LETTER TO THE EDITOR

Influence of mood states on the correlation between changes in oxygenated hemoglobin concentration and behavioral performance during Tetris gameplay in the frontal cortex

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Dear Editors,

In our previous paper, we reported our analysis on the differences between Tetris's high and low performers by using functional near-infrared spectroscopy (Nakahachi, 2020). However, we could not detect frontal cortical areas with significant correlation by the direct method of calculating Pearson correlation coefficient (PCC) between activation (mean values of relative changes in oxygenated hemoglobin concentration during Tetris gameplay) and LINE (numbers of the deleted lines) of 24 participants. Therefore, by comparing eight high performers with eight low performers, we could only estimate that high performers had greater activation of the right dorsolateral prefrontal cortex (DLPFC) than low performers (the difference was not significant after adjusting for multiple comparisons).

This time, aiming to increase PCC between activation and LINE, we utilized Profiles of Mood States (POMS), a self-rating questionnaire for mood assessment consisting of six subscales: Fatigue, Anger-Hostility, Vigor, Depression-Dejection, Tension-Anxiety, and Confusion (Yokoyama, 1990), which had been filled out by the subjects immediately after the experiment. These analyses allowed us to calculate the partial correlation coefficients (PR) which exclude the influence of mood.

We calculated PR between LINE and activation of each of the 52 measurement points (channels), controlling for each or all of the six subscales of the POMS in the 24 subjects. Next, PCC and PR between LINE and activation were compared in the 52 channels using repeated measures one-way ANOVA followed by Dunnett's correction.

The results showed that channels with significant PR between LINE and activation were not detected using the significant α levels of 0.05 corrected by the false discovery rate to control multiple comparisons. Repeated measures one-way ANOVA showed that there were significant differences with Greenhouse-Geisser correction at $p < 0.05$ ($F = 25.916$, $p = 9.31E\text{-}08$). According to Dunnett's correction, significantly different PR from PCC were those controlling for Fatigue, Tension-Anxiety, Vigor, or all subscales of POMS (Table 1). Among these significant PR, those whose mean values were higher than the mean value of PCC were when Fatigue or all subscales of POMS were controlled. This suggests that by excluding the influence of fatigue or overall mood state, the correlation between LINE and activation would increase significantly on average.

Especially, we focused on channel 24, which indicated the highest PCC between LINE and activation ($r = 0.294$, $p = 0.163$), most significant activation ($t = 4.137$, $p = 0.0004$) in Nakahachi (2020), and is most likely to correspond to Brodmann area (BA) 46 in the right DLPFC. Among PR between LINE and activation controlling for each of the six subscales of POMS, when controlling for Fatigue, channel 24 showed the highest PR and it was the only channel with PR above the mean + 2 standard deviation of PR for all channels (Table 1). Therefore, we expect that the correlation coefficient between LINE and activation of the right DLPFC is likely to increase, especially when the influence of fatigue is excluded.

Our findings suggested that the improvement of LINE by playing Tetris would be able to be applied to neurorehabilitation training, if the mood states are kept as constant as possible when the brain activation is assessed over time in the same patient. As future application, it would be recommended at least keeping fatigue constant because fatigue is predicted to have the greatest influence on the correlation between LINE and activation of BA 46 in the right DLPFC and may be easier to control than the other mood states due to many simple means reducing fatigue by oneself, such as rest.

Table 1. Correlation and partial correlation coefficients between the number of lines deleted during Tetris gameplay and activation in each channel

