Decreased susceptibility contrast in sensory cortex is associated with reduced cognitive performance

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INTRODUCTION: Magnetic susceptibility of brain tissues provides good contrast between cortical gray and white matter, which reflects the spatial variation in tissue chemical composition, especially iron and myelin (1, 2). Previous studies have shown that the altered iron and myelination contents in gray or white matter were associated with abnormal brain function in many neurological diseases, such as Parkinson's diseases, multiple sclerosis, and so on (2, 3). However, no studies have been performed to evaluate the potential relationship between the gray and white matter susceptibility contrast and cognitive function. In this study, we correlated susceptibility contrast in sensory and motor cortex with clinical cognitive scores in 115 healthy volunteers. It is found that decreased susceptibility contrast in sensory cortex was associated with reduced cognitive performance as demonstrated by the increased errors in Wisconsin card sorting test. These results may suggest the potential value of magnetic susceptibility contrast for assessment of the healthiness of cerebral cortex in the human brain.

METHODS: A group of healthy adult volunteers ranging from 40-83 y/o (64±11, n=115) was included in this study. The subjects were scanned using a 3D multi-echo gradient-echo sequence with FOV = 23.0x16.6 cm^2, matrix = 256×208, slice thickness = 4 mm, TE1 = 4.92ms, inter-echo spacing = 4.92ms, and 6 echoes. Local tissue phase were extracted with Laplacian-based phase unwrapping followed by background phase removal using spherical-mean-value (SMV) filtering, and susceptibility was calculated using the LSQR method (4). The regions of interest (ROI) for gray and white matter in the sensory and motor area were manually drawn at similar axial positions using a Matlab-based tool (Fig. 1), in the order of MRI ID number, which is completely randomized with regard to the age and cognitive function. The gray and white susceptibility contrast was calculated for both sensory cortex and motor cortex.

The volunteers also underwent a series of tests for cognitive function. The mini mental score (MMSE) test was first used to screen for cognitive impairment. All volunteers have a score higher than 25 and are considered normal. The subjects then performed trail making test B, digit span test, Purdue Pegboard test, Wisconsin card sorting test (WCST), word fluency test and walking speed test. The scores were correlated with susceptibility contrast in motor and sensory regions using a linear regression model that yields both the regression coefficients and the significance level (p-value).

RESULTS: Table 1 summarized the regression coefficients and p-values between various cognitive scores and susceptibility contrast in sensory/motor cortex. Interestingly, the sensory cortex gray and white matter susceptibility contrast is negatively correlated with WCST scores, including errors, perseverative responses, nonperseverative errors and perseverative errors. In other words, the lower the susceptibility contrast in the sensory cortex region, the more errors made by the subjects (e.g. Fig. 2 B&C, P<0.05) during this test. While the sensory cortex susceptibility contrast does not correlate with other test scores (e.g. Fig. 2A, P=0.59). In contrast, motor cortex gray and white matter susceptibility contrast does not correlate with any of these cognitive test scores (e.g. Fig. 2D-F, P=NS).

Table 1. The regression coefficients and p-values between various cognitive scores and susceptibility contrast in sensory/motor cortex

		Sensory cortex		Motor cortex	
		coeff.	p-value	coeff.	p-value
Track making B	time (sec)	-603	0.28	-309	0.59
Digit span	forward	10.1	0.38	22.9	0.05
	backward	3.78	0.79	-1.51	0.92
	sum score	13.9	0.53	21.4	0.35
Purdue Pegboard Test	right hand	1.92	0.93	-7.41	0.76
	left hand	-12.0	0.58	4.12	0.86
	both hands	-9.08	0.67	-15.3	0.49
	left+right+both	-13.5	0.82	-9.84	0.88
	assembly	-62.2	0.39	7.37	0.92
Wisconsin Card Sorting Test (WCST)	correct	-54.6	0.59	129	0.22
	errors	**-148**	**0.00**	-103	0.06
	perseverative responses	**-317**	**0.01**	-25.6	0.84
	nonperseverative errors	**-239**	**0.01**	34.8	0.74
	perseverative errors	**-104**	**0.01**	-71.6	0.11
	categories	15.8	0.10	-11.2	0.27
Word fluency	word per minute	65.7	0.32	-30.8	0.65
Walking speed		-0.02	0.96	0.52	0.17

DISCUSSIONS AND CONCLUSIONS

The susceptibility contrast between gray and white matter at cerebral cortex is mainly determined by the content of strong paramagnetic molecules, e.g. iron and deoxyglobin, diamagnetic materials, e.g. myelin, and the white matter fiber orientation (1, 2, 5). In this study, we analyzed the susceptibility contrast at similar axial slice localizations to minimize the confounding effects due to fiber orientation, so the results are considered to mainly reflect the changes in tissue chemical composition. A positive correlation between sensory susceptibility contrast and cognitive performance as measured by WCST was observed. The WCST was known as a good measure of executive function of frontal lobe (6). It is unknown why it is related with the susceptibility contrast in the sensory cortex. It is possible that the executive function is ultimately related to the sensory functions in the complicated neurological system. While these results shows potential correlation between susceptibility contrast and cognitive function, more comprehensive studies are needed for frontal cortex and other brain regions to further validate this relationship. Such studies will necessitate the development of automated methods for efficient and comprehensive measurement of susceptibility contrast in various brain regions.

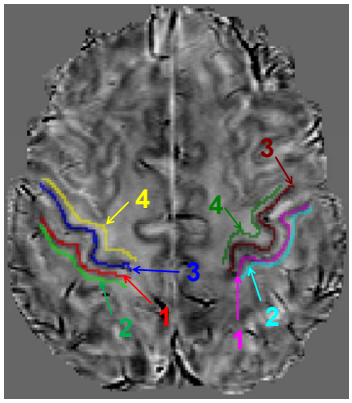

Fig. 1. Region of interests. 1: Sensory cortex gray matter; 2: Sensory cortex white matter; 3: Motor cortex gray matter; 4: Motor cortex white matter.

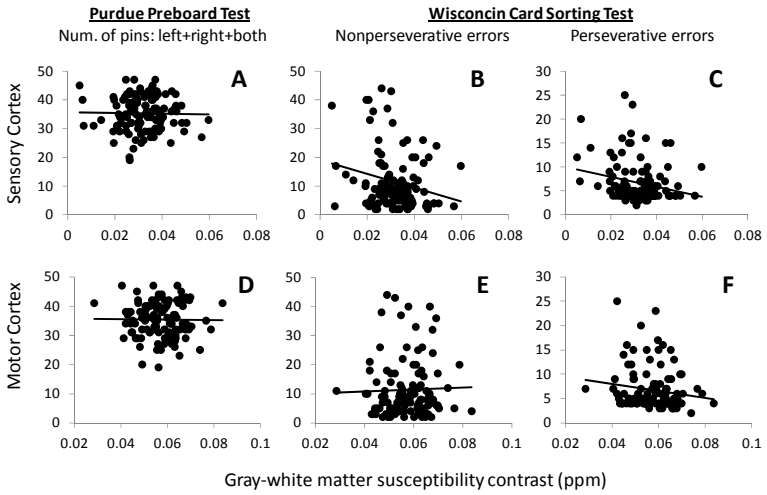

Fig. 2. Examples of the correlation between cognitive test score and susceptibility contrast.

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