Detecting Brain Oxygenation Changes during Screaming: A Deep Learning Approach to MRI Analysis

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Abstract: - Screaming, often seen as a primal response to intense emotion, serves as a cathartic outlet that helps individuals release pent-up negative emotions, especially during moments of anxiety. Psychologists have long recognized the therapeutic value of this emotional release and have incorporated it into various treatment modalities. This study seeks to explore changes in brain oxygenation levels captured in MRI scans during the act of screaming and to determine whether these changes can be detected using deep learning models. MRI scans were performed on four subjects to assess brain oxygenation levels during screaming. Each subject underwent two MRI recordings: one before screaming and one during. The resulting images were analyzed using deep learning algorithms trained to identify differences between the two states. An AlexNet classifier was employed, and the results indicated significant changes in brain oxygenation during screaming, detectable with an accuracy of 89.92%. These findings highlight clear distinctions between brain activity in non-screaming and screaming states, demonstrating the potential of MRI-based analysis in detecting such physiological changes. The study concludes by discussing open questions, lessons learned, and the promising directions for future research. This innovative approach, even without relying on dedicated functional MRI (fMRI), underscores the value of using texture data extracted from standard MRI images to deepen our understanding of the brain's functional responses during intense emotional expression.

Key-Words: - catharsis, Magnetic Resonance Imaging, Convolutional neural networks

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1 Introduction

The act of screaming serves a cathartic purpose, enabling the release of negative emotions during times of nervousness. Expressing our emotional discharge through yelling can be effective even if we direct it towards individuals unrelated to those who have upset us. Additionally, screaming in solitude, away from the presence and observation of others, can also be beneficial. When we scream, the tone and volume of our voice differ from normal speech patterns. Human screams typically possess an acoustic intensity of approximately 80dB, the same as the one of a freight train, 100 ft away; sounds between 95 and 110 dB not only exceed tolerance (75 dB- just above the usual classroom shatter) and danger (85 dB- close to the noise of a boiler room) thresholds for audition, they come relatively close to the pain threshold of 120 dB (operating heavy equipment equivalent) [1], [2]. Extensive scientific studies conducted in the fields of psychology and neurology have examined the brain processes involved in screaming and how they aid in the release of negative emotions [3], [4], [5]. These studies have revealed that the stress-relieving effect of screaming stems from two key factors: heightened oxygenation in the brain regions responsible for regulating emotions and the activation of endorphin secretion. Nevertheless, the act of screaming can induce panic and generate intense negative emotions in those who hear it, which they themselves could alleviate by screaming as well.

Psychologists incorporate the therapeutic benefits of emotional release through screaming in various therapeutic approaches. The earliest form of scream therapy was pioneered by Dr. Arthur Janov in the 1970s. Dr. Janov proposed that yelling, under the guidance of a therapist, could effectively address mental issues rooted in childhood traumas [6]. He emphasized the significance of producing inarticulate sounds while screaming for the therapy to facilitate healing.

A good method to understand and manipulate the information that happens in the human brain when they scream is the use of an important and innovative medical tool. A proper approach in investigating the activity of the brain when yelling is the MRI. Magnetic Resonance Imaging (MRI) represents the" gold standard" method in brain assessment, excelling over other exploration methods due to the detail and clarity of the images provided. MRI allows us to deeply understand the structures of the brain and the processes taking place at their level [7]. MRI can provide high-resolution images of the brain structures, regardless of the viewing plane, allowing quantification of cerebral blood flow, metabolism, and neuronal connectivity.

This information is essential in understanding brain function [8]. Although functional MRI (fMRI) is most used to examine brain activity by detecting changes associated with blood flow, texture analysis in MRI can also provide valuable information about brain functioning. This is because the texture of an MRI image can reflect differences in the microscopic composition of brain tissue, which can be related to its functioning. Thus, even in the absence of a dedicated fMRI analysis, extracting texture data from MRI images can contribute to understanding the functional processes of the brain. This extends the applicability of MRI beyond strict anatomical evaluation of the brain, providing a more detailed and integrated view of its functioning.