	R (*p* value)	F *R* (*p* value)**	A-H *R* (*p* value)	V *R*(*p* value)**	D *R* (*p* value)	T-A *R*(*p* value)**	C *R* (*p* value)	PO *R* (*p* value)**
CH1	-0.072(0.738)	-0.013(0.953)	-0.069(0.754)	-0.092(0.675)	-0.084(0.704)	-0.133(0.544)	-0.115(0.601)	0.097(0.7)
CH2	-0.164(0.445)	-0.11(0.619)	-0.156(0.476)	-0.225(0.302)	-0.179(0.414)	-0.224(0.304)	-0.252*(0.246)	-0.053(0.836)
CH3	-0.036(0.866)	-0.016(0.944)	-0.041(0.853)	-0.161(0.463)	-0.049(0.826)	-0.077(0.725)	-0.068(0.758)	-0.081(0.75)
CH4	0.156(0.467)	0.171(0.434)	0.16(0.465)	0.112(0.611)	0.147(0.505)	0.137(0.532)	0.151(0.491)	0.212(0.398)
CH5	0.105(0.625)	0.094(0.669)	0.113(0.607)	0.054(0.806)	0.098(0.656)	0.073(0.74)	0.139(0.528)	-0.034(0.892)
CH6	0.242(0.255)	0.251(0.248)	0.262(0.227)	0.228(0.296)	0.234(0.282)	0.199(0.363)	0.232(0.286)	0.106(0.676)
CH7	0.223(0.295)	0.245(0.26)	0.235(0.28)	0.184(0.402)	0.216(0.323)	0.182(0.405)	0.193(0.378)	0.185(0.463)
CH8	0.036(0.868)	0.029(0.894)	0.039(0.861)	-0.055(0.804)	0.028(0.899)	0.014(0.948)	0.061(0.781)	-0.042(0.869)
CH9	0.069(0.747)	0.111(0.615)	0.097(0.659)	-0.006(0.977)	0.054(0.808)	0.028(0.9)	0.073(0.741)	0.124(0.623)
CH10	-0.084(0.697)	-0.017(0.938)	-0.073(0.739)	-0.148(0.5)	-0.095(0.666)	-0.141(0.521)	-0.126(0.566)	0.091(0.718)
CH11	-0.226*(0.288)	-0.195*(0.372)	-0.232*(0.288)	-0.263(0.225)	-0.238* (0.274)	-0.292*(0.177)	-0.279*(0.198)	-0.197(0.434)
CH12	0.236(0.267)	0.302(0.161)	0.248(0.254)	0.316(0.141)	0.232(0.287)	0.208*(0.342)	0.221(0.31)	0.461(0.054)
CH13	0.208(0.328)	0.252(0.246)	0.229(0.293)	0.26(0.231)	0.199(0.362)	0.165(0.452)	0.159(0.47)	0.191(0.447)
CH14	-0.094(0.663)	-0.049(0.824)	-0.086(0.696)	-0.204(0.351)	-0.119(0.589)	-0.148(0.501)	-0.155(0.479)	-0.081(0.749)
CH15	0.042(0.845)	0.066(0.766)	0.052(0.815)	-0.028(0.901)	0.028(0.898)	-0.016(0.944)	0.028(0.898)	-0.04(0.874)
CH16	0.13(0.545)	0.139(0.526)	0.148(0.501)	0.098(0.657)	0.125(0.57)	0.112(0.611)	0.138(0.53)	0.074(0.769)
CH17	0.196(0.359)	0.223(0.306)	0.213(0.329)	0.115(0.603)	0.186(0.395)	0.143(0.516)	0.157(0.474)	0.03(0.907)
CH18	0.05(0.816)	0.102(0.643)	0.053(0.81)	-0.066(0.764)	0.042(0.848)	0.003(0.989)	0.02(0.929)	0.116(0.646)
CH19	-0.026(0.902)	0.002(0.991)	-0.011(0.962)	-0.064(0.773)	-0.041(0.854)	-0.062(0.78)	-0.012(0.956)	0.047(0.853)
CH20	0.074(0.733)	0.127(0.565)	0.072(0.743)	0.056(0.799)	0.067(0.76)	0.041(0.851)	0.042(0.85)	0.256(0.305)
CH21	0.146(0.495)	0.177(0.419)	0.138(0.53)	0.02(0.929)	0.146(0.506)	0.099(0.652)	0.12(0.584)	0.102(0.686)
CH22	-0.014(0.948)	0.042(0.851)	-0.013(0.954)	0.025(0.91)	-0.024(0.915)	-0.079(0.72)	-0.013(0.954)	0.269(0.28)
CH23	0.249(0.24)	0.294(0.173)	0.265(0.221)	0.384*(0.071)	0.242(0.266)	0.215(0.323)	0.253(0.243)	0.494(0.037)
CH24	0.294(0.163)	0.352*(0.099)	0.331(0.123)	0.316(0.142)	0.291(0.178)	0.258(0.235)	0.254(0.243)	0.308(0.214)
CH25	-0.178(0.406)	-0.132(0.548)	-0.173(0.431)	-0.353*(0.099)	-0.211(0.334)	-0.32*(0.137)	-0.263*(0.226)	-0.352*(0.152)
CH26	-0.074(0.73)	-0.033(0.88)	-0.06(0.787)	-0.165(0.451)	-0.09(0.683)	-0.113(0.609)	-0.114(0.606)	-0.072(0.776)
CH27	0.178(0.405)	0.188(0.391)	0.196(0.371)	0.106(0.629)	0.169(0.441)	0.146(0.507)	0.17(0.438)	0.061(0.809)
CH28	0.127(0.554)	0.167(0.446)	0.131(0.551)	-0.014(0.95)	0.122(0.58)	0.078(0.724)	0.096(0.663)	0.057(0.823)
CH29	-0.118(0.583)	-0.074(0.737)	-0.107(0.626)	-0.176(0.422)	-0.128(0.56)	-0.158(0.472)	-0.13(0.556)	0.01(0.967)
CH30	0.131(0.541)	0.154(0.483)	0.137(0.532)	0.162(0.46)	0.122(0.578)	0.114(0.606)	0.153(0.487)	0.328(0.185)
CH31	0.209(0.328)	0.22(0.313)	0.197(0.369)	0.156(0.478)	0.212(0.331)	0.184(0.4)	0.228(0.295)	0.316(0.201)
CH32	0.105(0.625)	0.138(0.531)	0.099(0.654)	0.124(0.572)	0.098(0.656)	0.071(0.749)	0.098(0.656)	0.289(0.246)
CH33	0.229(0.281)	0.283(0.19)	0.25(0.249)	0.316(0.142)	0.221(0.31)	0.205(0.349)	0.223(0.306)	0.46(0.055)

