, i.e. they show up-regulation of activity across a range of
60 cognitive tasks, e.g. [5], [6], [7], [8]. The general-domain networks further share
61 characteristics with several domain-specific networks, such as the dorsal attention and
62 salience networks [9], [10], [11], [12]), central executive network [13], [14], fronto-parietal
63 network [15], and ventral attention network [16], see also Lee et al. [17], and Cabeza and
64 Nyberg [18] for overviews. In the current study, we asked how the EMN as a general-domain
65 network relates to the more known default mode network (DMN) [19], [20], [12], see also
66 [21], [22], [23], [24], which is typically observed in the absence of specific tasks. It could be
67 predicted that the DMN should be negatively, or anti- correlated with a general-domain
68 network, like the EMN. This prediction is derived from previous findings that neuronal
69 activity varies reciprocally between characteristic DMN- and task-positive network-areas,
70 when studied under both resting-state [16], [25], [26], [23], and during active task conditions
71 [27], [28], [29]. Lustig et al. [27] used alternating blocks of passive viewing of a fixation
72 cross and active processing of a semantic judgement task. Results showed increased
73 activations in the left frontal cortex during task-processing and deactivation in the same area

74 during passive fixation blocks. An opposite pattern was seen in the lateral parietal cortex, with
75 deactivations during task processing. The study by Lustig et al. [27] therefore showed inverse
76 activations and deactivations in brain areas linked to active task-processing compared to
77 passive viewing. Following previous findings we therefore asked whether a similar
78 relationship should hold for general-domain networks, and in particular for the EMN, when
79 different cognitive tasks are alternated during the scanning session. Thus, we alternated brief
80 periods with task presentations with brief periods of resting with no tasks present.

81 Conventional analysis of block-design data is to subtract activity during OFF-blocks from
82 activity during ON-blocks, where the OFF-blocks act as a baseline control-condition (we
83 leave out here the discussion in the literature whether the assumption of "pure insertions" in
84 block-designs is a valid assumption or not, cf. [30]. The resulting activity pattern would thus
85 reflect active task-processing. By subtracting activity obtained during task-processing ON-
86 blocks from activity obtained during resting OFF-blocks, cf. [19], it should be possible to
87 display activity that would be deactivated during task-processing blocks. We are not focusing
88 here on whether task-positive and task-negative networks are anti-correlated per se in resting-
89 state fMRI situations, cf. [31], [27], but on the time-dynamics of up- and down-regulations
90 across the transitions between task-present and task-absent periods, with a focus on the
91 interaction between the DMN and EMN networks. For this purpose, we used a finite-impulse
92 response (FIR) function to model the BOLD response as implemented in the Statistical
93 Parametric Mapping (SPM) analysis software (<https://www.fil.ion.ucl.ac.uk/spm/>). We re-
94 analyzed fMRI data from >100 healthy individuals from a previous study in our laboratory
95 [32], where the subjects had been tested with an auditory dichotic listening (DL) task with
96 three instruction conditions that emphasized either perception [33], attention/vigilance [34] or
97 executive control functions [35]. We chose this task because it reflects the changing cognitive
98 demands and coping situations during an ordinary day, including both low-, perception, and

99 high-, executive control, level demands. The so called forced-attention DL paradigm was
100 originally developed by Hugdahl and Andersson [34] for the study of the role of cognitive
101 factors in auditory perception, and it has repeatedly been shown to produce valid and reliable
102 results with regard to perception, attention and executive control, see e.g. [36], [37], [38],
103 [39], [40], [41], [42], [43]. We now report how the EMN interact with the DMN within a
104 single paradigm which included alternating task-presence (ON) and task-absence (OFF)
105 periods, and with recurring and varying cognitive tasks and demands. Such an experimental
106 design would be a novel way of capturing the dynamic interaction between passive rest and
107 active processing periods, going beyond a fMRI "resting period" data acquisition approach. In
108 order to capture the dynamics of network up- and down-regulation over time, and especially
109 at the transition points between ON- and OFF-blocks, we specified the onset of each condition
110 and used a 3s finite-impulse response function (FIR) as basis function for estimation of the
111 BOLD response. This approach modelled each scan per task-ON- and task-OFF-block
112 separately, which would allow an analysis of the fine-grained dynamics in the critical time-
113 window when the situation switched from active to passive, and from passive to active time
114 periods.

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116

117 **Materials and Methods**

118

119 **Participants**

120 The participants were 104 healthy adults, with mean age of 29.3 years, standard deviation 8.3
121 years. Approximately half of the participants were males, and half were females. The
122 participants volunteered for participation, and further details can be found in [33]. The study
123 was conducted according to the Declaration of Helsinki regarding ethical standards. The re-
124 analyzed data had in addition previously been approved by the Regional Ethics Committee for

125 Medical Research in the Western Health Region of Norway (REK-Vest), and also been
126 completely anonymized before the current analyses were made.

