Deep learning in brain disorders: from data processing to disease treatment

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Supplementary materials

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Note: In this document, the references in brackets refer to the articles cited in the main document while the (Author, Date) references correspond to the datasets mentioned in the tables and are listed below.

Table S1. Summary of the studies reviewed in section 2 (data reconstruction and preprocessing)

A. Image reconstruction

Study	Reconstruction domain/type	Modalities reconstructed	Datasets	Number of subjects	Methods
Kwon et al. 2017 [23]	Image domain (no k-space update)	MRI	Local	18	MLP
Han et al. 2018 [27]	Image domain (no k-space update)	MRI	Local, HCP	8 for testing	U-Net like
Quan et al. 2018 [24]	Image domain (no k-space update)	MRI	IXI	Unspecified	cGAN
Yang et al. 2018 [25]	Image domain (no k-space update)	MRI	2013 MICCAI Challenge Workshop on Segmentation, BrainLes	150, unspecified	cGAN
Sun et al. 2019 [32]	Image domain (no k-space update)	MRI	MRBrainS	4	CNN
Jun et al. 2019 [31]	Image domain (no k-space update)	MRI	Local	7	Multistream CNN
Dar et al. 2020 [35]	Image domain (no k-space update)	MRI	MIDAS	64	CNN
Wang et al. 2016 [21]	Image domain (k-space update)	MRI	Local	Unspecified	CNN
Hyun et al. 2018 [26]	Image domain (k-space update)	MRI	Local	30	U-Net like
Lee et al. 2018 [28]	Image domain (k-space update)	MRI	HCP, local	200, 9	U-Net like
Do et al. 2020 [34]	Image domain (k-space update)	MRI	Local	37	Multistream CNN
Yang et al. 2016 [22]	Image domain (iterative k-space update)	MRI	2013 MICCAI Challenge Workshop on Segmentation	Unspecified	CNN
Aggarwal et al. 2019 [30]	Image domain (iterative k-space update)	MRI	Local	5	CNN
Chen et al. 2019 [29]	Image domain (iterative k-space update)	MRI	Local	150 images	CNN
Zhang et al. [33]	Image domain (iterative k-space update)	MRI	HCP, IXI	10, 10	CNN

Akçakaya et al. 2019 [36]	k-space domain	MRI	Local	7	CNN
Han et al. 2020 [37]	k-space domain	MRI	HCP	199	U-Net like
Eo et al. 2018 [38]	Both k-space and image domains	MRI	ADNI, local	Unspecified, 25	CNN
Zhu et al. 2018 [39]	k-space/sinogram to image domain	MRI, PET	HCP, local	131, 4	MLP + CNN
Balsiger et al. 2018 [40]	MR fingerprinting	MRI	Local	6	CNN
Chen et al. 2020 [41]	MR fingerprinting	MRI	Local	13	MLP + U-Net like
Zhang et al. 2020 [42]	MR fingerprinting	MRI	Local	10	MLP
Wang et al. 2018 [45]	Image domain (no sinogram update, PET only)	PET	Local	16	cGAN
Yang et al. 2018 [46]	Image domain (no sinogram update, PET only)	PET	BrainWeb, local	Digital phantom, 2	MLP
Ouyang et al. 2019 [43]	Image domain (no sinogram update, PET only)	PET	Local	39	cGAN
Sanaat et al. 2020 [44]	Image domain (no sinogram update, PET only) / Sinogram domain	PET	Local	140	U-Net like
Xiang et al. 2017 [49]	Image domain (no sinogram update, PET & MRI)	PET	Local	16	CNN
Chen et al. 2018 [47]	Image domain (no sinogram update, PET & MRI)	PET	Local	39	U-Net like
Wang et al. 2019 [48]	Image domain (no sinogram update, PET & MRI)	PET	BrainWeb, local	Digital phantom, 16	cGAN
Kim et al. 2018 [51]	Image domain (iterative reconstruction)	PET	Local	27	CNN
Gong et al. 2019 [50]	Image domain (iterative reconstruction)	PET	Local	17 + digital phantom	U-Net like
Häggström et al. 2019 [52]	Sinogram to image domain	PET	Local	2 + digital phantom	Convolutional encoder-decoder
Liu et al. 2019 [53]	Sinogram to image domain	PET	Local	10 + phantom	cGAN

B. Signal enhancement

Study	Enhancement type	Modalities	Datasets	Number of subjects	Methods
Ran et al. 2019 [55]	Image denoising	T1, T2, PD	IXI, BrainWeb	110, digital phantom	cGAN
Hashimoto et al. 2019 [57]	Image denoising	FDG PET	BrainWeb, local	Digital phantom, 1	U-Net like
Benou et al. 2017 [54]	Spatio-temporal signal denoising	Dynamic contrast-enhanced MRI	Local, TCIA	14, 19	MLP
Yang et al. 2020 [56]	Spatio-temporal signal denoising	T1, functional MRI	HCP	88	LSTM
Klyuzhin et al. 2020 [58]	Spatio-temporal signal denoising	^{11}C raclopride PET	Local	7	Encoder-decoder
Zeng et al. 2018 [68]	Example-based super-resolution	T1, T2	BrainWeb, NAMIC, local	digital phantom, 20, 3	CNN
Chen et al. 2018 [59]	Example-based super-resolution	T1	HCP	1113	cGAN
Kim et al. 2018 [66]	Example-based super-resolution	T1, T1c, T2, FLAIR	BraTS, local	244, 10	cGAN
Gu et al. 2019 [61]	Example-based super-resolution	T1	Local	154	cGAN
Pham et al. 2019 [62]	Example-based super-resolution	T1, T2, FLAIR	Kirby 21, NAMIC, dHCP, local	Not clearly specified	CNN