The paper is structured as follows: Section 1 and Section 2 present the domain and the State of the Art in catharsis study. Section 3 and Section 4 present the study setup, data and the equipment used for data acquisition. Section 5 presents the methods used and the paper concludes with Section 6.

2 State of the art

Catharsis was, at the beginning, the process of releasing strong or pent-up emotions through art. Aristotle coined the term catharsis—which comes from the Greek kathairein meaning" to cleanse or purge"—to describe the release of emotional tension that he believed spectators experienced while watching dramatic tragedy. Today, catharsis can be obtained by experiencing art in any form, the only essential condition is that the one who experiences it identifies with the respective artistic elements (literary characters, characters in the play, etc.) The word" cathartic" is often used to refer to just about any experience that provides someone with a feeling of emotional release—even as the term also retains the original connotation of an experience in the arts [9]. Leaving aside the connotation of artistic experience, but keeping the connection with emotions, we will define catharsis from this psychological perspective. A description of catharsis is that it has two fundamental elements: the emotional aspect, characterized by intense emotional expression and processing, and the cognitive aspect, which involves gaining insight, new realizations, and a shift towards positive change [10]. These two components of catharsis- the discharge of emotions and bodily sensations, as well as cognitive awareness (or distancing) make the person experiencing catharsis to assume the role of an observer rather than an active participant, thereby maintaining a sense of control and heightened awareness of the immediate environment. During the latter stages of emotional and somatic release, detailed and vivid recollections of forgotten events and newfound insights often arise. However, there exists some confusion and misunderstanding surrounding the definition and interpretation of catharsis. While some researchers view catharsis as solely an emotional discharge, equating it with the act of expressing strong emotions, others emphasize its cognitive aspect and the emergence of new awareness following the reliving of past traumatic events [11].

Catharsis can be achieved through various techniques, including expressive arts therapy, psychodrama, primal therapy, and emotion-focused therapy. Not lastly, it can be achieved through sports practice. [12] provides a historical overview of catharsis and its use in cultural healing practices, literature, drama, religion, medicine, and psychology. Some contemporary modalities such as Psychodrama, Primal therapy, Emotion- Focused therapy, to mention a few, use catharsis as their core technique to achieve positive therapeutic change.

Modern research on the subject is limited and presents contradicting data about the effectiveness of cathartic techniques in psychotherapy practice.

[13] proposes a new theory of emotion that integrates social, psychological, and neurological components, building upon a socio-biological model of emotions by John Dewey and G. H. Mead. The climax idea, together with the concept of an optimal distance for experiencing emotions, explains phenomena and points towards the conditions under which bodily processes such as laughing and crying become cathartic. [14] collected data from interviews with 12

students who had been members of a university Taekwondo demonstration team (Taekwondo, a traditional Korean martial art, is a physical activity that allows people to experience catharsis, which is a mental health effect of sports). The phenomenological results were expressed as six themes:

- vicarious purgation of repressed emotions
- emotional catharsis through pity and fear
- catharsis from ethics
- catharsis through mimesis
- catharsis from vicarious satisfaction through teammates
- catharsis from being the object of envy.

Recent research suggests that human screams comprise an innate call type, yet the defining acoustic structure of screams has not been determined. [15] investigate the acoustic characteristics of human screams, finding that screams are positively correlated with high pitch and roughness, a wide fundamental frequency range and narrow bandwidth, and a third factor negatively correlated with roughness. We found mixed evidence on whether screaming is cathartic. [16] found that crying can be cathartic, but only in certain social contexts. More precisely, this study collected self-report data from over 5,000 students in 35 countries and found that contextual factors play a significant role in crying-related catharsis.