127

128 **Cognitive tasks**

129 The cognitive task was an auditory speech perception task, with repeated dichotic
130 presentations of two different consonant-vowel (CV) syllables presented on each trial, one in
131 the right ear and the other at the same time in the left ear. The participant is not told that there
132 are two different sounds, one in each ear, on every trial. The baseline instruction to the
133 participant was to report which syllable they perceived most clearly on each trial,
134 emphasizing a single response, and with no instruction about allocation of attention to either
135 the right or left ear. The task consists of repeated presentations of syllable-pair, using all
136 combinations of the six stop-consonants /b/, /d/, /g/, /p/, /t/, /k/ paired with the vowel /a/,
137 making up the CV-syllables /ba/, /ga/, /pa/, /da/, /ka/, /ta/. A trial could thus be the
138 presentation of /ba/ in the left ear and simultaneously the syllable /pa/ in the right ear, see [36]
139 for an overview of the dichotic listening task. The dichotic CV-syllable task has historically
140 been used for the study of hemispheric asymmetry, which is reflected in the typical higher
141 accuracy scores for reporting of the right ear stimulus, called a right-ear advantage (REA)
142 [44], [35], [45], [46]. The paradigm has however also been used for the study of higher
143 cognitive functions, like attention and executive control functions [47], [43], [48], [49], which
144 Hugdahl and Andersson [33] labelled "the forced-attention" dichotic listening paradigm. In
145 the latter case instructions to explicitly focus attention to and report from only the right or left
146 ear is alternated between trial-blocks, and mixed with blocks of no-attention-focus instruction.
147 A methodological advantage with the forced-attention variant is that it allows for the study of
148 perception, attention and executive functions within the same experimental paradigm, by
149 simply changing the instructions to the participants in the course of the experimental session,

150 see [35] for further examples. In the present fMRI-variant of the DL paradigm, each of the
151 three instruction blocks (no instruction, instruction to focus on the right ear, instruction to
152 focus on the left ear) were repeated three times during the session. The order of the
153 presentation of the three conditions were pseudorandomized among the non-forced (NF),
154 forced-right ear (FR), and forced-left ear (FL) instruction epochs. To approximate an every-
155 day situation with brief processing and resting periods, the nine task-present epochs
156 (ON-blocks) were alternated with nine resting epochs (OFF-blocks) with no stimuli or
157 instruction present. Each ON- and OFF-block had a duration of 55 sec. Since the focus of the
158 present study was the dynamic interaction of the EMN and DMN networks, we present data
159 averaged across the three instruction conditions, since this will capture the conglomerate
160 activity across the three cognitive tasks, to act as a proxy of for the fluctuations of cognitive
161 demands experienced during the course of a day.

162

163 **MR imaging**

164 The MR scanner was a 3T GE SignaHDx scanner, and for the initial anatomical scanning, a
165 T1 3D Fast Spoiled Gradient Recall sequence (FSPGR) was applied: TE = 14 ms, TR = 400
166 ms, TI = 500 ms), with 188 consecutive sagittal slices (1 mm thick, no gap, scan matrix: 256 x
167 256; FOV 256 mm). For the following echo-planar functional imaging (EPI), a sparse-
168 sampling sequence was applied with TR of 5.5 sec, and with acquisition time (TA) of 1.5 sec,
169 leaving a silent gap of 4 sec when the stimuli were presented, see [46]. 180 EPI-volumes
170 were acquired, consisting of 25 axial slices in each volume (FOV: 220 mm; scan matrix 64 x
171 64; 5 mm slice thickness, 0.5 mm gap; TE = 30 ms). There were 10 EPI-volume acquisitions,
172 or scans, during each of the task-present and task-absent blocks, each of 55 sec. Total session
173 time for the EPI-imaging part was thus $(9 \times 55) \times 2 = 16.5$ min, with regularly alternating
174 task-present and task-absent blocks.

175 **Statistical analysis and visualization of fMRI data**

176 The fMRI-data were analyzed with the SPM12 software package ((Wellcome Department of
177 Cognitive Neurology, London, UK, <http://www.fil.ion.ucl.ac.uk/spm/>), following standard
178 SPM settings. In brief, the raw DICOM images were converted to nifty-format, and pre-
179 processed following SPM implanted routines for realignment and unwarping, normalizing the
180 EPI-images to the MNI template, and smoothing with an 8 mm kernel. Thereafter, 1st-level
181 analysis was performed, by specifying the onset of each condition and using a finite-impulse
182 response function (FIR) as basis function, which modeled each scan per ON and OFF block
183 separately, but averaged across repetitions of the same condition. The resulting beta-
184 images/time-bins (TBs) (20 per condition, NF , FR, FL) were then used as input for the next,
185 2nd-level analysis, which was defined as a 3 x 20 repeated measure ANOVA model, with the
186 factor condition (NF, FR, FL) and the factor time-bin (TB) (1-20). This model allows
187 exploring not only averaged bock-effects, mimicking “classical” ON-OFF contrasts, but also
188 the temporal dynamics and time derivatives by specifying contrasts for each TB separately.
189 (see Figure 1).