Du et al. 2019 [60]	Example-based super-resolution	T1, T2	Kirby 21, BrainWeb	21, digital phantom	CNN
Du et al. 2020 [64]	Example-based super-resolution	T1	Kirby21, ANVIL-adult, BraTS, MSSEG, local	21, 7, 5, unspecified, 1	Convolutional encoder-decoder
Zhao et al. 2019 [65]	Self super-resolution	T1, T2, FLAIR	Local, OASIS	95, 15	CNN
Song et al. 2020 [67]	Self super-resolution	FDG PET	BrainWeb, ADNI	Digital phantom, 30	cGAN

C. Cross-modality image synthesis

Study	Application	Modalities	Datasets	Number of subjects	Methods
Gong et al. 2018 [73]	PET/MR attenuation correction	Dixon + zero-echo time → CT	Local	40	U-Net like
Arabi et al. 2019 [76]	PET/MR attenuation correction	T1 → CT	Local	50	cGAN
Ladefoged et al. 2019 [78]	PET/MR attenuation correction	Ultrashort echo time → CT	Local	79	U-Net like
Spuhler et al. 2019 [81]	PET/MR attenuation correction	T1 → CT	Local	76	U-Net like
Shiri et al. 2019 [98]	PET/MR attenuation correction	NAC → AC FDG PET	Local	129	U-Net like
Yang et al. 2019 [99]	PET/MR attenuation correction	NAC → AC FDG PET	Local	35	U-Net like
Dinkla et al. 2018 [71]	MRI-only radiotherapy treatment planning	T1 → CT	Local	52	cGAN
Kazemifar et al. 2019 [77]	MRI-only radiotherapy treatment planning	T1c → CT	Local	77	cGAN
Neppl et al. 2019 [80]	MRI-only radiotherapy treatment planning	T1 → CT	Local	89	U-Net like
Koike et al. 2020 [84]	MRI-only radiotherapy treatment planning	T1 + T2 + FLAIR → CT	TCIA	15	cGAN

Yang et al. 2020 [90]	Improved segmentation, registration and lesion detection	T1 → T2, T2 → T1, T1 → FLAIR, T2 → FLAIR, PD → T2, T2 → PD	BraTS, iSeg17, MRBrainS, ADNI, RIRE	220, 23, 50, 19	cGAN
Mehta and Arbel 2018 [93]	Improved lesion detection	T1 + T2 + FLAIR + T1c → T1 + T2 + FLAIR + T1c	BraTS	285	U-Net like
Wei et al. 2019 [95]	Improved lesion detection	T1 + T2 + PD + T1 spin-echo + DIR → FLAIR	Local	24	Multimodal CNN
Wei et al. 2019 [102]	Improved lesion detection	Magnetization transfer ratio + diffusion MRI → Amyloid PET	Local	28	cGAN
Van Nguyen et al. 2015 [91]	Improved classification	T1 + T1c + T2 + FLAIR → T1 + T1c + T2 + FLAIR	BraTS	30	Restricted Boltzmann machine
Huang et al. 2019 [86]	Improved classification	T1 → ASL	Local	355	CNN
Li et al. 2014 [100]	Improved classification	T1 → FDG PET	ADNI	830	CNN
Pan et al. 2018 [101]	Improved classification	T1 → FDG PET	ADNI	1457	Cycle GAN
Choi and Lee 2018 [103]	MR-less PET quantification	Amyloid PET → T1	ADNI	261	cGAN
Schilling et al. 2019 [88]	Distortion correction in diffusion MRI	T1 → diffusion MRI	BLSA	586	cGAN
Han 2017 [69]	General image synthesis	T1 → CT	Local	18	U-Net like
Wolterink et al. 2017 [70]	General image synthesis	T1 → CT	Local	24	Cycle GAN
Xiang et al. 2018 [75]	General image synthesis	T1 → CT	Local	38	CNN
Emami et al. 2018 [72]	General image synthesis	T1c → CT	Local	15	cGAN
Lei et al. 2019 [79]	General image synthesis	T1 → CT	Local	44	Cycle GAN
Zeng and Zheng 2019 [82]	General image synthesis	T1 → CT	Local	50	cGAN
Nie et al. 2018 [74]	General image synthesis	T1 → CT, T1 3T → 7T	Local	38 / 15	cGAN
Cao et al. 2020 [83]	General image synthesis	T1 → CT, T1 + T1c + FLAIR → T2	Local, BraTS	16, 352	cGAN

