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SHORT COMMUNICATION

Association Between Resting-State Microstates and Ratings on the Amsterdam Resting-State Questionnaire

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Abstract There is a gap in understanding on how physiologically observed activity is related to the subjective, internally oriented experience during resting state. Microstate analysis is a frequent approach to evaluate resting-state EEG. But the relationship of commonly observed resting-state microstates to psychological domains of resting is not clear. The Amsterdam Resting-State Questionnaire (ARSQ) was recently introduced, offering an effective way to quantify subjective states after a period of resting and associate these quantifiers to psychological and physiological variables. In a sample of 94 healthy volunteers who participated in closed-eyes 5 min resting session with concurrent EEG recording and subsequent filling of the ARSQ we evaluated parameters of microstate Classes A, B, C, D. We showed a moderate negative association between contribution ($r = -0.40$) of Class C and experienced somatic awareness (SA). The negative correlation between Class C and SA seems reasonable as Class C becomes more dominant when connections to contextual information (and bodily sensations as assessed with SA) are loosened (in reduced attention states, during sleep, hypnosis, or psychosis). We suggest that the use of questionnaires such as the ARSQ is helpful in exploring the variation of resting-state EEG parameters and its relationship to variation in sensory and non-sensory experiences.

Keywords Microstates · Amsterdam resting-state questionnaire · Somatic awareness · Class C

Evaldas Pipinis and Sigita Melynyte have contributed equally to this work.

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Introduction

The state of wakeful rest—or "resting state"—is frequently employed during functional neuroimaging studies (Uddin and Menon 2010; van Diessen et al. 2015). However, there is a gap in understanding on how physiologically observed activity is related to the subjective, internally oriented experience during resting state (Andrews-Hanna et al. 2010).

Microstate analysis—an extraction and evaluation of the topographical shapes/microstate maps (A, B, C, and D) (Koenig and Melie-García 2010)—is a frequent approach to evaluate resting state EEG. With the assumption that different maps are generated by the coordinated activity of different neural assemblies (Lehmann et al. 1987), microstates are considered "atoms of thought", representing a sequence of different states of the conscious mind and giving rise to spontaneous mental activity (Lehmann et al. 1998).

Earlier studies point to the correspondence of individual microstates to particular classes of mentation by influencing how incoming information is processed and reacted to, and reported afterwards to some degree: Class A has been associated with abstract thoughts (Lehmann et al.

1998, 2010), activity within auditory areas (Britz et al. 2010) and visualization (Milz et al. 2016); Class B was associated with visual imagery-type activities (Britz et al. 2010), verbalization (Milz et al. 2016) and paranormal belief (Schlegel et al. 2012). MRI–EEG coupled studies suggested that Class C stems from a network related to saliency, whereas Class D - from a dorsal attention network (Britz et al. 2010). Nevertheless, the relationship of commonly observed resting-state microstates to psychological domains of resting is not clear. Recently, the Amsterdam Resting-State Questionnaire (ARSQ) was introduced (Diaz et al. 2013, 2014), offering an effective way to quantify subjective states after a period of resting in a number of domains (theory of mind, discontinuity of mind, self, planning, somatic awareness, sleepiness, comfort, health concern, visual thought, verbal thought) and associate these quantifiers to psychological and physiological variables (Diaz et al. 2013; Stoffers et al. 2015; Diaz et al. 2016).

We aimed to relate microstate analysis and subjective experience during rest to shed the light on psychological domains underlying the observed microstates. Detailed methods are provided as electronic supplementary material (Supplement 1). 94 healthy volunteers (52 females, mean age 21.6, SD 1.8 and 42 males, mean age 23.2, SD 3.5) participated in closed-eyes 5 min resting session with concurrent 64 channels EEG recording and subsequent filling of the ARSQ. Parameters of microstate Classes A, B, C, D (Fig. 1a)—duration, occurrence, contribution—were extracted (Koenig et al. 1999) and Pearson correlations between ARSQ categories and the parameters were computed followed by Bonferroni-Holm correction for multiple comparisons (statistical correction was carried out across 120 correlations (3 × 3 × 10)).

Results and Discussion

We have used correlational approach to estimate relationships between parameters of four classes of resting-state microstates and subjectively reported experiences. Eight correlations out of 120 possible were found to be significant at the $p < 0.05$ level (Table 1). The most significant finding of the current study is a moderate negative association ($r = -0.40$) between contribution of Class C and experienced Somatic Awareness (SA) that survived multiple tests correction (Fig. 1b). This significant correlation was followed by a stepwise multiple regression analysis. A stepwise multiple regression model was significant [$F(2,91) = 11,917$, $p < 0.001$] with two predictors—Class C contribution (Con C) and Class D occurrence (Occ D). However, only 20.8 % of the variance of the SA could be accounted for by predictors ($R^2 = 0.208$) and predicted by the following regression equation: SA = 2.651− 3.672*(Con C) + 0.258*(Occ D).