190 -----

191 Insert Figure 1 about here

192 -----

193 **Figure 1:** *Outline of the block-design with alternating ON-and OFF-periods with*
194 *corresponding task-processing and resting, respectively. The time-line illustrates the*
195 *specification of the separate time-bins (TB) for respective ON- and OFF-blocks, with the*
196 *transition points between blocks marked with circles. The tables under the design illustrates*
197 *the contrasts used in the analysis for the time-bin (left) and time-derivative (right) analyses,*
198 *respectively (see text for further details).*

199

200 The following contrasts were specified: First, the average ON-OFF and OFF-ON contrasts
201 were specified. Second, corresponding averaged TBs for the ON and OFF contrast were
202 compared, i.e. TB1 ON against TB1 OFF, TB2 ON against TB2 OFF, etc, and repeated for
203 the remaining eight pairs of time-bins, and t-contrasts were specified in both directions. Third,
204 we explored the time-derivatives of the activity by contrasting averaged time-bins next to
205 each other, i.e. TB1 against TB2, TB2 against TB3, etc, i.e., TB n against TB $n+1$. These
206 latter contrasts will reveal consecutive significant changes from one TB to the next, i.e. from
207 TB n to TB $n+1$ as a “sliding window”. The “sliding window” contrast would be sensitive for
208 picking up the time dynamics in the relative up- and down-regulation of the task-positive and
209 task-negative networks, i.e. sensitive to the transition from the last TB for an ON-block to the
210 first TB for an OFF-block, and vice versa (see Figure 1). If an activity remained unchanged
211 from one TB to the next (as one would expect for adjacent TBs in the middle of a block), this
212 contrast would not show anything. Again, both directions of contrasts were estimated, i.e.
213 whether there was a significant increase or decrease from one TB to the next. For simplicity,
214 differential effects between the three conditions (NF, FR, FL) were not explored, since the
215 focus was on activity that were common across diverse cognitive tasks, cfr. [4], [2], [1].
216 Results were explored for statistical significance, using a family-wise error (FWE)-corrected
217 threshold level of $p < .05$ in the main analyses, to protect against Type-I errors, and with at
218 least 10 voxel per cluster.

219

220 **Results**

221 The results of the averaged ON-OFF contrast revealed the typical task-positive activity
222 pattern with bilateral activity in the auditory cortex and surroundings, and of the task-positive,
223 EMN, network [1] in the prefrontal cortex, including the anterior and middle cingulate cortex,
224 supplementary motor area (SMA/preSMA), and thalamus. The opposite contrast revealed

225 areas, belonging to the task-negative, DMN, network [20], revealed significant activity in the
226 precuneus, inferior parietal, and medial orbitofrontal areas, and in occipital areas (see Figure
227 2b and Table 1b). This could be activity returning to baseline during resting periods, as
228 previously found, see e.g. [20], or as a new finding with increases above baseline in situations
229 with alternating task-negative and task-positive periods.

230 -----

231 Insert Figure 2a,b and Table 1a,b about here

232 -----

233 **Figure 2 (a,b):** Figure 2a shows BOLD activity for the ON – OFF contrast, thresholded at
234 FEW .05, 10 voxels, in sagittal images through the entire brain volume, from “ear-to-ear”,
235 rendered on an average MNI template. Figure 2b shows BOLD activity for the OFF-ON OFF
236 contrast, thresholded at FEW .05, 10 voxels, in sagittal images through the entire brain
237 volume, from “ear-to-ear”, rendered on an average MNI template.

238 **Table 1a**

239 Summary of significantly activated clusters (with local maxima), and peak voxel x, y, z
240 coordinates and corresponding t- and z-values and AAL atlas anatomical localizations, for the
241 OFF-ON contrast

Cluster size	Peak t-value	Peak z-value	X	Y	Z	Anatomical localization
4356	17.07	Inf	60	-21	-3	rSTG
	15.78	Inf	57	-12	-6	rSTG
	14.02	Inf	45	15	-6	rInsula
4145	16.48	Inf	-60	-15	0	ISTG
	16.44	Inf	-60	-24	3	ISTG
	14.76	Inf	-60	-39	9	ISTG
917	15.11	Inf	0	6	60	l/rSMA
	13.31	Inf	3	18	47	rSMA
119	6.85	6.78	0	-27	6	lThlmus
	4.90	4.87	-15	-6	12	lThlmus

242

243

244

245 **Table 1b**

246 Summary of significantly activated clusters (with local maxima), and peak voxel x, y, z
247 coordinates and corresponding t- and z-values and AAL atlas anatomical localizations, for the
248 ON-OFF contrast

249

Cluster size	Peak t-value	Peak z-value	X	Y	Z	Anatomical localization
7669	12.18	inf	-9	-57	15	lPrecun
	11.73	inf	12	-54	18	rPrecun
	11.31	inf	-3	-63	21	lPrecun
972	11.55	inf	6	51	0	rSFG
	11.51	inf	-9	45	6	lACC
	10.93	Inf	12	39	6	lSFG
203	8.44	Inf	-24	24	45	lSFG
40	5.56	5.52	27	27	45	rMFG

250

251 The differential, TB-wise contrasts are presented as activity changes rather than contrast-by-
252 contrast activity. First, the temporal evolution of the task-positive networks, including the
253 EMN network, was explored. As can be seen from Figure 3, the task-positive activity started
254 with a strong visual activity, reflecting the on-screen instruction, followed by activity of the
255 auditory and EMN network after about 5.5 sec (one time bin), which remained constant
256 throughout the entire ON period and faded away during the first scan of the OFF block.
257 Interestingly, the task-negative and DMN networks showed more dynamic changes than the
258 task-positive and EMN networks. There was an initial time-lag of about 5.5 sec where neither
259 the EMN nor the DMN or any other task-related networks was active. After this initial period,
260 the DMN showed the strongest recurrence, which however faded away towards the end of the
261 OFF block. The only activity that later evolved during the OFF blocks and remained
262 throughout the block was the orbitofrontal recurrence. Figure 3 shows the overall activity
263 including also line plots for the activity profiles from the posterior cingulate cortex and the
264 right inferior frontal gyrus, representing hubs of the DMN and EMN networks, respectively.