Chartsias et al. 2018 [92]	General image synthesis	T1 + T2 + diffusion MRI → FLAIR, T1 → T2, T1 → FLAIR	ISLES, BraTS, IXI	28, 54, 28	Multimodal convolutional encoder-decoder
Dar et al. 2019 [85]	General image synthesis	T1 → T2, T2 → T1	MIDAS, IXI, BraTS	66, 40, 41	cGAN
Yu et al. 2019 [89]	General image synthesis	T1 → T2, T1 → FLAIR, PD → T2	BraTS, IXI	274, 578	cGAN
Li et al. 2019 [94]	General image synthesis	T1 + T2 + FLAIR → DIR, T1 + T2 + FLAIR → T1c	Local, WMH Segmentation	65, 40	Multimodal cGAN
Qu et al. 2020 [87]	General image synthesis	T1 3T → 7T	Local	15	Convolutional encoder-decoder
Sharma and Hamarneh 2020 [96]	General image synthesis	T1 + T2 + diffusion MRI → FLAIR, T1 + T2 + T1c + FLAIR → T1 + T2 + T1c + FLAIR	ISLES, BraTS	22, 285	Multimodal cGAN
Zhou et al. 2020 [97]	General image synthesis	T1 + T2 → FLAIR, T1 + FLAIR → T2, T2 + FLAIR → T1	BraTS	285	Multimodal convolutional encoder-decoder

Modalities: 3T, 3 Tesla magnetic resonance imaging; 7T, 7 Tesla magnetic resonance imaging; AC PET, attenuation corrected positron emission tomography; CT, computed tomography; DIR, double inversion recovery; EEG, electroencephalography; FDG PET, ^{18}F-Fluorodeoxyglucose positron emission tomography; FLAIR, fluid-attenuated inversion recovery; MRI, magnetic resonance imaging; NAC PET, non-attenuation corrected positron emission tomography; PD, proton density-weighted magnetic resonance imaging; PET, positron emission tomography; T1, T1-weighted magnetic resonance imaging; T1c, post-contrast T1-weighted magnetic resonance imaging; T2, T2-weighted magnetic resonance imaging

Datasets: 2013 MICCAI Challenge Workshop on Segmentation (https://my.vanderbilt.edu/masi/workshops/); ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/) (Jack et al., 2008); ANVIL-adult (Kempton et al., 2011); BLSA, Baltimore Longitudinal Study of Aging (Ferrucci, 2008); BrainLes, Brain Lesion workshop (http://www.brainlesion-workshop.org/); BrainWeb (http://www.bic.mni.mcgill.ca/brainweb/) (Collins et al., 1998); BraTS, Brain Tumor Segmentation (http://braintumorsegmentation.org/) (Bakas et al., 2019; Menze et al., 2015); BBCI Competition III (dataset V), Dataset V of the Berlin Brain Computer Interface Competition III (http://www.bbci.de/competition/iii/) (Millan, 2004); dHCP, Developing human connectome project (Hughes et al., 2017); HCP, Human Connectome Project (http://www.humanconnectomeproject.org/); iSeg17, Infant brain MRI segmentation challenge (https://iseg2017.web.unc.edu/) (L. Wang et al., 2019); ISLES, Ischemic Stroke Lesion Segmentation challenge (http://www.isles-challenge.org/); IXI (https://brain-development.org/ixi-dataset/); Kirby 21 (Landman et al., 2011); WMH Segmentation Challenge (Kuijf et al., 2019); MIDAS (Bullitt et al., 2005); MRBrainS, MR Brain Segmentation challenge (Mendrik et al., 2015); MSSEG, Multiple Sclerosis Lesion Segmentation challenge (Commowick et al., 2018); NAMIC (https://www.insight-journal.org/midas/collection/view/190); RIRE (https://www.insight-journal.org/rire/) (West et al., 1997); OASIS, Open Access Series of Imaging Studies (https://www.oasis-brains.org/) (Marcus et al. 2010); TCIA, The Cancer Imaging Archive (https://www.cancerimagingarchive.net/) (Clark et al., 2013)

Methods: cGAN, conditional generative adversarial network; CNN, convolutional neural network; LSTM, long short-term memory; MLP, multilayer perceptron

Table S2. Summary of the studies reviewed in section 3 (extraction of biomarkers)