Factors that were positively related to catharsis were positive, supportive, social interactions in which the individual received comfort from others, a resolution or new understanding/perception of the issues that precipitated the crying episode, and positive reactions from intimate others such as comfort words and gestures, offering understanding, and friendly/warm reactions. Furthermore, factors that led to stopping crying and were linked to mental and physical improvements included regaining stability, improved circumstances, achieving objectives, a shift in the perception of the situation, and making peace with the event that triggered the crying. [17] suggests that the effects of crying depend on various factors, including how the effects are measured, the social environment, personality traits, and the affective state of the crier. [18] did not directly address screaming, but rather found that self-reported catharsis is associated with better health outcomes.

According to various theories, crying can result in emotional catharsis, which was defined here as the experience of relief or release of emotional tension as well as a decrease in felt distress or physiological arousal. Crying is commonly described as health-promoting in a cathartic way. It alleviates built-up emotional stress, whether this stress is in the form of psychological tension or in the form of toxic waste products resulting from the exposure to stressful conditions. Some studies have also suggested that crying can have physiological benefits, such as reducing stress hormones and increasing endorphins, which can improve mood and reduce pain. However, the relationship between crying and physical and emotional well- being is complex and contradictory research results have emerged from studies of this relationship. Overall, the relationship between screaming and catharsis is complex and depends on various factors [13, [16, [17], [18], [19], [20], [21], [22].

3 Setup of the study

The purpose of this study is to determine if there are any brain oxygenation level changes that appear while the subject is screaming that can be detectable in the MRI scans. This way, it can be proven that the MRI that is usually used for determining structural characteristics of the brain, can also be used for studying functional characteristics such as oxygenation level.

MRI scans were carried out as part of evaluation of brain oxygenation levels during screaming for 4 subjects. Two types of recordings were acquired from each one of them: pre-screaming MRI and screaming MRI. The screaming was induced by different emotional states such as anger, sadness, happiness, fear etc. The information relevant to the subjects enrolled in this study and the screaming type is summarized in Table 1. The first subject provided 4 different types of screams. The other 3 subjects provided only one type of scream, which was further categorized.

All participants in the study voluntarily consented to take part in each phase, having been made aware from the outset that the research would induce negative emotions and that expressing these emotions through screaming was encouraged. They were also informed that they could withdraw from the study at any time should they find the negative emotions too distressing or beyond their control to manage. Every participant who signed up completed all stages of the study. Initially, each volunteer underwent an interview with psychologists and was assessed to create a psychological profile using the State-Trait Anger Expression Inventory- 2nd Edition (STAXI-2) [23], [24], [25].

#subject	Age	Gender	Screaming type
#1	57	F	Contempt
#1	57	F	Fear

#1	57	F	Happiness
#2	44	F	Frustration
#3	18	F	Anger
#4	25	M	Sadness

Table 1. Summary of subjects' information

The primary phase of the experiment took place in a laboratory equipped with MRI technology. Participants were placed inside the MRI scanner and subjected to negative emotions triggered through audio instructions provided by a psychologist. They were then prompted to express their emotions by screaming. Throughout the experiment, various brain regions associated with emotions, vocalization, behavioural control, and concentration were actively monitored.

4 Equipment and Data Acquisition

The MRI scans were conducted using a 3.0 T Signa Pioneer MRI scanner by GE Healthcare (USA), as shown in Figure 1, with a 21-channel phased-array head coil for brain imaging. Standard MRI sequences were employed, including 3D T2 Sag FLAIR CUBE and 3D T1 Ax FSPGR (fast spoiled gradient echo). The duration of each sequence varied across subjects, depending on individual anatomical differences. Larger anatomies required more slices, which consequently increased scan time. A detailed breakdown of the average scan duration for each sequence is as follows:

- 3D T2 Sag FLAIR CUBE: 5 minutes and 8s.
- 3D T1 Ax FSPGR: 3 minutes and 27s.

Figure 1. The equipment used in this study - 3.0 T Signa Pioneer MRI scanner produced by GE Healthcare

For both sequences, a slice thickness of 1.2 mm was used, resulting in a volumetric resolution of 1x1x1.2 mm. No specific preparation was required for the MRI investigation at the cerebral level.