265 -----

266 Insert Figure 3 about here

267 -----

268 **Figure 3:** *Figure 3 shows the corresponding axial glass brains for the ON- (upper row) and*
269 *OFF-periods (lower row), and split for corresponding time-bins (TBs). The line-graphs in the*
270 *middle of the figure show the development of the BOLD response across time for the ON (left*
271 *side) and OFF (right side) period, respectively, and extracted from the posterior cingulate*
272 *cortex (PCC) and inferior frontal gyrus (IFG), representing the default mode network (blue*
273 *line, DMN) and extrinsic mode network (red line, EMN), respectively.*

274 When the time-derivative (TD) contrasts were explored, which reflect a significant increase or
275 decrease of activity from one time-bin to the next, activity changes were observed only at the
276 transitions between the blocks. When the ON block started (see Figure 4), the EMN switched
277 on at once, together with the visual response to the instructions on the screen.

278 -----

279 Insert Figure 4 about here

280 -----

281 **Figure 4:** *Figure 4 shows the axial glass brains obtained from the time-derivative (TD)*
282 *analysis during ON (left side) and OFF (right side) periods, separately for each time-*
283 *derivative contrast, contrasting time-bin (TB)1 with TB2, TB2 with TB3 etc in a “sliding*
284 *window” through all TBs (1-20). The upper row of glass brains show increases in activity, the*
285 *lower row shows decreases in activity. See text for further details.*

286

287 However, the visual activity faded away over the first three TBs (cf. Logothetis et al., 2001),
288 i.e. over the first 11-16.5 sec, while the auditory activity faded in from TB1 to TB2 and
289 remained stable after that. At the end of the ON block, the auditory and articulatory motor
290 activity rapidly disappeared in the transition from TB 10 to TB 11, with a remaining decrease

291 into TB 12 within the right planum temporale. Interestingly, the DMN was not observed in
292 these time-derivatives-like contrasts, indicating that the DMN did not show a sharp onset of
293 activity at the beginning of the OFF block, comparable to the EMN did at the beginning of the
294 ON block. Neither EMN, nor DMN showed a sharp decrease of activity in this analysis.

295

296

Discussion

297 To sum up the main findings, the ON- and OFF-blocks, corresponding to active task-
298 processing versus passive resting, produced two orthogonal, non-overlapping activity patterns
299 (see Figure 2). As is obvious from Figure 2, while task-present epochs resulted in a more
300 anterior activity pattern, with the SMA/preSMA and the auditory cortices as the dominant
301 activity regions, the task-absent epochs resulted in a more posterior activity pattern, including
302 activity in the precuneus, and the parietal lobules as the dominant regions. These activity
303 patterns would partially correspond to the EMN and DMM networks, respectively [1] [20].
304 2001). The FIR analysis of the network dynamics based on time-derivative contrasts in
305 addition revealed that the EMN showed a relatively sharp onset of the up-regulation at the
306 beginning of the ON-blocks, while there was a more gradual up-regulation of the DMN
307 during OFF-blocks. As expected, the DMN was more active during the OFF-blocks (see
308 Figure 3), but no abrupt change was seen in the time-derivative analysis at the ON-OFF block
309 intersections (see Figure 4). In their meta-analysis of nine PET blood-flow studies [19]) found
310 significant decreases for the active minus passive task condition in cortical areas that today
311 would qualify as the "classic" areas for the default mode network. One interpretation of the
312 decreases in the Schulman et al. [19] study is that task-processing may inhibit activity in areas
313 that otherwise would be tonically activated in the absence of a task, as was suggested by Popa
314 et al. [50]. These authors used electrophysiology recordings and found that local field
315 potential power was lower in anterior cingulum and retrosplenial cortex during task-OFF

316 compared to task-ON periods, while the reverse was found in somato-sensory association
317 cortex and middle temporal gyrus. A further confirmation of this hypothesis would be if
318 activity in approximately the same areas would be increased during passive resting periods in
319 between active task processing periods, which the current results have shown. The areas
320 showing decreased activity during active minus passive epochs in the Schulman et al. [19]
321 study were primarily in the posterior cingulate/precuneus, dorsolateral and inferior frontal
322 cortex, and in the inferior temporal gyrus (passive here meaning being exposed to the same
323 stimulus, but without instruction to act on the stimulus). Approximately the same areas were
324 activated in the present study, but now when subtracting active task-processing periods from
325 activity during a resting period, which would confirm the hypothesis of inhibition of tonically
326 active areas during phasic task-processing. Similarly, Schulman et al. [19] found increases in
327 the visual cortex in the occipital lobe during active visual task processing, after averaging data
328 from 10 different studies with visual tasks. This is paralleled in the present study which found
329 corresponding increases in the auditory cortex in the temporal lobe to an auditory task.

