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Action observation and imitation in autism spectrum disorders: an ALE meta-analysis of fMRI studies

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ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Data extraction.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 8 January 2026 and was last updated on 8 January 2026.

INTRODUCTION

Review question / Objective The authors conducted a comprehensive meta-analysis of task-based functional magnetic resonance imaging studies examining motor observation and imitation in individuals with autism spectrum disorder.

Condition being studied Autism spectrum disorder is characterized by impairments in social communication and interaction, accompanied by restrictive and repetitive behavioral patterns. Emerging evidence suggests these deficits may stem from abnormalities within the mirror neuron system. This neural network exhibits activation not only during motor execution but also when observing identical movements performed by others. Through creating an internal simulation mechanism, the MNS facilitates mapping between self-generated and observed actions, thereby contributing critically to comprehension of intentional behavior, imitative learning, interpersonal engagement, and linguistic processing.

METHODS

Participant or population People with autism spectrum disorder.

Intervention None.

Comparator People with normal development.

Study designs to be included Case-control study and cohort study.

Eligibility criteria
Inclusion Criteria
Studies were included in the present meta-analysis if they met all of the following criteria:
1.Participants and groups
Studies recruited at least one group of individuals with autism spectrum disorder (ASD) and one group of typically developing (TD) participants as controls. Studies that included ASD participants together with other clinical groups were also included, provided that brain activation results for the ASD group were reported separately.
2.Imaging modality

Only studies employing functional magnetic resonance imaging (fMRI) were included, with a primary focus on task-related brain activation rather than brain structure.
3.Task paradigms
Studies involved action observation and/or action imitation tasks, targeting the role of the mirror neuron system in action processing in individuals with ASD.
4.Reported results
Eligible studies reported whole-brain activation results for the ASD and TD groups during action observation or imitation tasks, or explicitly reported between-group differences in brain activation. Activation foci had to be reported in standardized Talairach space or Montreal Neurological Institute (MNI) space.
5.Analytical approach
Studies were required to perform whole-brain analyses and report statistically significant activation effects.
6.Publication type and language
Only original, peer-reviewed journal articles written in English and published up to August 2015 were included. All studies were retrievable from the PubMed database.
Exclusion Criteria
Studies were excluded if they met any of the following conditions:
1.Non-fMRI studies
Studies using neuroimaging techniques other than fMRI, such as magnetoencephalography (MEG), electroencephalography (EEG), transcranial magnetic stimulation (TMS), eye-tracking, or other behavioral methods; structural MRI or diffusion tensor imaging (DTI) studies; positron emission tomography (PET) studies; as well as review articles and previous meta-analyses.
2.Ineligible participants
Studies involving non-human subjects, single-case designs, studies including only healthy participants, or studies including participants with disorders other than ASD.
3.Inappropriate task paradigms
Studies focusing on emotional processing (e.g., observation or imitation of emotional expressions), theory of mind tasks, other motor tasks (e.g., saccade generation), or resting-state fMRI were excluded.
4.Insufficient reporting of results
Studies that did not report brain activation results for action observation or imitation in ASD or TD groups, or failed to provide peak activation coordinates in Talairach or MNI space.
5.Restricted analysis scope
Studies reporting only region-of-interest (ROI) analyses without whole-brain results were excluded.

Information sources Databases were search (PubMed, The Cochrane Library, Web of Science, EBSCO (MEDLINE, APA PsycInfo Em, base ERIC), , Scopus, and ProQuest,) up until 5th January 2026. Reference lists of included studies will be scanned for further relevant literature.

Main outcome(s) Based on the perspective that autism spectrum is a disorder reflecting dysfunction of large-scale neuronal systems , we interpreted abnormally activated brain regions from our metaanalysis as dysfunctional nodes of largescale networks described in the current neuroscienceliterature.

Quality assessment / Risk of bias analysis The Fail-Safe N method was used to assess the impact of negative results and potential publication bias on current study findings.

Strategy of data synthesis Aggregate data will be used for quantitative coordinatebased ALE meta-analyses. Analyses will be performed in Brainmap GingerALE version 3.02 We will adhere to the ALE method (http://www.brainmap.org/ale/) of Eickhoff et al. [1, 2] . A p value will be calculated for each voxel based on probabilities of attaining an ALE value which differed from that of the corresponding voxel on a nulldistribution map, In all analyses, the threshold was set at $p < 0.001$ uncorrected with an extent-threshold of 120 mm3.
[1] Eickhoff, S.B., et al. Human Brain Mapping, 2009. 30(9): p. 2907-2926
[2] Eickhoff, S.B., et al. Neuroimage, 2012. 59(3): p.2349-2361.

Subgroup analysis To systematically investigate activation patterns in mirror neuron system–related brain regions during action processing in individuals with autism spectrum disorder, and to compare these patterns with those of typically developing individuals, four contrasts were defined based on the 13 studies included in the final sample, and separate activation likelihood estimation meta-analyses were conducted for each contrast.
The four contrasts were defined as follows:
Contrast 1: brain activation during action tasks in the ASD group;
Contrast 2: brain activation during action tasks in the TD group;
Contrast 3: greater activation in the ASD group than in the TD group (ASD > TD);
Contrast 4: greater activation in the TD group than in the ASD group (TD > ASD).

Sensitivity analysis The stepwise exclusion method was used to assess heterogeneity.

Language restriction Chinese; English.

Country(ies) involved China.

Keywords Autism spectrum disorders . The mirror neuronsystem . Action observation . Action imitation. Activationlikelihoodestimation. Functionalmagnetic resonanceimaging.

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