**Table S1: Summary and principal findings of TMS/ fMRI studies exploring treatment of schizophrenia**

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| --- | --- | --- | --- | --- | --- | --- |
| **Author** | **Type of study** | **Subjects** | **Concurrent pharmacotherapy** | **Role of fMRI**  | **rTMS target** | **Findings** |
| **Hallucinations** |  |  |  |  |  |  |
| Slotema et al. (2011)(1) | Randomised, double-blinded, placebo controlled | 20 SZ fMRI guided, 22 SZ left TP, 20 SZ sham(Medication resistant AVH) | FGAs, SGAs, Lithium and antidepressants, doses not known. Those on AED and BZD excluded. | Target localisation | fMRI group and sham group: variable, based on individual AVH related activation patternsLeft TP group: TP3 | ↓ in AHRS scores across all 3 groups; no group differences.No differences in PANSS Positive subscale and PSYRATS across the 3 groups. |
| Paillère-Martinot et al. (2016)(2) | Randomised, double blinded, placebo controlled | 15 SZ active12 SZ sham (medication resistant AVH) | Active: 474.40 mg (± 84.33)Sham: 547.92 mg (± 94.29) inCPZE | Target localisation | STG in 14 and MTG in 13 patients based on a language recognition task | Sig ↓ in SAPS hallucination subscale in both arms; no difference between groups. Those with external AVH improved more than those with internal AVH.  |
| Vercammen et al. (2010)(3) | Randomised, double-blinded, placebo controlled | 9 SZ active9 SZ sham(medication resistant AVH) | On stable dose, details not known | fMRI change | TP3 | Trend level significant improvement in AVH with a rTMS, but no changes in connectivity between TPJ, ACC and amygdala.a rTMS ↑ connectivity between L TPJ and R insula |
| Bais et al. (2017)(4) | Randomised, double blinded, placebo controlled  | Left rTMS (n=7)B/l rTMS (n=9)Sham (n=8)(medication resistant AVH) | FGAs and SGAs; doses not known. | fMRI change | TP3, TP4  | PANSS P3 – trend towards decreased score in left rTMS group, no change in B/l and sham groups; no group differences in AHRS total change scores.Left rTMS caused ↓ network contribution of L SMG to BFT and ↑ network contribution of R STG to ASM, R IFG to LFP, L MFG to DMN. |
| De Weijer et al. (2014)(5) | Randomised, double-blinded | 18 SZ randomised to 1Hz (n=10) and 20Hz group (n=8)(medication resistant AVH) | 1 Hz group: 733 mg (± 417) in CPZE20 Hz group: 545 mg (± 379) in CPZE. Those on AED and BZD excluded. | Target localisation | Cluster with highest signal change in the area containing b/l AG, HG and SMG based on individual AVH related activation patterns | ↓ in AHRS scores in both groups after 5d. No difference between the groups.No treatment effect after 3w of follow-up treatment. |
| Schönfeldt-Lecuona et al. (2004)(6) | Cross-over sham controlled  | 12 SZ (medication resistant AVH) | 616.66 mg (± 461.57) in CPZE. BZD stopped 1 week before beginning of TMS. | Target localisation(all underwent structural imaging, fMRI in additional 6) | PAC or Broca’s area using block design. Midline parieto-occipital in sham. Stimulated inrandomised order. | No significant reduction in hallucination severity |
| Kindler et al. (2013)(7) | Open-label | 15 SZ rTMSvs 15 SZ TAU(medication resistant AVH) | rTMS group: 591.1 mg (± 254.1) TAU group: 479.9 mg (± 241.0) in CPZE | Target localisation and fMRI change | Area Spt based on a language task | ↓ rCBF in PAC, L Broca and cingulate gyrus in rTMS group.No differences in rCBF decrease between 1Hz and TBS groups↓ rCBF in PAC correlated with ↓ in AVH scores. |
| Maïza at al. (2013)(8) | Open-label | 9 SZ9 HC(medication resistant AVH) | 626 mg (± 598) in CPZE | Target localisation and fMRI change | L pSTS, based on a language task | Pre-treatment activity in L pSTS negatively correlated with AHRS.Post-treatment ↓AHRS, no change in L pSTS activity, along with decoupling of correlation.Positive correlation between mean GM volume and activation in L pSTS. |