330 Previous studies have shown that the DMN is still up-regulated during task-presence periods
331 but attenuated or suspended compared to task-related activity, e.g [51], [52], [10]. Although
332 the present findings are in line with these results, we cannot say if the corresponding networks
333 were down-regulated or merely attenuated during reversals. An advantage with the present
334 paradigm over previous paradigms that have been used, e.g. [53], [2], [54] is that the three
335 different cognitive tasks were all embedded within the same experimental paradigm. The
336 dichotic listening (DL) task is moreover exceptionally easy to understand and perform, so that
337 the understanding of the task in itself does not require the allocation of additional cognitive
338 resources which could confound task processing.

339

340 Figure 3 shows that the time-course for the task-positive EMN network followed a square-like
341 trajectory, with a rapid initial up-regulation during ON-periods which peaked latest after
342 about 11 sec (TB2), followed by a similarly rapid down-regulation during OFF-periods,
343 peaking after about 22 sec (TB14). The corresponding trajectory for the task-negative DMN
344 network showed a similar rapid down-regulation during ON-periods, peaking after about 22
345 sec (TB4), while the up-regulation during OFF-periods were more gradual than for the EMN
346 network, actually beginning already in the middle of the ON-period (see Figure 3). This could
347 be an anticipatory effect of waiting for the "next task to be presented", and may represent an
348 anticipatory shift of attention focus from task processing to resting, a kind of "readiness" for
349 what is to come [55], which previously has been associated with alterations in EEG alpha-
350 activity [56], [57]. A look at the time-course trajectories in Figure 3 shows a marked
351 difference in the "gap" between the up-regulated and down-regulated network for ON versus
352 OFF blocks. Although the two networks to a certain extent were down-regulated at about the
353 same level, the level of up-regulation for the EMN was about twice the level of up-regulation
354 for the DMN, which caused a gap difference between the two networks. The gap difference
355 could reflect the additional increase in metabolism demands during active task-processing
356 compared to resting. There was finally a delay for EMN up- and down-regulation of about 5.5
357 sec, which may reflect the delay and slowness of the BOLD-response in itself [58], and not an
358 effect of network interaction and interference.

359

360 **In conclusion**, the EMN and DMN networks seem to alternate with the same frequency as the
361 switch from active task-periods (ON-blocks) to passive rest-periods (OFF-blocks) which
362 alternated on a 55 sec basis. From recent work that the DMN may represent a unique state of
363 the mind e.g. [59], [60], [61], [52], we now suggest that the DMN is a marker of an egocentric
364 state of mind, while a task-positive network, like the extrinsic mode network (EMN) [1] is a

365 marker of an allostatic state of mind. These states dynamically fluctuate over time, such that
366 the individual is either in one or the other state, with corresponding network activity being
367 dominant in a particular state, and that this is mapped onto how environmental processing
368 demands change over time. It may finally be suggested that the dynamic interaction between
369 task-positive and task-negative networks may be disrupted in certain psychiatric and
370 neurological disorders, extending what previously has been suggested for DMN abnormality
371 [62], [63], [64]. We now suggest that what is abnormal in certain mental disorders may not be
372 so much abnormality of a single network, but rather abnormality of network interaction and
373 network dynamics, and that this is better captured in an experimental design with alternating
374 task-ON and task-OFF periods, rather than a prolonged resting period during the scanning e.g.
375 [65], [66], [67].

376

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381 Medicine, USA, for constructive comments on earlier versions of the paper.

382 **Conflict of interest:** The authors declare no conflict of interest. The co-authors KH, LE,
383 RG and KS own shares in the company NordicNeuroLab Inc., which produced the
384 headphones used for the presentation of the auditory stimuli. These authors declare no
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391 **References**

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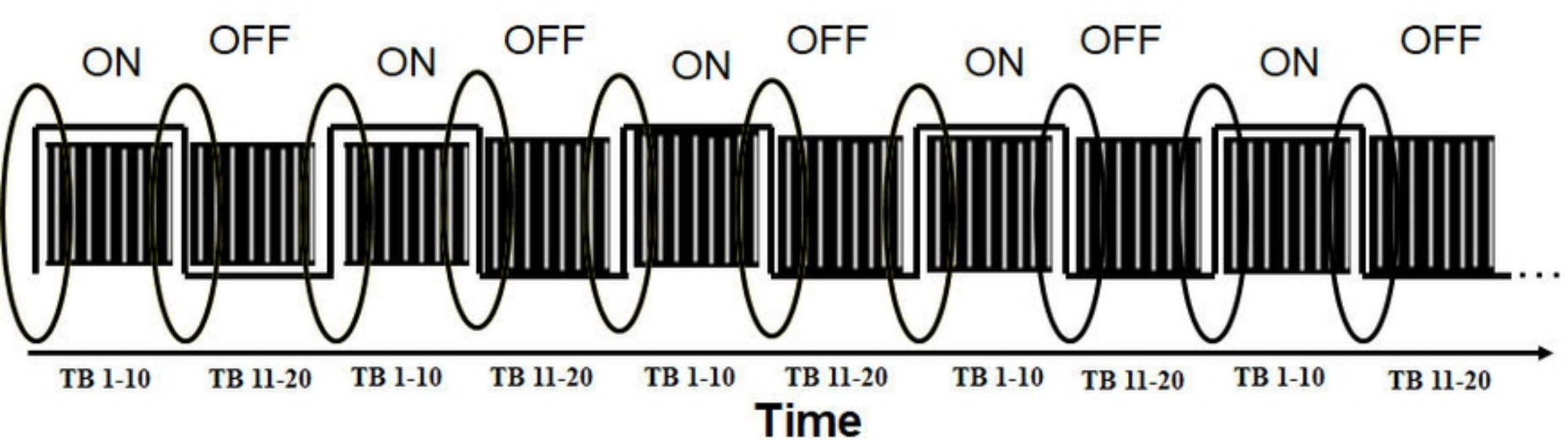
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Figure 1