Study	Tasks	Modalities	Datasets	Number of subjects	Methods
De Brébisson et al. 2015 [106]	Segmentation of normal structures	T1	2012 MICCAI Challenge on multi-atlas labeling	55	CNN (sliding-window)
Milletari et al. 2017 [109]	Segmentation of normal structures	T1, US	Local	55, 34	CNN (sliding-window)
Moeskops et al. 2016 [108]	Segmentation of normal structures	T1, T2	Local, 2013 MICCAI Challenge Workshop on segmentation, 2012 MICCAI Challenge on multi-atlas labeling	22, 20, 15	CNN (sliding-window)
Zhang et al. 2015 [107]	Segmentation of normal structures	T1, T2, diffusion MRI	Local	10	CNN (sliding-window)
Chen et al. 2018 [111]	Segmentation of normal structures	T1, T1-inversion recovery, T2	2013 MICCAI Challenge Workshop on segmentation	5	3D CNN (residual)
Li et al. 2017 [110]	Segmentation of normal structures	T1	ADNI	543	3D CNN (residual)
Mohseni Salehi et al. 2017 [112]	Segmentation of normal structures	T1, T2	LPBA40, OASIS, local	40, 77, 75	2D CNN (dual pathway), U-Net
Karani et al. 2018 [113]	Segmentation of normal structures	T1, T2	HCP, ADNI, ABIDE, IXI	328	U-Net
Moeskops et al. 2017 [114]	Segmentation of normal structures	T1, T2	2013 MICCAI Challenge Workshop on segmentation, 2012 MICCAI Challenge on multi-atlas labeling	35, 20	Adversarial 2D CNN
Kamnitsas et al. 2017 [117]	Detection of lesions (brain tumor and stroke)	T1, T2, FLAIR	BraTS, ISLES, local	220, 28 datasets, 66	Multiscale 3D CNN dual pathway (DeepMedic)

Amin et al. 2018 [129]	Detection of lesions (brain tumor and stroke)	T1, post-contrast T1, T2, FLAIR	BraTS, ISLES	904, 139	CNN (sliding-window)
Charron et al. 2018 [119]	Brain tumor detection	T1, T2	Local	182	3D, 2D CNN (DeepMedic)
Chen et al. 2019 [122]	Brain tumor detection	T1 MRI, post-contrast T1, T2, FLAIR	BraTS	unspecified	3D CNN (DeepMedic, U-Net)
Dong et al. 2017 [126]	Brain tumor detection	Post-contrast T1, FLAIR	BraTS	274	2D, 3D CNN (U-Net)
Hussain et al. 2018 [120]	Brain tumor detection	T1, post-contrast T1, T2, FLAIR	BraTS	304	2D CNN (dual pathway)
Fabelo et al. 2019 [130]	Brain tumor detection	Intraoperative hyperspectral imaging	Local	16	2D CNN + 2D U-Net + MLP
Havaei et al. 2017 [124]	Brain tumor detection	T1, post-contrast T1, T2, FLAIR	BraTS	40	2D CNN (dual pathway, cascade CNN)
Liu et al. 2017 [118]	Brain tumor detection	Post-contrast T1, T2, FLAIR	BraTS, local	265, 255	3D CNN (DeepMedic)
Myronenko et al. 2019 [127]	Brain tumor detection	T1, post-contrast T1, T2, FLAIR	BraTS	542	3D CNN (autoencoder, VAE)
Pereira et al. 2016 [128]	Brain tumor detection	T1, post-contrast T1, T2, FLAIR	BraTS	unspecified	CNN (sliding-window)
Wang et al. 2018 [125]	Brain tumor detection	T1, post-contrast T1, T2, FLAIR	BraTS	477	3D CNN (cascade CNN)
Brosch et al. 2016 [132]	Multiple sclerosis lesion detection	T1, T2, FLAIR, PD	2008 MICCAI lesion segmentation challenge, 2015 ISBI lesion segmentation, local	377	3D CNN (U-Net)
Valverde et al. 2017 [131]	Multiple sclerosis lesion detection	T1, T2, FLAIR	2008 MICCAI lesion segmentation challenge, Local	45, 60	3D patch-wise CNN (cascade CNN)
Dou et al. 2016 [134]	Cerebral microbleed detection	SWI	Local	320	3D CNN (cascade

					CNN)
Wang et al. 2017 [135]	Cerebral microbleed detection	SWI	Local	10	2D CNN
Guerrero et al. 2018 [133]	Differentiation of white matter hyperintensities and stroke lesions	T1, FLAIR	Local	167	2D CNN (U-Net)
Kamnitsas et al. 2017 [123]	Traumatic brain injury detection	T1, T2, FLAIR, PD	Local	102	3D CNN (DeepMedic)
Cole et al. 2017 [141]	Brain age	T1	Mix of 14 public datasets	2001	3D CNN
Jonsson et al. 2019 [142]	Brain age	T1	deCODE, UK Biobank, IXI	1264, 15040, 544	3D CNN (residual)
Cecotti et al. 2011 [143]	EEG biomarker	EEG	BBCI Competition III (dataset II)	2	2D CNN
Hossain et al. 2019 [144]	EEG biomarker	EEG	CHB-MIT	23	2D CNN

