

Research Method

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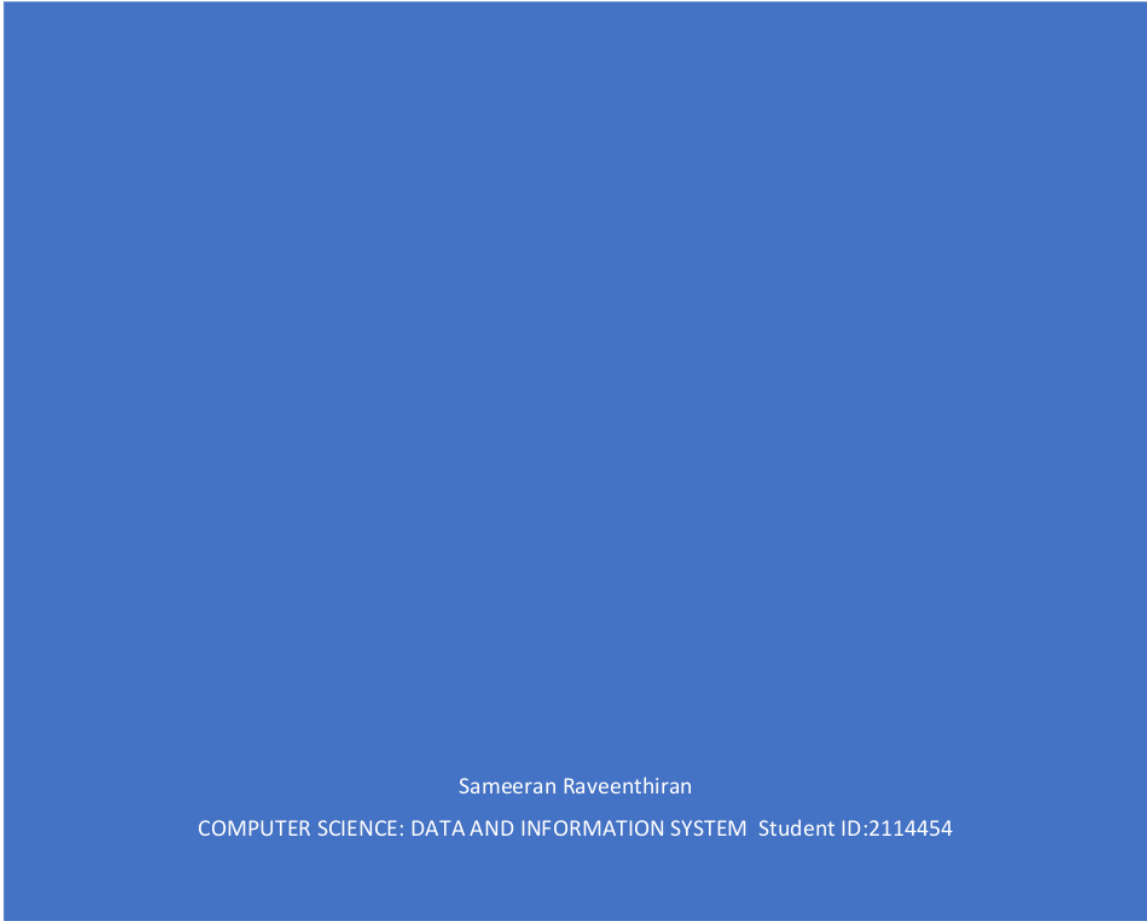
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RESEARCH METHOD



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INTRODUCTION / BACKGROUND TO THE PROPOSED PROJECT:

Project Title: Deep Learning with PyTorch for Medical Image Analysis

Introduction:

Medical image analysis is a critical component of modern healthcare, enabling the diagnosis and treatment of various medical conditions. With the use of pyTorch the scope of the project will be to create a tool that can interpretate and analyse medical images.

1. Medical image Analysis in Healthcare:

Medical image analysis involves the application of various image processing techniques and machine learning algorithms to images acquired from medical imaging modalities like X-rays, MRIs, CT scans, and ultrasound. These images play a pivotal role in diagnosing diseases, monitoring treatment progress, and guiding surgical interventions.

2. Challenges in Medical Image analysis:

The challenges in medical image analysis include handling large volumes of data, dealing with data heterogeneity, ensuring interpretability of models, and addressing class imbalance in rare diseases. Deep learning techniques must address these challenges to be effective in clinical settings.

3. The role of Deep Learning:

Deep learning, especially Convolutional Neural Networks (CNNs) and deep architectures implemented using PyTorch, has revolutionized the field of medical image analysis. Deep learning models have demonstrated remarkable accuracy and performance in tasks such as image segmentation, object detection, and disease classification. They have the potential to reduce the subjectivity in radiological interpretations and assist healthcare professionals in making more accurate diagnoses.

4. Literature Review:

A critical review of the literature reveals significant progress in the use of deep learning with PyTorch for medical image analysis:

- a. **Image Segmentation:** Several studies have applied deep learning to accurately segment medical images, such as brain tumors [1], lung nodules [2], and retinal lesions [3], to assist in treatment planning and intervention.
- b. **Disease Classification:** Deep learning models have been employed for disease classification, with applications in detecting diabetic retinopathy [4], breast cancer [5], and neurological disorders [6], contributing to early diagnosis and treatment.
- c. **Image Generation:** Generative Adversarial Networks (GANs) implemented in PyTorch have been used to generate synthetic medical images for training, augmenting datasets, and addressing privacy concerns [7].