| Briend et al. (2017)(9) | Open-label | 11 SZ10 HC | 575 mg (± 548) in CPZE. In 1 patient, dose of APD ↑ during treatment; 8 patients also on stable dose of BZD. | Target localisation and fMRI change | L pSTS, based on a language task | Reduced FC in L pSTS region in SZ as compared to HC at baselineSig ↓ in AHRS scores after treatmentNo correlation between AHRS and FC before and after treatment |
| Fitzgerald et al. (2007)(10) | Open label | 3 SZ, 4 HC (medication resistant AVH) | 750 mg (± 278.38) in CPZE. One patient additionally on Na Valproate 1500md/d and; another on Diazepam 15mg/d | fMRI change | TP3 | ↑ task related activation in language processing areas including L TPC |
| Homan et al. (2012)(11) | Open-label, rater-blinded | 24 SZ or SZA(medication resistant AVH) divided into 1Hz (n=12) and cTBS (n=12) group | Responders: 448.9 mg (± 132.2)Non-responders: 586.2 mg (± 257.1) in CPZE | Target localisation and fMRI change using ASL. | Area Spt in L STG based on a language task | Responders (AHRS reduction ≥50%, n=9) had higher resting rCBF in L STG as compared to non-responders. |
| Sommer et al. (2007)(12) | Open label | 7 SZ fMRI guided,6 SZ non-guided(medication resistant AVH) | No details | Target localisation | Based on individual AVH related activation patterns or TP3 if no activation map acquired. | ↓ severity of AVH in both groups, persisting at 13w from baseline; no group differences.Severity of psychosis showed trend towards more improvement in fMRI guided group. |
| Montagne-Larmurier et al. (2009)(13) | Open label | 11 SZ(medication resistant AVH) | 575 mg (± 548) in CPZE. In 1 patient, dose of APD ↑ during treatment; 8 patients also on stable dose of BZD. | Target localisation | L pSTS based on a language task | ↓ global severity and frequency of AVH. 2 patients reported no AVH at 6 months. |
| Zöllner et al. (2020)(14) | Case study | 1 VLOSLP, treated with TBS during 2 independent episodes | 1st episode: Olanzapine 20mg/d2nd episode:Olanzapine 15mg/d | fMRI change | TP3 | ↓ activation of L PAC during remission of AVH |
| Giesel et al. (2012)(15) | Case study | 1 SZ(medication resistant AVH) | Clozapine 550mg/d, Amisulpride 400mg/d, Lithium 800mg/d | fMRI change | 2cm above T3 (L STG) | ↓ frequency of AVH. Activation of insula and operculum remained stable.↑ activation in the temporal cortex during external verbal stimulation. |
| Jardri et al. (2008)(16) | Case study | 1 SZ(medication resistant) | No details | Target localisation | SSC based on activity during coenesthetic hallucinations. | 55% reduction in hallucinations; frequency: 73% to 18%; intensity: 84% to 30%, maintained for 8w |
| Jardri et al. (2007)(17) | Case study | 1 COS(medication resistant AVH) | No details | Target localisation | PAC based on AVH related activation. | AVH completely stopped. 40% improvement in CGAS. |
| **Negative symptoms** |  |  |  |  |  |  |
| Brady Jr et al. (2019)(18) | Randomised, double-blinded, placebo controlled | 35 SZ and 9 SZA for network discovery11 SZ for clinical trial | Network discovery cohort: 305.3 mg (± 232.6) Clinical trial: 614.2 mg (± 606.5) in CPZE | Target localisation (in network discovery cohort) and fMRI change (in network validation cohort) | Midline cerebellar vermis | FC between R DLPFC and midline cerebellar node predicted negative symptom severitya rTMS more effective in ↓ negative symptom severity and ↑ DLPFC-cerebellar FC |
| Basavaraju et al. (2019)(19) | Randomised, double-blinded, placebo controlled | 30 SZ active30 SZ sham | No details | fMRI change | Midline cerebellar vermis | ↓ SANS scores in both arms, no group differences.However, ↑ R PFC-cerebellar FC with a rTMS. |