Modalities: EEG, electroencephalography; FLAIR, fluid-attenuated inversion recovery; SWI, susceptibility weighted imaging; T1, T1-weighted magnetic resonance imaging; T2, T2-weighted magnetic resonance imaging; US, ultrasound imaging
Datasets: 2008 MICCAI lesion segmentation challenge (https://www.nitrc.org/projects/msseg/); 2012 MICCAI Challenge on multi-atlas labeling (http://www.neuromorphometrics.com/2012_MICCAI_Challenge_Data.html); 2013 MICCAI Challenge Workshop on Segmentation (https://my.vanderbilt.edu/masi/workshops/); 2015 ISBI lesion segmentation (https://biomedicalimaging.org/2015/program/isbi-challenges/); ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/) (Jack et al., 2008); BBCI Competition III (dataset II), Dataset II of the Berlin Brain Computer Interface Competition III (http://www.bbci.de/competition/iii/); BraTS, Brain Tumor Segmentation (http://braintumorsegmentation.org/) (Menze et al., 2015; Bakas et al., 2019); CHB-MIT, Boston Children's Hospital-MIT (Shoeb & Guttag, 2010); deCODE (https://www.decode.com/); HCP, Human Connectome Project (http://www.humanconnectomeproject.org/); ISLES, Ischemic Stroke Lesion Segmentation (http://www.isles-challenge.org/); IXI (https://brain-development.org/ixi-dataset/); LPBA40, LONI probabilistic Brain Atlas Project (Shattuck et al., 2009); OASIS, Open Access Series of Imaging Studies (https://www.oasis-brains.org/) (Marcus et al., 2010); UK Biobank (https://www.ukbiobank.ac.uk/) (Sudlow et al., 2015)
Methods: CNN, convolutional neural network; GAN, generative adversarial network; VAE, variational autoencoder

Table S3. Summary of the studies reviewed in section 4 (disease detection and diagnosis)

Study	Brain disorders	Modalities	Datasets	Number of subjects	Methods	Tasks
Chien et al. 2019 [152]	AD	Speech sample	Local	120	RNN	HC vs AD
Choi et al. 2019 [150]	AD, MCI	FDG PET	ADNI	636,666	3D CNN	HC vs AD, transfer learning on MCI for abnormality score
Punjabi et al. 2019 [151]	AD	T1, amyloid PET	ADNI	723	3D CNN	HC vs AD
Silva et al. 2019 [149]	AD	T1	MIRIAD	69	2D CNN	HC vs AD
Wada et al. 2019 [176]	AD, LBD	Diffusion MRI	Local	48	2D CNN	AD vs LBD
Afonso et al. 2019 [156]	PD	Hand-written data	Local	308	2D CNN	HC vs PD
Choi et al. 2017 [153]	PD	SPECT	PPMI, local	624, 82	3D CNN	HC vs PD
Choi et al. 2020 [182]	PD	FDG PET	ADNI, PPMI	1306, 62	3D CNN	HC vs AD, transfer learning on PD to recognize dementia patients
Kiryu et al. 2019 [184]	PD	T1	Local	419	2D CNN	PD vs MSA-P vs PSP vs HC
Naseer et al. 2020 [157]	PD	Hand-written data	PaHaW	72	2D CNN (transfer learning from Alex Net)	HC vs PD
Shinde et al. 2019 [154]	PD	NMS-MRI	Local	100	2D ResNet	HC vs PD
Zhang et al. 2018 [155]	PD	Diffusion MRI	PPMI	754	multi-view CNN	HC vs PD
Zhang et al. 2019 [183]	PD	Demographic, motor, non-motor data, SPECT, biospecimen	PPMI	683	LSTM	HC vs PD
Acharya et al. 2018 [187]	Depression	EEG	Local	30	2D CNN	HC vs depression

Banerjee et al. 2019 [160]	PTSD	Speech sample	Local	52	DBN + transfer learning	HC vs PTSD
Campese et al. 2020 [164]	SZ, BD	T1	Local	354	CNN (2D, 3D, Vnet, Unet, LeNet)	HC vs SZ, HC vs BD
Eslami et al. 2019 [165]	ASD	fMRI	ABIDE-1	1035	Autoencoder + SLP	HC vs ASD
Ghafouri-Fard et al. 2019 [167]	ASD	Genomics	Local	942	MLP	HC vs ASD
Huang et al. 2019 [177]	Depression, BD	Speech samples	Local	45	CNN with attention mechanism + LSTM	HC vs depression vs BD
Kim et al. 2016 [161]	SZ	fMRI	COBRE	100	Pre-trained SAE, sparse MLP	HC vs SZ
Li et al. 2019[168]	ASD	Eye tracking	Local	272	LSTM	HC vs ASD
Oh et al. 2019 [163]	SZ	fMRI	Local	144	3D CAE + 3D CNN	HC vs SZ
Xiao et al. 2018 [166]	ASD	fMRI	ABIDE	84	SAE	HC vs ASD
Yang et al. 2020 [159]	Depression	Speech samples	AVEC2016	107	GAN	HC vs depression
Zeng et al. 2018 [162]	SZ	fMRI	Local	743	Discriminant AE	HC vs SZ
Zhang et al. 2019 [170]	Conduct disorder	T1	Local	120	3D CNN	HC vs conduct disorder
Zou et al. 2017 [169]	ADHD	T1, fMRI	ADHD-200 Sample	730	3D CNN	HC vs ADHD
Acharya et al. 2018 [187]	Epilepsy	EEG	Freiburg hospital	5	2D CNN	Normal vs preictal vs seizure
Aoe et al. 2019 [171]	Epilepsy	MEG	Local	233	2D CNN	HC vs spinal cord injury, HC vs epilepsy, spinal cord injury vs epilepsy
San-Segundo et al. 2019 [188]	Epilepsy	EEG	Bern Barcellona EEG	5, 500	2D CNN	Focal vs non-focal signals