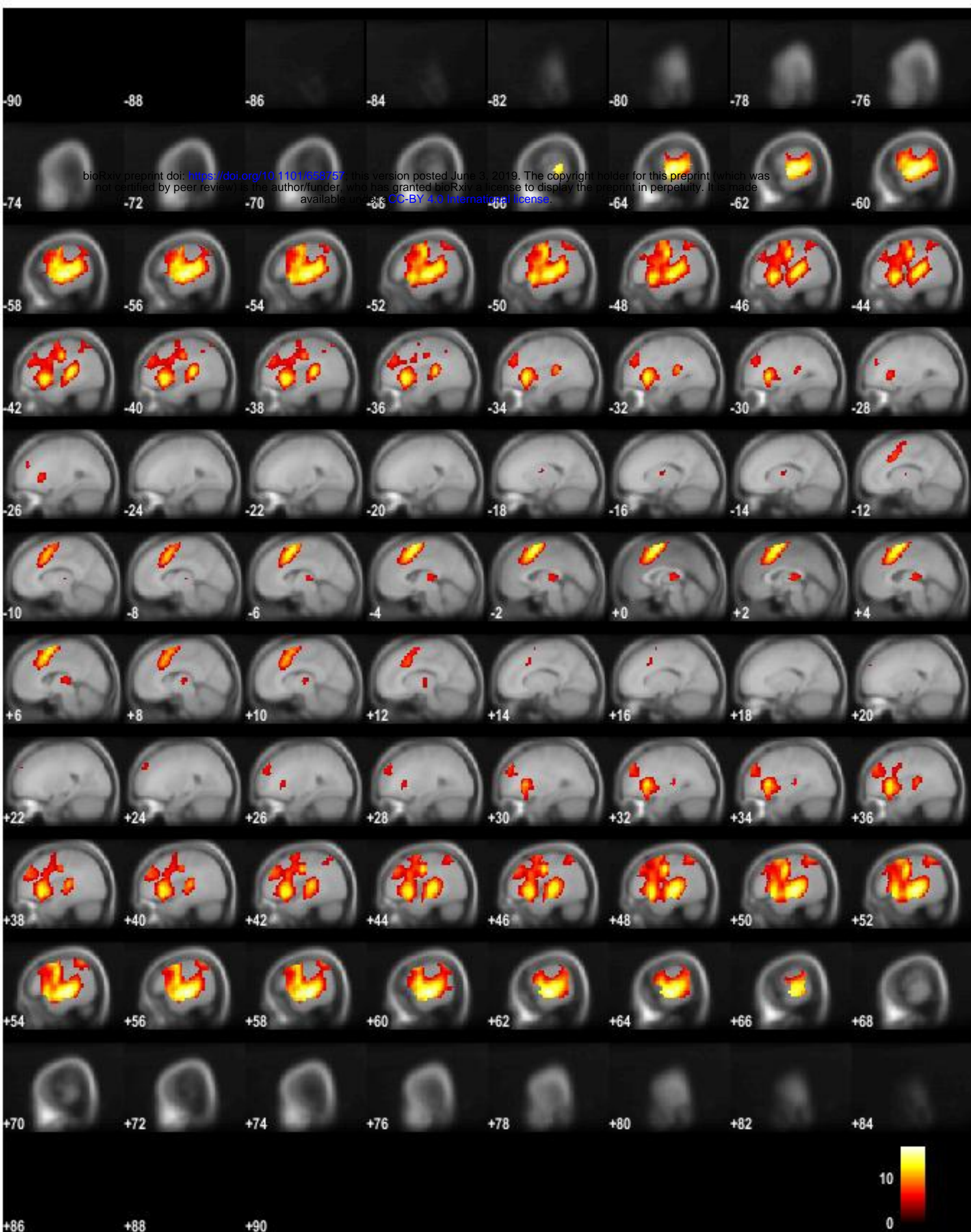


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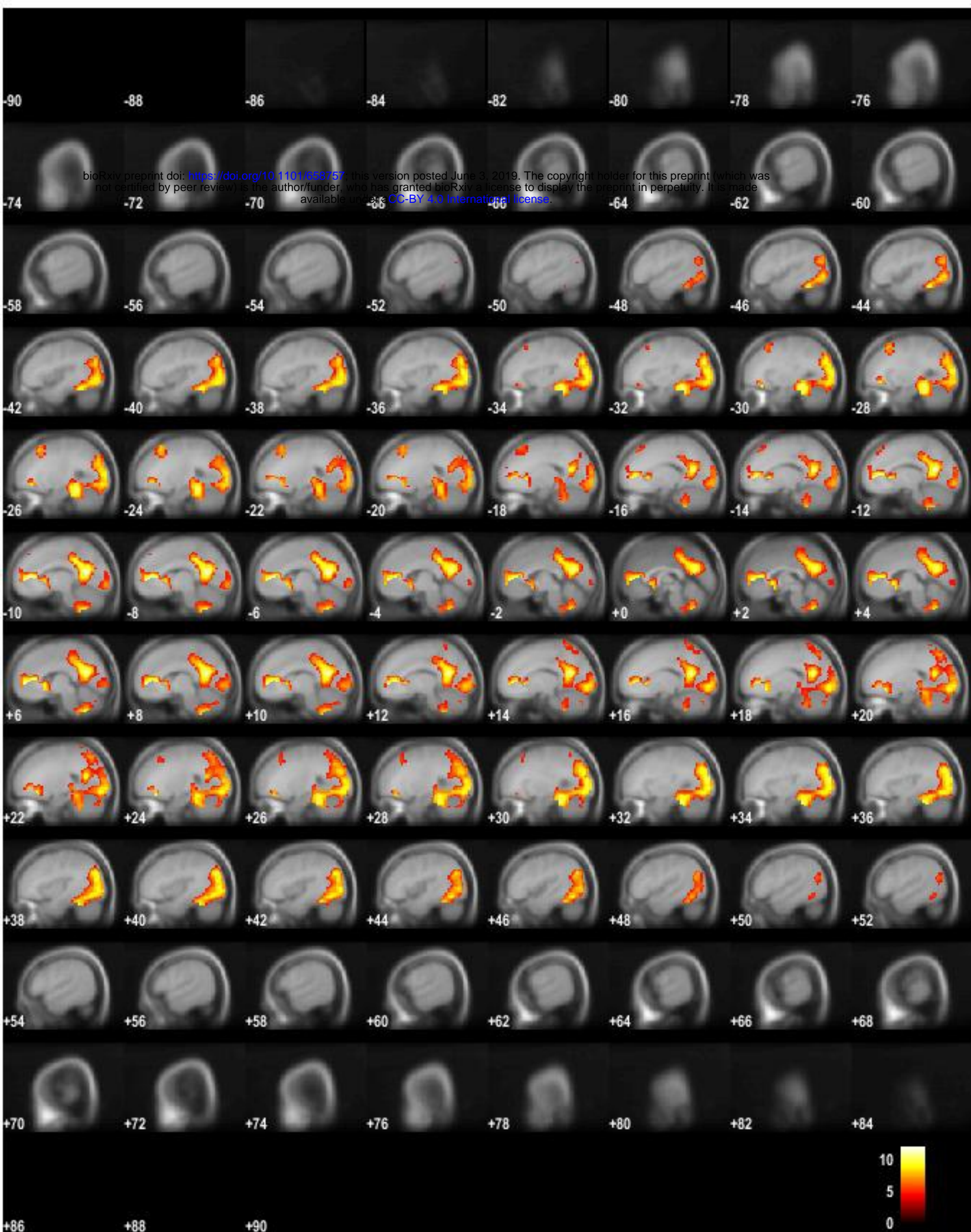