CH34	0.243(0.252)	0.265(0.222)	0.27(0.213)	0.356(0.095)	0.235(0.279)	0.224(0.304)	0.251(0.248)	0.367(0.134)
CH35	-0.025(0.906)	0.024(0.915)	-0.009(0.967)	-0.087(0.692)	-0.045(0.838)	-0.08(0.716)	-0.048(0.827)	0.041(0.87)
CH36	-0.118(0.583)	-0.076(0.73)	-0.104(0.636)	-0.202(0.355)	-0.15(0.494)	-0.195(0.372)	-0.164(0.456)	-0.151(0.549)
CH37	0.031(0.887)	0.059(0.79)	0.042(0.848)	-0.044(0.841)	0.022(0.921)	0.01(0.965)	0.002(0.991)	0.018(0.945)
CH38	0.107(0.619)	0.146(0.507)	0.115(0.601)	-0.019(0.931)	0.099(0.653)	0.054(0.808)	0.085(0.699)	0.041(0.871)
CH39	-0.104(0.63)	-0.055(0.804)	-0.09(0.684)	-0.213(0.33)	-0.12(0.586)	-0.153(0.487)	-0.135(0.54)	-0.047(0.854)
CH40	-0.063(0.769)	-0.027(0.902)	-0.05(0.82)	-0.023(0.918)	-0.071(0.749)	-0.073(0.739)	-0.034(0.877)	0.228(0.363)
CH41	0.24(0.259)	0.264(0.223)	0.246(0.258)	0.29(0.179)	0.233(0.285)	0.222(0.308)	0.258(0.235)	0.448(0.063)
CH42	0.105(0.624)	0.109(0.62)	0.09(0.684)	0.054(0.808)	0.112(0.612)	0.092(0.675)	0.134(0.543)	0.216(0.389)
CH43	0.108(0.617)	0.157(0.475)	0.115(0.601)	0.132(0.549)	0.097(0.66)	0.078(0.725)	0.104(0.637)	0.353(0.15)
CH44	0.019(0.928)	0.055(0.802)	0.033(0.882)	0.069(0.755)	0.008(0.97)	-0.001(0.995)	0.049(0.826)	0.3(0.226)
CH45	0.128(0.55)	0.149(0.496)	0.14(0.524)	0.183(0.404)	0.122(0.578)	0.116(0.597)	0.173(0.43)	0.352(0.152)
CH46	-0.076(0.724)	-0.041(0.851)	-0.07(0.75)	-0.162(0.461)	-0.09(0.683)	-0.118(0.591)	-0.089(0.686)	-0.009(0.97)
CH47	0.003(0.991)	0.034(0.876)	0.008(0.969)	-0.093(0.673)	-0.016(0.942)	-0.041(0.853)	-0.035(0.875)	-0.002(0.992)
CH48	0.111(0.607)	0.156(0.479)	0.121(0.581)	0.024(0.915)	0.098(0.657)	0.059(0.788)	0.066(0.763)	0.073(0.772)
CH49	-0.149(0.488)	-0.108(0.625)	-0.139(0.527)	-0.268(0.217)	-0.17(0.439)	-0.221(0.311)	-0.187(0.392)	-0.176(0.485)
CH50	-0.073(0.736)	-0.039(0.86)	-0.061(0.781)	-0.038(0.863)	-0.078(0.725)	-0.077(0.726)	-0.04(0.855)	0.227(0.365)
CH51	-0.036(0.866)	-0.024(0.915)	-0.032(0.886)	0.013(0.953)	-0.038(0.864)	-0.032(0.885)	0.008(0.97)	0.186(0.459)
CH52	0.023(0.914)	0.04(0.856)	0.022(0.921)	0.032(0.885)	0.022(0.92)	0.016(0.943)	0.068(0.758)	0.254(0.308)
Mean	0.054(0.596)	0.088(0.596)	0.063(0.599)	0.019(0.565)	0.044(0.598)	0.015(0.604)	0.041(0.583)	0.124(0.544)
SD	0.133(0.228)	0.13(0.259)	0.136(0.238)	0.176(0.281)	0.137(0.222)	0.144(0.231)	0.146(0.235)	0.186(0.302)

Leftmost *R*-only column shows Pearson's correlation coefficients between the mean changes in [oxy-Hb] (activation) and the numbers of deleted lines (LINE) during Tetris gameplay in 24 healthy subjects. The next seven columns show the partial correlation coefficient between activation and LINE controlling for *T* scores for the six subscales of Profiles of Mood States (POMS). The letters before *R* in the partial correlation coefficients represent the control variables, which are, in order, Fatigue (F), Anger-Hostility (A-H), Vigor (V), Depression-Dejection (D), Tension-Anxiety (T-A), Confusion (C), and all subscales of POMS (PO).

**, Partial correlation coefficients that were significantly different from Pearson correlation coefficient at $p < 0.05$ in Dunnett's correction for multiple comparisons.

*, Values outside the range of mean ± 2SD.

CH, Channel. (For the positional relationship of CH in the head, see Nakahachi, 2020.)

SD, standard deviation.

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