Initially, a thorough evaluation was conducted to confirm the absence of implants or metal prostheses that could contraindicate the procedure. Participants were then provided with detailed information about the MRI process. Before entering the machine, each subject changed into a disposable gown. Throughout the procedure, none of the participants exhibited anxiety or signs of claustrophobia. All individuals involved in the study were in apparent good health and not under the influence of any medication during the MRI investigation.

To focus on information pertinent to the study's objectives, sections containing anatomical elements outside the brain domain—such as facial bony structures and cranial integument—were manually excluded. Only segments derived from MRI acquisitions covering cerebral matter and designated regions of interest were retained. To preserve all relevant data, each image was saved and analyzed in DICOM format (Digital Imaging and Communications in Medicine). The scans were segmented, and 605 and 545 regions of interest were extracted and subsequently input into the classifier used in the study.

Figure 2 illustrates examples of MRI scans for two states (pre-scream and scream) from subjects #3 and #4. These images represent the 54th slice out of a total of 136 slices obtained using the FSPGR T1 sequence. A comparison of these images clearly shows that, although they correspond to the same slice and the same subject, they display different brain levels due to the subject's movements between scans.

During data acquisition, the following challenges and constraints were identified:

- A human subject cannot sustain continuous screaming for the entire duration of the scans, which last approximately 3 minutes for the transversal plane and 5 minutes for the sagittal plane. Therefore, it is inaccurate to claim that the entire scanning sequence represents a sustained state of screaming. Since the MRI system was not designed for such purposes, there are limited temporal markers to pinpoint specific slices corresponding to the screaming state within the complete dataset. To address this, we assumed that, while the subject was not screaming continuously during the scan, the emotion was induced and maintained throughout. Consequently, the entire sequence of slices was annotated as representing the screaming state.
- Scans taken during the screaming state exhibited acquisition noise caused by

movement and head vibration. When a person screams or produces loud vocalizations, the vibrations of their vocal cords generate sound waves, which can cause surrounding tissues and structures in the head, including the skull and brain, to vibrate. As shown in Figure 3, this noise was most pronounced in scans from the sagittal plane. For this study, we focused on transversal plane scans, as they were less affected by this noise, as demonstrated in Figure 2.

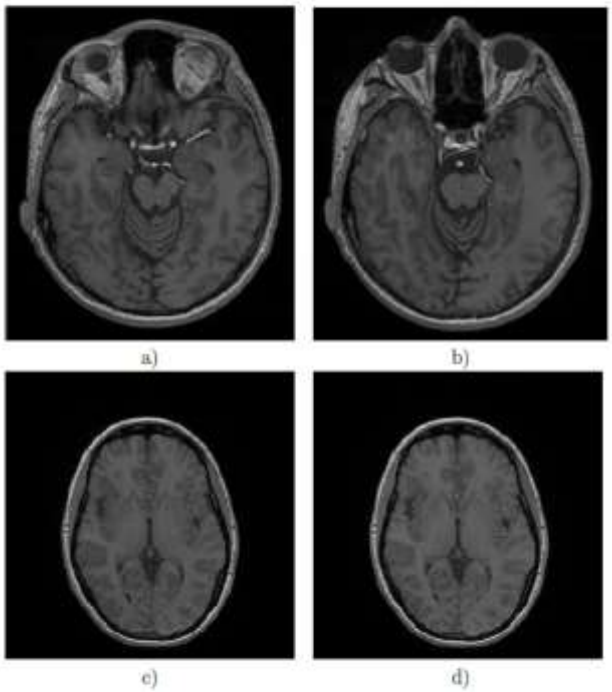

Figure 2. Examples of MRI 3D T1 Ax FSPGR sequence scan for the two subjects. The 54th slice for subject #4: a) pre-screaming state, b) screaming state and the 60th slice for subject #3: c) pre-screaming state, d) screaming state.