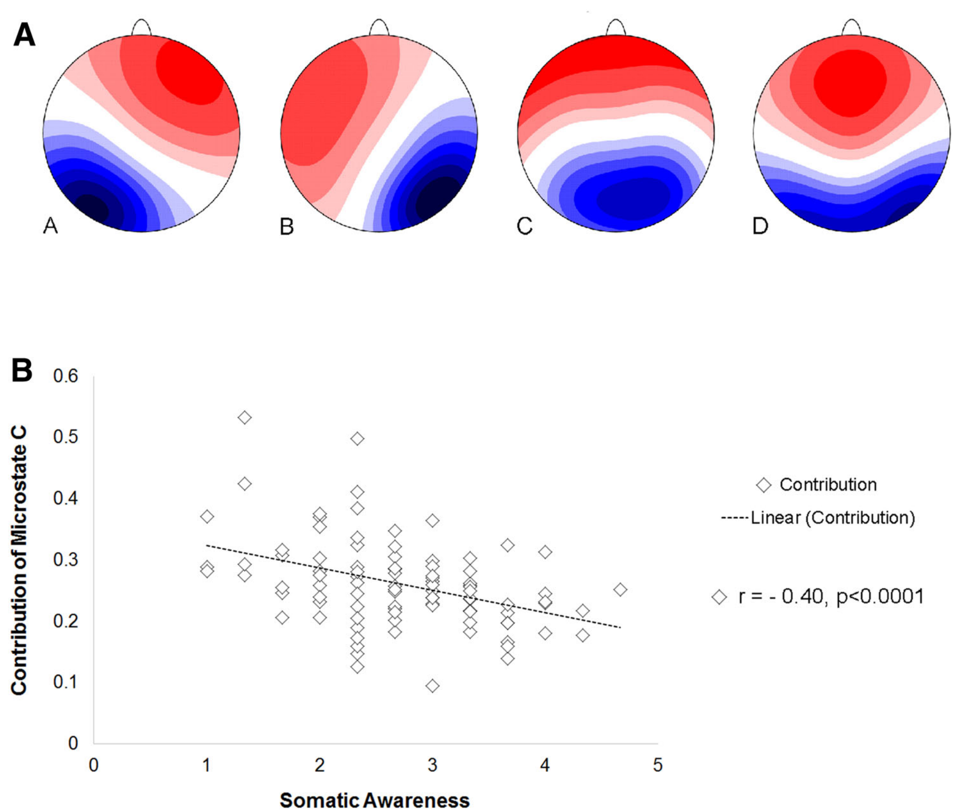

Fig. 1 **a** Topographies of microstates *A*, *B*, *C* and *D*. **b** Scatterplot of contribution of Class C and somatic awareness scores

Table 1 Pearson's correlation coefficients between parameters of four classes of resting-state microstates and ARSQ scores

Microstates													
		A			B			C			D		
		Con	Occ	Dur	Con	Occ	Dur	Con	Occ	Dur	Con	Occ	Dur
ARSQ	DoM	0	0.04	−0.1	0.04	0.1	−0.11	0.13	0.15	0	−0.16	−0.05	−0.17
	ToM	0.05	0.02	0.04	0.1	0.04	0.06	0.13	0.06	0.09	**−0.24**	−0.19	−0.14
	Self	−0.07	0.01	−0.1	0.12	0.17	−0.03	−0.01	0.07	−0.06	−0.01	0.02	−0.03
	Planning	−0.09	−0.03	−0.07	0.14	0.09	0.09	0.05	0.08	0.01	−0.08	−0.09	−0.02
	Sleep	0.11	0.02	0.15	−0.16	−0.16	−0.02	−0.02	−0.08	0.04	0.04	-0.07	0.07
	Comfort	−0.02	−0.11	0.19	**0.24**	0	**0.33**	−0.04	−0.17	0.12	−0.11	**−0.32**	0.13
	SA	0.1	0.16	−0.08	0.04	0.15	−0.13	**<u>−0.4</u>**	−0.14	**−0.35**	**0.3**	**0.33**	0.07
	Health	0.18	0.1	0.12	0.01	0.07	−0.07	−0.14	−0.1	−0.09	−0.02	−0.03	−0.01
	Visual	0.09	0.1	0	0.08	0.09	0.01	0.03	0.03	0.02	−0.16	−0.11	−0.09
	Verbal	0.06	0.04	0.06	0.15	0.11	0.1	−0.05	−0.03	−0.01	−0.1	−0.07	−0.04

Con contribution, *Occ* occurrence, *Dur* duration, *SA* somatic awareness

Coefficients significant at $p < 0.05$ are highlighted in bold. Values significant after Bonferroni-Holm correction are underlined

Somatic Awareness was evaluated by questions related to the sensation of bodily signals ("I was conscious of my body"; "I thought about my heartbeat"; "I thought about my breathing"). The negative correlation between Class C and SA thus seems reasonable: it was previously proposed by Rieger et al. (2016) that Class C becomes more dominant when connections to contextual information (including perception of bodily signals, as measured with SA) are loosened, similarly to what happens in reduced attention states (Brandeis and Lehmann 1989), during sleep (Brodbeck et al. 2012), hypnosis (Katayama et al. 2007), or psychosis (metaanalysis by Rieger et al. 2016). A negative association between Class C and D measures (r values from −0.29 to −0.52, Supplement 5) and the positive association of SA and Class D measures (not surviving correction, Contribution: $r = 0.30$, Table 1) is also worth mentioning as it fits to the notion of antagonistic functional roles of Class C and D (Rieger et al. 2016).

Unexpectedly, we failed to show any correlations between the parameters of Classes A and B and visual/auditory subjectively reported experiences, although based on prior observations (Lehmann et al. 1998; Britz et al. 2010; Milz et al. 2016), some relationships could have emerged.

Although further research is necessary, we suggest that the use of questionnaires such as the ARSQ is helpful in exploring the variation of resting-state EEG parameters and its relationship to variation in sensory and non-sensory experiences.

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