Evaluating the Impact of Attention Mechanisms on ResNet50V2 for MRI Tumor Classification: A Comparative Analysis

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Background

MRI-based tumor classification remains a challenging task due to variability in imaging and histopathological complexity.

Deep learning models, particularly convolutional neural networks (CNNs), have shown promise in improving classification accuracy.

Attention mechanisms such as Squeeze-and-Excitation (SE), Convolutional Block Attention Module (CBAM), Self-Attention (SA), and Attention Gate Network (AGNet) have been introduced to enhance feature selection.

This study aims to evaluate the impact of different attention mechanisms when integrated into a fine-tuned ResNet50V2 model for MRI tumor classification.

Methods

Model Architecture: ResNet50V2 was fine-tuned for MRI tumor classification with layers beyond *conv5_block1_preact_bn* set as trainable.
Attention Mechanisms: Four models were created, each integrating one of the following: SE, CBAM, SA, or AGNet.
Training Details:
Learning Rate: 0.0001 (Adam Optimizer)
Regularization: Dropout (0.5) applied in fully connected layers
Callbacks: Early stopping and learning rate reduction used to optimize performance
Evaluation Metrics: Accuracy, AUC, Precision, Recall, and F1 Score were used for model comparison.
Statistical Analysis: Two-proportion tests were performed to compare performance differences between models.

Discussion

Attention mechanisms enhanced MRI tumor classification by improving feature selection and reducing noise.

SE and CBAM mechanisms provided the most consistent improvements across all performance metrics.

Domain adaptation techniques, such as stain normalization and transfer learning, may further enhance model robustness.

Future research should explore multimodal approaches combining imaging and clinical data for more comprehensive diagnostic models.

Comparison	Test Statistic	P-Value
SE vs. CBAM	3.055	0.002*
SE vs. AGNet	2.775	0.006*
SE vs. SA	-0.425	1.329
SE vs. Base	-0.313	1.246
Meningioma (SE vs. SA)	2.823	0.005*
Meningioma (SE vs. Base)	2.485	0.013*
Pituitary (SE vs. CBAM)	2.038	0.042*
Pituitary (SE vs. AGNet)	2.039	0.041*

Results

These results indicate that SE-based models significantly outperform others in certain tumor classifications, particularly meningioma and pituitary tumor detection. However, no significant advantage was observed in glioma or no-tumor classification. These findings highlight the potential benefits of SE-based models while suggesting areas where future improvements in attention mechanisms could enhance classification accuracy.

(*$p < 0.05$ indicates statistical significance.)

Table 1: Statistical Comparisons of Model Performance