			Dataset, Epileptic Seizure Recognition Dataset			
Akkus et al. 2017 [178]	Cancer	T1, T2	TCIA	159	2D CNN	Presence vs absence of 1p/19q codeletion
Ge et al. 2018 [179]	Cancer	T1, T2, FLAIR	BraTS, TCIA	285, 159	2D CNN	Tumor grading / presence vs absence of 1p/19q codeletion
Li et al. 2017 [180]	Cancer	FLAIR, T1	Local	151	2D CNN	Classification of genetic mutation status
Hollon et al. 2020 [181]	Cancer	Stimulated Raman histology	Local	709	2D CNN	Classification between 13 histological classes
Fu et al. 2019 [172]	Silent brain infarction	Medical records	Local	1000	CNN	Detection of silent brain infarction
Marzullo et al. 2019 [185]	MS	T1	Local	114	GCNN	MS in four clinical profiles
Yang et al. 2018 [173]	Migraine	fMRI	Local	64	3D CNN (~Alex Net, Inception module)	HC vs migraine
Ye et al. 2019 [186]	Intracranial hemorrhage	Non-contrast CT	Local	2836	2D CNN, RNN	Five subtypes of intracranial hemorrhage
Nakao et al. 2018 [174]	Aneurysm	MRA	Local	508	2D CNN	Detection of aneurysm
Ueda et al. 2019 [175]	Aneurysm	MRA	Local	1271	ResNet-18	Detection of aneurysm

Brain disorders: AD, Alzheimer's disease; ADHD: attention deficit hyperactivity disorder; ASD, autism spectrum disorder; BD, bipolar disorder; HC, healthy control; LBD, Lewy body dementia; MCI, mild cognitive impairment; MS, Multiple Sclerosis; MSA-P, multiple system atrophy, parkinsonian type; PD, Parkinson's disease; PSP, progressive supranuclear palsy; PTSD, post traumatic stress disorder, SZ: schizophrenia
Modalities: CT, computed tomography; EEG, electroencephalography; FDG PET, ^{18}F-Fluorodeoxyglucose positron emission tomography; FLAIR, fluid-attenuated inversion recovery; fMRI, functional magnetic resonance imaging; MRA, magnetic resonance angiography; NMS-MRI, neuromelanin sensitive magnetic resonance imaging; PET, positron emission tomography; SPECT, single-photon emission computed tomography; T1, T1-weighted magnetic resonance imaging; T2, T2-weighted magnetic resonance imaging
Datasets: AVEC2016**,** (Valstar et al., 2016) ABIDE, Autism Brain Imaging Data Exchange (http://fcon_1000.projects.nitrc.org/indi/abide/); ADHD-200 Sample, (http://fcon_1000.projects.nitrc.org/indi/adhd200/); ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/) (Jack et al., 2008); Bern Barcellona EEG Database,

(https://www.upf.edu/web/mdm-dtic/-/1st-test-dataset#.XsvCIifgqRs) COBRE, Center of Biomedical Research Excellence, (http://fcon_1000.projects.nitrc.org/indi/retro/cobre.html); Epileptic Seizure Recognition Dataset, (https://archive.ics.uci.edu/ml/datasets/Epileptic+Seizure+Recognition); Freibug Hospital (https://epilepsy.uni-freiburg.de/freiburg-seizure-prediction-project/eeg-database); MIRIAD, Minimal Interval Resonance Imaging in Alzheimer's Disease (Malone et al. 2013); PaHaW, Parkinson's Disease Handwriting (https://bdalab.utko.feec.vutbr.cz/) (Drotár et al., 2016); PPMI, Parkinson's Progression Markers Initiative (https://www.ppmi-info.org/); TCIA, The Cancer Imaging Archive (https://www.cancerimagingarchive.net/) (Clark et al., 2013)**;** BraTS, Brain Tumor Segmentation (http://braintumorsegmentation.org/)(Menze et al., 2015; Bakas et al., 2019)**;**
Methods: CAE, convolutional autoencoder; CNN, convolutional neural network; DBN, deep belief network; GAN, generative adversarial network; GCNN, graph convolutional neural network; LSTM, long short-term memory; MLP, multilayer perceptron; NN, neural network; RNN, recurrent neural network; SLP; single layer perceptron; SAE, sparse autoencoder

Table S4. Summary of the studies reviewed in section 5 (disease prediction)

