Supplemental material

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General Psychiatry

Caliper-based Precise Positioning of the Target (CALIPPOT) for Transcranial Magnetic Stimulation without neuro-navigation system

Supplementary material

Steps for verification of positioning accuracy (Figure. S1)

We recruited 10 healthy adults (5 males and 5 females, aged 24 ± 2.1 years old). Two experimenters performed the verification steps as follows.

Step 1. Markers on the scalp

Six imageable markers were pasted on the scalp, including 1) M1-M4 on the forehead for positioning purpose and 2) T1 and T2 taken as the predefined scalp targets on roughly the vertex.

Step 2. MRI scanning and target measurement

3D-T1 was scanned for each participant. On the T1 image, the Euclidean distance from the scalp targets (T1 and T2) to the markers (M1 – M4) were measured, including T1-M1, T1-M2, T1-M3, T1-M4, T2-M1, T2-M2, T2-M3, and T2-M4.

Step 3. Verification points and verification distances

Two markers were labelled by using marker pen besides each of the two scalp targets (A1 and B1 for T1, A2 and B2 for T2). Then the distances between the scalp targets and verification points were

measured, i.e., A1-T1, B1-T1; A2-T2, and B2-T2 by using Vernier caliper.

We here use Vernier caliper instead of outside caliper to measure the verification distance. Vernier caliper measurement is very accurate when the distance is not very long. To test the measurement error of Vernier caliper, three subjects were measured by two experimenters (i.e., raters), the distances including A1-T1, B1-T1, A2-T2, and B2-T2. The inter-rater error was 0.03 - 0.89 mm, with an average of 0.13mm (Table S1).

Step 4. Positioning and verifying the scalp targets

The predefined markers on the scalp targets (i.e., T1 and T2) were firstly removed. Then two experimenters used outside calipers to define and used Vernier caliper to verify the scalp targets. The following is an example of using markers M1 and M2 to define and verify the scalp target T1.

As did in the positioning step (Figure. 1), two experimenters used outside calipers and positioned the scalp target T1'. Then, one experimenter used Vernier caliper to measure the distance from A1 and B1 to the measured scalp target T1'. After one experimenter completed this step, the scalp target T1' marker was erased. Then the other experimenter repeated this step.

Two experimenters performed the above positioning and verifying steps twice for each scalp target of each participant. In each verification

procedure, the markers of "M1 and M2" or "M3 and M4" were used for positioning. The error of each positioning was shown in Table S2. Generally, the mean error was 2.32 mm. It should be noted that, although there were a few big errors (e.g., 6.55 mm), we did not intend to reduce the error by repeated measurement. In practice, we suggest use 3 markers, with two markers for positioning and the third marker for validation. If the distance error is larger than 3 mm, redo the positioning step.
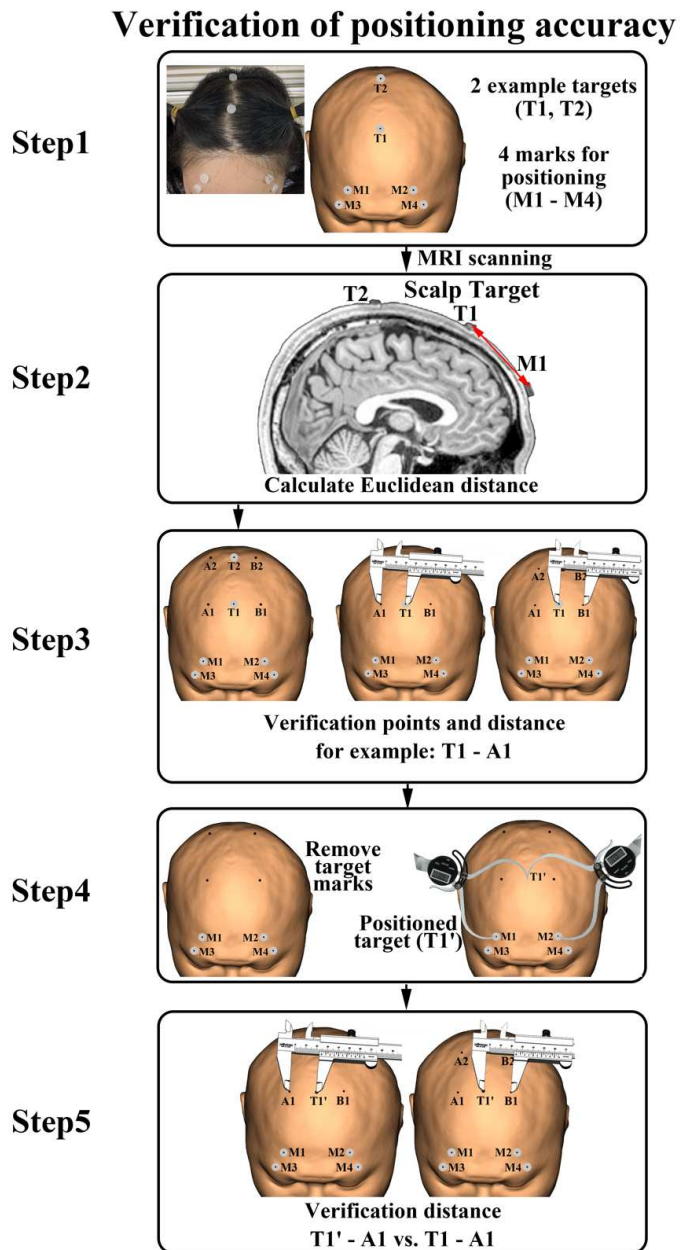
Figure S1. The verification procedure of CALIPPOT. M1-M4: imageable markers for positioning; T1 and T2: the predefined scalp targets; A1 and B1: verification points for T1 target; A2 and B2: verification points for T2 target.