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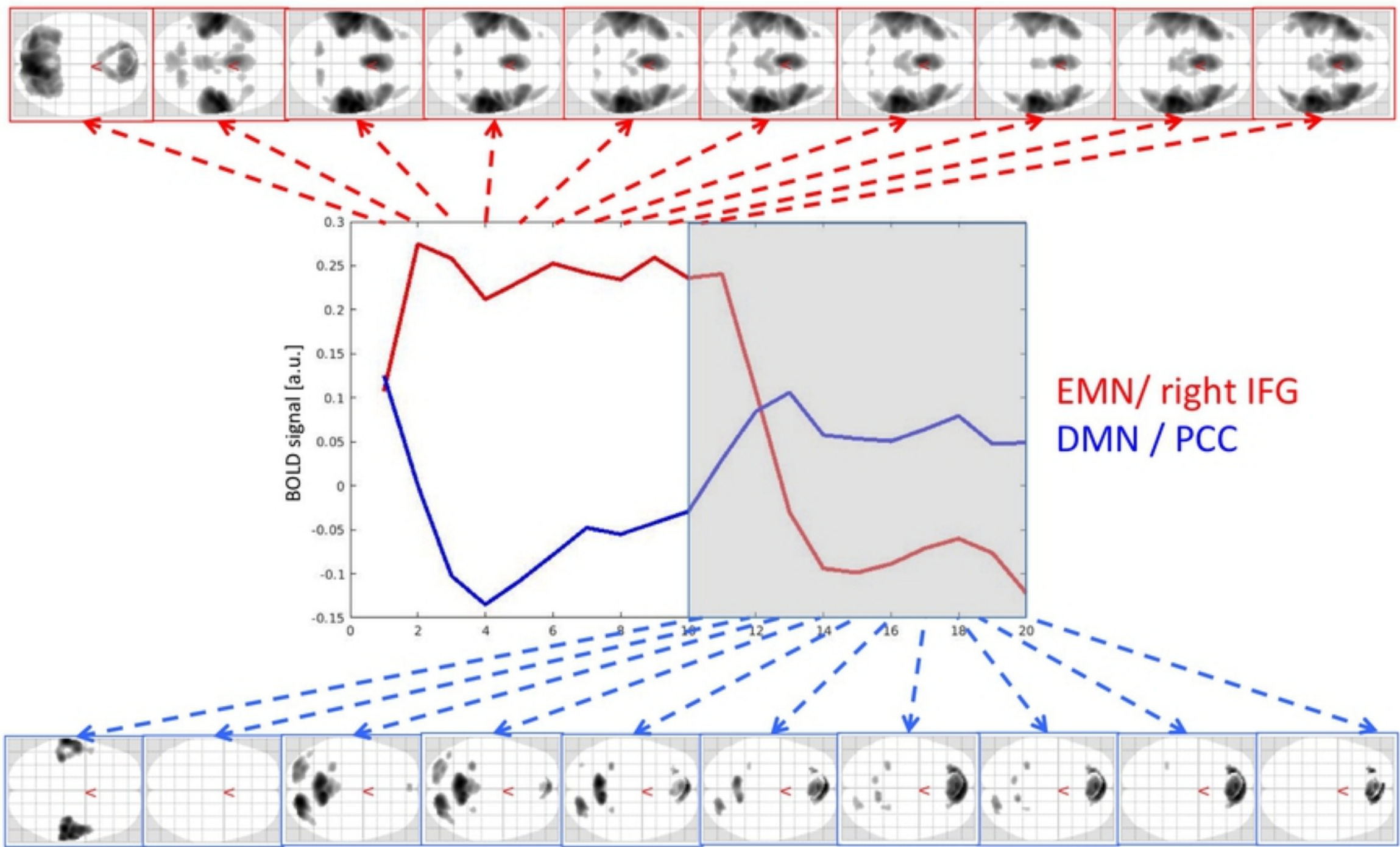