Study	Brain disorders	Modalities	Datasets	Number of subjects	Methods	Tasks
Basaia et al. 2018 [191]	AD	T1	ADNI, local	1409, 229	3D CNN	Stable vs progressive classification
Shmulev and Belyaev 2018 [194]	AD	T1	ADNI	859	3D-VGGNet / 3D-ResNet	Stable vs progressive classification
Choi and Jin 2018 [195]	AD	FDG PET, amyloid PET	ADNI	492	3D CNN	Stable vs progressive classification
Lian et al. 2018 [192]	AD	T1	ADNI	1457	3D CNN	Stable vs progressive classification
Liu et al. 2018 [193]	AD	T1	ADNI, MIRIAD	1456, 69	3D CNN	Stable vs progressive classification
Bowles et al. 2018 [199]	AD	T1	ADNI	Unspecified	2D GAN	Future image prediction
Ravi et al. 2019 [200]	AD	T1	ADNI	1055	2D cGAN	Future image prediction
Wegmayr et al. 2019 [201]	AD	T1	ADNI, AIBL	3438	2D cGAN + 2D CNN	Future image prediction + prodromal vs AD classification
Hao et al. 2019 [196]	Cancer	Histology, genomics, age	TGCA	477	2D CNN	Survival time regression
Mobadersany et al. 2018 [197]	Cancer	Histology, genomics	TGCA	769	2D CNN	Survival time regression
Rachmadi et al. 2019 [198]	Stroke	FLAIR	Local	152	2D cGAN	Future image prediction
Truong et al. 2018 [189]	Epilepsy	Scalps & intracranial EEG	Freiburg hospital, CHB-MIT, Kaggle seizure prediction	13, 13, 2 + 5 dogs	2D CNN	preictal vs interictal classification
Yoo et al. 2016 [190]	Multiple sclerosis	T2, PD	Local	140	3D CNN	Stable vs progressive classification

Brain disorders: AD, Alzheimer's disease
Modalities: CSF, cerebrospinal fluid; EEG, electroencephalography; FDG, ^{18}F-Fluorodeoxyglucose; FLAIR, fluid-attenuated inversion recovery; PD, proton density-weighted magnetic resonance imaging; PET, positron emission tomography; T1, T1-weighted magnetic resonance imaging; T2, T2-weighted magnetic resonance imaging
Datasets: ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/) (Jack et al., 2008); AIBL, Australian Imaging, Biomarkers and Lifestyle (https://aibl.csiro.au/about/) (Ellis et al., 2009); CHB-MIT, Boston Children's Hospital-MIT (Shoeb & Guttag, 2010); Freibug Hospital (https://epilepsy.uni-freiburg.de/freiburg-seizure-prediction-project/eeg-database); Kaggle seizure prediction (https://www.kaggle.com/c/seizure-prediction); MIRIAD, Minimal Interval Resonance Imaging in Alzheimer's Disease (Malone et al., 2013); TGCA, The Cancer Genome Atlas (https://www.cancer.gov/about-nci/organization/ccg/research/structural-genomics/tcga) (Weinstein et al., 2013)
Methods: cGAN, conditional generative adversarial network; CNN, convolutional neural network; GAN, generative adversarial network; SVM, support vector machine

Table S5. Summary of the studies reviewed in section 6 (disease understanding)

Study	Brain disorders	Modalities	Datasets	Number of subjects	Methods	Tasks
Zhang et al. 2018 [183]	PD	Clinical, CSF, SPECT	PPMI	683	LSTM	Clustering of PD subjects
de Jong et al. 2019 [203]	AD, PD	Clinical	ADNI, PPMI	689 AD, 362 PD	LSTM + VAE	Clustering of AD / PD subjects
Schiratti et al. 2017 [204]	AD	Clinical/cognitive	ADNI	248	Non-linear mixed effects model	Estimating trajectories of progression
Fonteijn et al. 2012 [205]	AD, HD	Structural MRI	Local	9 AD, 61 HD	Event-based model	Ordering of events
Lorenzi et al. 2019 [206]	AD	Structural MRI, FDG PET, Amyloid PET, Clinical / cognitive	ADNI	163 HC, 402 MCI, 220 AD	Gaussian process regression	Estimating trajectories of progression
Louis et al. 2019 [207]	AD	Structural MRI, clinical/cognitive	ADNI	325	RNN and Riemannian geometry learning	Estimating trajectories of progression
Fisher et al. 2019 [270]	AD	Clinical	CPAD	1909	CRBM	Estimating trajectories of progression
Zhou et al. 2019 [209]	ASD	Genomics	SSC	1,790 families	CNN	Identification of genetic risk factors
Yin et al. 2019 [210]	ALS	Genomics	Project MinE	11,908	CNN	Binary classification ALS vs HC
Khan et al. 2018 [211]	ASD, schizophrenia	Genomics	8 datasets	Unspecified	MLP	Classification of single-nucleotide polymorphisms

Brain disorders: AD, Alzheimer's disease; ALS, amyotrophic lateral sclerosis; ASD, autism spectrum disorder; HC, healthy control; HD, Huntington's disease; PD, Parkinson's disease

Modalities: CSF, cerebrospinal fluid**;** FDG, ^{18}F-Fluorodeoxyglucose; MRI, magnetic resonance imaging; SPECT, single-photon emission computed tomography; PET, positron emission tomography