Table S1. The measurement (mm) with Vernier caliper of two experimenters.

Subject	Experimenter	A1 – T1	B1 – T1	A2 – T2	B2 – T2
Subject 01	Experimenter 1	44.75	49.33	44.10	49.50
	Experimenter 2	44.66	49.17	44.93	49.01
	error	0.09	0.16	0.83	0.49
Subject 02	Experimenter 1	39.67	51.23	48.00	56.32
	Experimenter 2	39.64	51.92	47.63	56.94
	error	0.03	0.69	0.37	0.62
Subject 03	Experimenter 1	47.46	61.92	45.48	41.99
	Experimenter 2	47.88	61.88	45.56	42.12
	error	0.42	0.04	0.08	0.13

The population mean value: 0.32mm; T1, T2: The predefined scalp targets; A1, B1, A2, B2: The verification points.

Table S2. The positioning error (mm) of ten participants.

Marker	Sub	verification 1 of T1 (d - d') E_{A1}	verification 1 of T1 (d - d') E_{B1}	verification 2 of T1 (d - d') E_{A1}	verification 2 of T1 (d - d') E_{B1}	Mean (SD)	verification 1 of T2 (d - d') E_{A2}	verification 1 of T2 (d - d') E_{B2}	verification 2 of T2 (d - d') E_{A2}	verification 2 of T2 (d - d') E_{B2}	Mean (SD)
M1 and M2	Sub01	1.45	2.7	3.21	4.88		2	3.47	1.69	1.07	
	Sub02	1.58	5.1	1.85	4.21		2.1	0.63	0.31	0.74	
	Sub03	4.34	2.26	3.53	1.26		4.59	0.53	2.65	3.86	
	Sub04	3.08	2.01	1.68	1.92		1.82	1.38	1.88	1.1	
	Sub05	2.49	0.11	2.6	1.26	2.32 (1.43)	3.92	0.08	4.48	2.32	2.43 (1.52)
	Sub06	0.1	1.25	2.27	1.55		4.6	3.98	2.2	2.18	
	Sub07	1.16	2.09	2.69	1.38		4.47	0.62	2.04	0.57	
	Sub08	0.38	0.8	1.4	0.12		2.62	1.86	2.89	2.51	
	Sub09	3.6	5.07	4.29	3.73		4	3.72	0.45	5.31	
	Sub10	4.23	3.31	1.92	0.11		4.5	5.19	0.72	2.12	
M3 and M4	Sub01	0.34	1.9	1.93	0.3		0.71	1.68	2.72	0.35	
	Sub02	0.52	0.75	2.25	2.92		1.44	2.69	0.78	2.61	
	Sub03	5.72	0.78	2.78	1.15		6.55	1.09	5.54	0.94	
	Sub04	1.78	0.66	1.63	0.75		1.7	0.35	2.24	1.25	
	Sub05	3.3	1.18	3.75	0.34	2.13 (1.48)	4.78	2.24	5.14	3.76	2.40 (1.57)
	Sub06	1.11	0.32	1.75	1.04		1.21	4.55	2.26	2.38	
	Sub07	2.03	2.19	4.55	5.1		4.47	3.49	3.07	2.8	
	Sub08	2.69	0.97	1.05	0.49		1.25	2.28	2.04	2.47	
	Sub09	4.33	3.66	4.08	3.23		0.09	1.61	4.31	3.67	
	Sub10	4.58	1.74	2.85	2.85		0.37	2.63	0.44	2	
mean(SD)						2.23 (1.45)					2.42 (1.54)

Verification 1: Two experimenters positioning and verify two predefined scalp targets for the first time; verification 2: Two experimenters positioning and verify two predefined scalp targets for the second time; d: verification distance before target position*ing*; d': verification distance after target positioning; E_{A1}: absolute error value measured by A1 of T1 target; E_{B1}: absolute error value measured by B1 of T1 target; E_{A2}: absolute error value measured by A2 of T2 target; E_{B2}: absolute error value measured by B2 of T2 target.