| Dlabac-deLange et al. (2015)(20) | Randomised, double-blinded, placebo controlled | 24 SZ with PANSS Negative subscale score ≥15 randomized to active (n=11) and sham (n=13) | Clozapine, Olanzapine, Risperidone, Paliperidone, Aripiprazole, Haloperidol and other typicals. No details of doses. | fMRI change | b/l DLPFC (F3 and F4) | a rTMS caused ↓ SANS scores compared to sham, upto 3m followup.Active group showed ↑ activity in R DLPFC, R MeFG and ↓ activity in L PCC after treatment.No differences in cognitive measures post-treatment between the groups.No correlation between improvement and changes in brain activation. |
| **Neurocognition** |  |  |  |  |  |  |
| Prikryl et al. (2012)(21) | Randomised, double-blinded, placebo controlled | 30 SZ randomized to active (n=19) and sham (n=11) | Active: 328.95 mg (± 143.44)Sham: 304.55 mg (± 140.01) inCPZE | fMRI change | L DLPFC | ↓ negative symptoms in both groups, active > shamEqual ↑ in mean VFT score in both groupsNo differences in neuronal activation during VFT task after rTMS treatment in either groups. |
| Guse et al. (2013)(22) | Randomised, double-blinded, placebo controlled | 25 SZ22 HCBoth groups randomised to active and sham | Stable dose of SGAs, details not known. AEDs and high dose BZSs avoided. | fMRI change | F3 | Both SZ and HC showed equal activity in FP and subcortical regions during WM taskNo activity change in these regions overtime in either groups. |
| **Social cognition** |  |  |  |  |  |  |
| Liemburg et al. (2018)(23) | Randomised, double-blinded, placebo controlled | 22 SZ with PANSS Negative subscale score ≥15 randomised into 11 active and 11 sham | Active: 7.6 mg (± 3.5)Sham: 8.7 mg (± 8.0) inHaloperidol equivalents | fMRI change  | B/l DLPFC (F3 and F4) | ↓ activation of frontal, parietal and striatal regions during Wall of Faces (social-emotional evaluation) task after a rTMS; whereas, ↑ activation compared to baseline after s rTMS |
| **Agency** |  |  |  |  |  |  |
| Jardri et al. (2009)(24) | Case study | 1 COS | Hydorxyzine, Lorazepam up to 10mg/d | Target localisation and fMRI change | 1st treatment: R TPJ (for self-agency),L TPJ (for AVH)2nd treatment: L TPJ for both | 1st treatment: Improved scores on self-other discrimination tasks associated with ↑ activity in R IPL after treatment to R TPJ. AVH improved only after L TPJ targeted.2nd treatment: both symptoms improved with L TPJ rTMS |

SZ = schizophrenia; SZA = schizoaffective disorder; COS = childhood onset schizophrenia; VLOSLP = very late onset schizophrenia like psychosis; HC = healthy controls; a = active; s =sham; TAU = treatment as usual; d = days; w = week; L = left; R = right; b/l = bilateral; AVH = auditory verbal hallucinations; TP3 – midpoint of the line joining T3 to P3 as per EEG 10-20 system; TP4 – midpoint of the line joining T4 to P4 as per EEG 10-20 system; TPJ – temporoparietal junction; TPC – temporoparietal cortex; STG = superior temporal gyrus; MTG = middle temporal gyrus; AG = angular gyrus; HG = Heschl’s gyrus; SMG = supramarginal gyrus; PAC = primary auditory cortex; Spt = Sylvian parietotemporal; pSTS = posterior superior temporal sulcus; SSC = somatosensory cortex; PFC = prefrontal cortex; DLPFC=dorsolateral prefrontal cortex; ACC = anterior cingulate cortex; PCC = posterior cingulate cortex; MFG = middle frontal gyrus; IFG = inferior frontal gyrus; MeFG = medial frontal gyrus; FP = frontoparietal; IPL = inferior parietal lobule; DMN = default mode network; ASM = auditory sensorimotor network; SAN = salience network; LFP = left frontoparietal network; RFP = right frontoparietal network; BFT = bilateral frontotemporal network; ↑ = increases; ↓ = decreases; AHRS = Auditory Hallucinations Rating Scale; PANSS = Positive And Negative Syndromes Scale; PSYRATS = Psychotic Symptom Rating Scales; SAPS = Scale For The Assessment of Positive Symptoms; SANS = Scale For The Assessment of Negative Symptoms; VFT = verbal fluency task; ASL = arterial spin labelling; FC = functional connectivity; rCBF = regional cerebral blood flow; CPZE=Chlorpromazine equivalents.

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