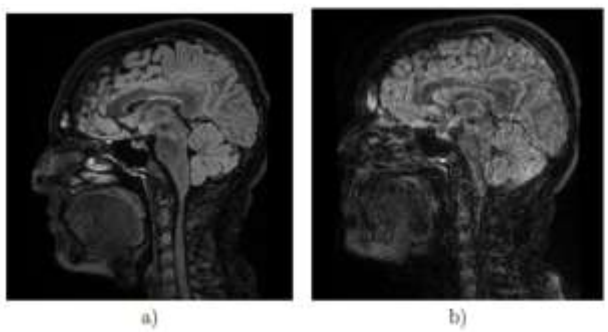

Figure 3. An example of MRI 3D T2 Sag FLAIR CUBE sequence scan for the same subject: a) pre-screaming, b) screaming. Comparing the two, the screaming scan is affected by noise introduced by the subject's movement and head vibration.

5 Methods and Experimental Results

Our method for determining whether an MRI scan can be classified as a screaming slice or a normal state slice is illustrated in Figure 4. The raw data was not preprocessed to preserve the integrity of the information captured by the MRI equipment. After training, the model was evaluated using a 10-fold cross-validation approach.

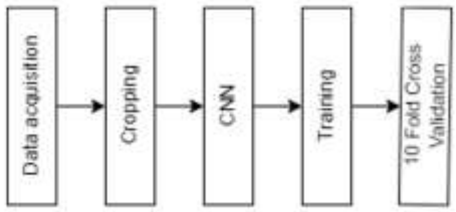

Figure 4: Overview of the proposed approach for determining screaming state from MRI scans.

The convolutional neural network (CNN) architecture used in this study is based on an adapted version of AlexNet [26]. AlexNet, one of the pioneering deep convolutional neural networks, was selected for its ability to learn and identify complex patterns and features in images.

The architecture begins with a convolutional layer containing 96 filters and an 11x11 kernel, followed by a MaxPooling layer and a BatchNormalization layer. Subsequent layers include a 256-filter convolutional layer with 5x5 kernels and a 1x1 stride, accompanied by another MaxPooling layer and BatchNormalization. This is followed by three consecutive convolutional layers with filter sizes of 384, 384, and 256, each using 3x3 kernels and ReLU activation. MaxPooling and BatchNormalization are applied sequentially after each of these layers.

The network then transitions to a flatten layer, converting the convolutional output into a one-dimensional vector. Two fully connected layers are included, each with 4096 neurons and ReLU activation, interspersed with dropout layers at a 0.4 rate to reduce overfitting, and BatchNormalization layers for enhanced stability. The final fully connected layer contains 1000 neurons with ReLU activation, also accompanied by dropout and BatchNormalization. The output layer consists of 2 neurons with sigmoid activation, designed for binary classification.

Throughout the design, BatchNormalization improves stability, while dropout mitigates overfitting. The model was trained over 30 epochs with a batch size of 32, using the Adam optimizer and a learning rate of 0.001.

The trained model was evaluated using the 10-fold cross-validation method. This approach divides the dataset into 10 equally sized folds, where nine folds are used for training the model and the remaining fold is reserved for testing. By rotating the test fold across iterations, this method provides a comprehensive assessment of the model's generalization capabilities.

Performance was evaluated using accuracy (Acc), sensitivity (Sen), and specificity (Spec), which are defined as follows:

$$Acc = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Sen = \frac{TP}{TP + FN}$$

$$Spec = \frac{TN}{TN + FP}$$

A True Positive (TP) refers to an outcome where the model correctly predicts the positive class; a True Negative (TN) indicates an outcome where the model correctly predicts the negative class; a False Positive (FP) occurs when the model incorrectly predicts the positive class; and a False Negative (FN) happens when the model incorrectly predicts the negative class.

Overall, we achieved an accuracy of 89.92%, a sensitivity of 91.20%, and a specificity of 93.58%. These results suggest that brain oxygenation changes occur during screaming and can be detected using MRI analysis. Cross-validation was employed to assess detection performance, ensuring that all subject data was combined before selecting the training and testing folds.