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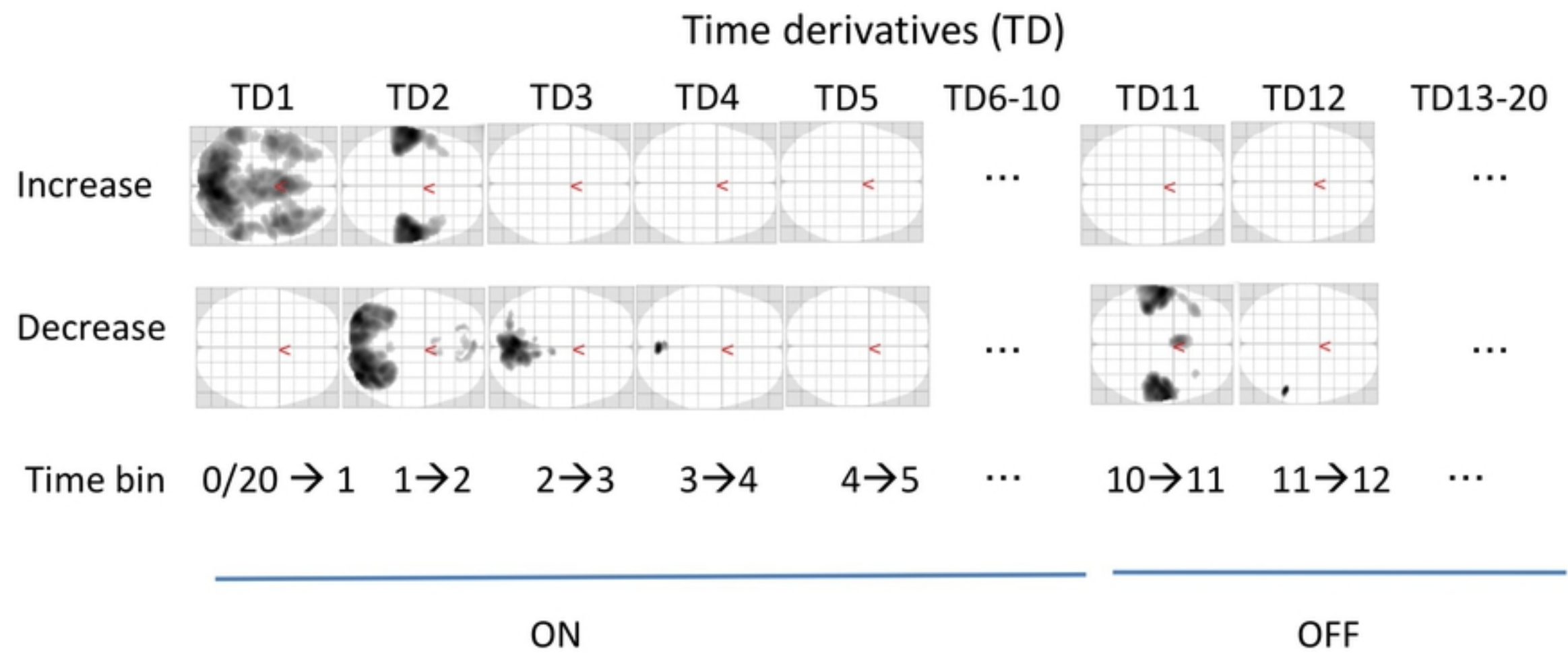


Figure 4