Datasets: ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/) (Jack et al., 2008); CPAD, Critical Path for Alzheimer's Disease (https://c-path.org/programs/cpad/); PPMI, Parkinson's Progression Markers Initiative (https://www.ppmi-info.org/); Project MinE (https://www.projectmine.com/); SSC, Simons Simplex Collection (https://www.sfari.org/resource/simons-simplex-collection/)

Methods: CRBM, conditional restricted Boltzmann machine; LSTM, long short-term memory; MLP, multilayer perceptron; RNN, recurrent neural network; VAE, variational autoencoder

Table S6. Summary of the studies reviewed in section 7 (treating diseases)

Study	Brain disorders	Modalities	Datasets	Number of subjects	Methods	Tasks
Chang et al. 2018 [212]	Cancer	Genomics	TCGA	152,594	CNN	Regression of inhibitory concentration values of anticancer compounds
Hilbert et al. 2019 [213]	Acute ischemic stroke	Computed tomography angiography	MR CLEAN Registry	1,301	CNN	Classification of good / poor reperfusion patients after endovascular treatment
Lin et al. 2018 [214]	Major depressive disorder	Clinical, genetic	Local	455	MLP	Classification of remission after use of selective serotonin reuptake inhibitors
Munsell et al. 2015 [215]	Epilepsy	Structural brain connectome	Local	70	SAE	Classification of surgical treatment outcome
Subramanian et al. 2016 [218]	Alzheimer's disease	Molecular descriptors	Protein Data Bank	N/A	MLP	Prediction of binding affinity

Datasets: TCGA, The Cancer Genome Atlas (https://www.cancer.gov/about-nci/organization/ccg/research/structural-genomics/tcga);
MR CLEAN Registry, Multicenter Clinical Registry of Endovascular treatment for Acute ischemic stroke in the Netherlands (https://mrclean-trial.org/); Protein Data Bank (https://www.wwpdb.org/)
Methods: CNN, convolutional neural network; MLP, multilayer perceptron; RNN, recurrent neural network; SAE, stacked autoencoder

Table S7. Summary of the studies reviewed in section 8 (future trends)

Study	Brain disorders	Modalities	Datasets	Number of subjects	Methods	Tasks
Punjabi et al. 2019 [151]	AD	Structural MRI, PET	ADNI	723	CNN	Classification of AD vs HC
Kim et al. 2018 [219]	PD	Tremor signals	Local	92	2D CNN	Classification of UPDRS scores
Nancy Jane et al. 2016 [220]	PD	Walking patterns	Local	166	Q-BTDNN	Classification of severity of gait disturbances
Li et al. 2019 [168]	ASD	Eye tracking measurements	Local	272	LSTM	Classification of ASD children vs HC
Hao et al. 2019 [196]	Cancer	Histology, genomics	TCGA	477	CNN	Survival prediction in cancer
Mobadersany et al. 2018 [197]	Cancer	Histology, genomics	TCGA	769	CNN	Survival prediction in cancer
Zhou et al. 2019 [209]	ASD	Genomics	SSC	1,790 families	CNN	Identification of new contributing regions to ASD
Yin et al. 2019 [210]	ALS	Genomics	Project MinE	11,908	CNN	Classification of ALS vs HC
Camps et al. 2018 [221]	PD	Inertial measurements	REMPARK	21	1D CNN	Classification of freezing of gait
Little et al. 2019 [222]	Late-life depression	Speech samples	Local	58	LSTM / CNN	Classification of late-life depression vs HC
Zhang 2017 [223]	PD	Speech samples	Local	N/A	SAE	Classification of PD vs HC
Park et al. 2020 [224]	PD	Smartphone test	Local	429	CNN	Scoring of the Interlocking Pentagon Drawing Test
Sun et al. 2019 [225]	Cancer	Genomics	TCGA	8,074	MLP	Classification of 12 cancer types
Suk and Shen 2013	AD	MRI, PET, CSF,	ADNI	202	SAE	Prediction of MCI-to-AD conversion

[226]		clinical, genetic				
Ning et al. 2018 [227]	AD	MRI, genetic	ADNI	621	MLP	Prediction of MCI-to-AD conversion

Brain disorders: AD, Alzheimer's disease; ALS, amyotrophic lateral sclerosis; ASD, autism spectrum disorder; HC, healthy control; MCI: mild cognitive impairment; PD, Parkinson's disease

Modalities: CSF, cerebrospinal fluid**;** magnetic resonance imaging; PET, positron emission tomography

Datasets: ADNI, Alzheimer's Disease Neuroimaging Initiative (https://adni.loni.usc.edu/); SSC, Simons Simplex Collection (https://www.sfari.org/resource/simons-simplex-collection/); TCGA, The Cancer Genome Atlas (https://www.cancer.gov/about-nci/organization/ccg/research/structural-genomics/tcga)

Methods: CNN, convolutional neural network; LSTM, long short-term memory; MLP, multilayer perceptron; Q-BTDNN: Q-backpropagated time delay neural network; SAE, stacked autoencoder

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