Figure 5 shows the training loss and accuracy curves for each fold. A significant reduction in training loss is observed in the early epochs, followed by variable oscillations with values below 0.2 until the final epochs, when it stabilizes. In contrast, there is a marked increase in training accuracy during the initial epochs.

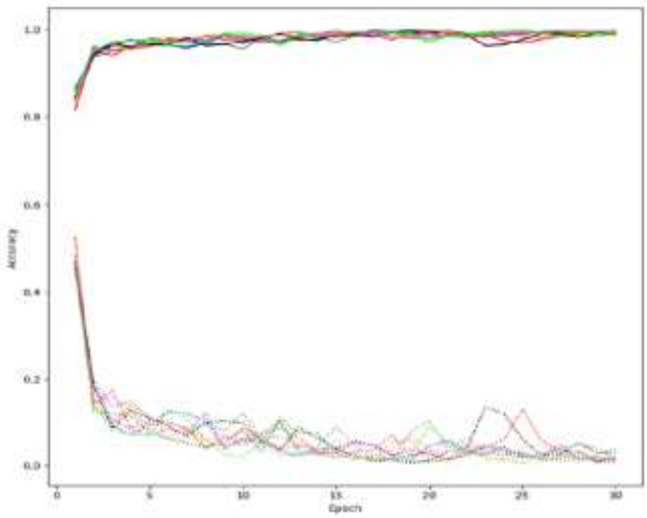

Figure 5. Training loss and accuracy curves for each fold during the 30 epochs of training.

6 Conclusions and Further Directions

In this study, we analyzed oxygenation changes in the brain during screaming without applying feature extraction, focusing on classifying MRI scans based on these changes. Our classifier achieved an accuracy of 89.92%, highlighting clear distinctions between MRI scans taken during normal, non-screaming conditions and those during instances of screaming. Cross-validation was used to evaluate the model; however, this represents a limitation, as it does not provide subject-specific assessments of the ability to detect patterns independent of individual differences.

Future directions for this research include using a leave-one-subject-out validation approach and exploring various deep neural network architectures. Having confirmed the presence of observable MRI changes during screaming, the next steps will involve identifying the anatomical regions most affected, with a particular focus on assessing the impact of screaming on oxygenation within specific brain areas.

Our study involved a small sample of four subjects, three of whom were women. This deliberate choice reflects the nature of the research challenge and the inherent variability in brain responses. The human brain is a highly complex and individualized organ, with each person responding uniquely to different stimuli. Developing a generalized, one-size-fits-all model for variations in brain oxygenation is inherently difficult.

While we acknowledge that a larger sample size might have provided a broader range of data, it would not necessarily have produced more accurate or generalizable results. In fact, expanding the sample size to include a more varied population could introduce confounding variables, potentially obscuring the specific patterns we aimed to investigate. By carefully selecting a small group with distinct characteristics, we were able to delve deeper into the unique cerebral oxygenation responses within this controlled context. Although our findings are not broadly generalizable, they offer valuable insights into the intricacies of brain oxygenation changes and lay the groundwork for future research.

During the study, it was noted that noise induced by subject movement and vibrations from screaming was more pronounced in images from the T2 sagittal sequence. This raises an important question: how can noise introduced during MRI scanning be addressed and minimized to objectively analyze sagittal sequence scans and assess brain oxygenation changes during shouting?

To tackle this issue, innovative approaches such as generating synthetic MRI images using data from multiple sensors could be explored. These methods employ data fusion techniques to integrate information from various sources, creating artificial MRI images. While synthetic images cannot entirely replace actual MRI scans, they can complement the analysis by providing additional insights and helping researchers differentiate between noise caused by movement and shouting and genuine changes in brain oxygenation.

Further investigations related to this topic and aligned with the current findings could include: exploring the long-term effects of screaming on emotional well-being (examining the impact of regular screaming as a method of emotional release over time), evaluating the effectiveness of different emotional release techniques (such as comparing the benefits of screaming to other methods like physical exercise, journaling, or meditation), and examining the effects of screaming on cognitive performance (assessing how it influences cognitive functions such as attention, memory, and decision-making).

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