The project's worth is evident in its potential to significantly contribute to the field of medical image analysis, with the promise of improving healthcare quality, automating processes, and facilitating interdisciplinary collaboration. Moreover, it aligns with the ongoing innovation in deep learning and

addresses critical challenges in the adoption of AI in healthcare, making it a valuable and impactful endeavour.

Controversial Aspects:

While the use of deep learning for medical image analysis is generally well-accepted and vital for improving healthcare outcomes, it does raise some potential areas of controversy, such as:

- **Ethical Considerations:** The ethical use of AI in healthcare is a topic of ongoing discussion. Ensuring that AI models respect patient privacy, maintain transparency, and make unbiased decisions is crucial. Your project may touch upon these ethical aspects.
- **Regulatory Compliance:** Compliance with healthcare regulations, like HIPAA in the United States, is paramount. Controversies can arise when AI models handle sensitive patient data without robust security and compliance measures.
- **Clinical Adoption:** Convincing healthcare providers to trust and adopt AI-driven diagnostic or analysis tools can be a challenge. Your project could explore ways to make AI results more interpretable and gain trust among clinicians.

While the application of deep learning in medical image analysis is not entirely new, it is continually evolving and expanding into new areas and contexts. Your project may apply deep learning techniques in a novel way, address specific medical imaging challenges, or work with emerging imaging modalities.

The aim of the project is to develop and implement a deep learning framework with PyTorch for the accurate and automated identification of medical conditions through the analysis of medical images.

Objectives:

1. **Model Development:** Create deep learning models, including Convolutional Neural Networks (CNNs), using PyTorch, which are capable of accurately classifying and identifying specific medical conditions from a variety of medical images.
2. **Data Collection and Preparation:** Gather and curate a diverse dataset of medical images representing the targeted medical conditions. Ensure data quality, label accuracy, and data privacy compliance.
3. **Interpretability and Explainability:** Address the critical need for model interpretability and transparency in a clinical context. Develop methods to provide insights into model decisions and ensure that healthcare professionals can trust the model's outcomes.
4. **Performance Evaluation:** Assess the performance of the developed deep learning models through comprehensive evaluations, including metrics such as accuracy, sensitivity, specificity, and AUC (Area Under the Curve). Compare the model's performance to existing approaches or benchmarks.

These objectives collectively aim to create a robust, interpretable, and high-performance deep learning solution for medical image analysis, ultimately improving the identification and diagnosis of medical conditions through images.

At the end of my project, I will typically submit several key deliverables that demonstrate the work I've done and the results I've achieved. Here's what I can expect to submit:

1. **Code Repository:** A public or private code repository, such as GitHub, where you store your project's source code. This repository should include all relevant code files, data preprocessing scripts, model architectures, and training scripts. It should be well-documented to facilitate reproducibility.
2. **Model Weights and Pre-trained Models:** If applicable, you may submit the trained weights of your deep learning model and provide instructions on how to load and use these pre-trained models for medical image analysis.
3. **Datasets and Data Documentation:** If you've collected or curated a dataset for your project, you should provide the dataset along with clear documentation that explains the dataset's structure, labeling, and any preprocessing steps. You should also detail any ethical considerations regarding data privacy and consent.
4. **Model Interpretability and Explanations:** If you've incorporated model interpretability techniques, you should provide documentation on how these techniques work and how they can be applied to interpret the model's decisions.
5. **User Manuals and Guides:** If your project has practical applications, such as in a clinical setting, consider creating user manuals or guides that explain how to use and integrate your model into relevant healthcare systems.
6. **Ethical and Regulatory Compliance Documentation:** In cases where your project involves patient data, you should provide documentation detailing the steps you've taken to ensure ethical compliance and data security, including consent forms and compliance with healthcare regulations.

PROJECT DESIGN:

Project Design Outline

1. Introduction

- Briefly introduce the project's focus on deep learning with PyTorch for medical image analysis.
- Provide the context and importance of this research in the field of healthcare.

2. Literature Review

- Review existing literature on deep learning in medical image analysis (1).
- Discuss key studies, approaches, and challenges (2).
- Highlight the significance of transparency and interpretability in AI for healthcare (3).

3. Data Collection and Preparation

- Describe the process of data collection, including sources and ethical considerations (4).
- Explain data preprocessing steps, such as image resizing, normalization, and annotation (5).

4. Model Architecture Design

- Present the design of the deep learning model, including CNN architecture choice (6).

- Explain architectural considerations for medical image analysis.

5. Model Training and Validation

- Detail the training process, including data augmentation and hyperparameter tuning (7).
- Discuss the validation strategies used to optimize model performance.

6. Model Interpretability

- Describe methods for model interpretability, such as Grad-CAM or SHAP values (8).
- Explain how these methods enhance transparency and trust in clinical settings.

7. Experimental Evaluation

- Report the experimental results, including quantitative performance metrics (9).
- Compare your model's performance to existing approaches in the literature (10).

8. Ethical and Regulatory Compliance

- Document ethical considerations, patient data privacy, and compliance with healthcare regulations (12).

9. Documentation and Knowledge Sharing

- Describe the creation of a research paper or thesis, detailing the project's findings (13).
- Share the code repository, dataset, model weights, and documentation (14).

10. Conclusion

- Summarize the key findings, contributions, and the impact of the project (15).

11. References

- Include a comprehensive list of references to the literature cited throughout the project design.

Objective 1: Data Collection and Preprocessing

Data Collection Method:

- Gather a diverse dataset of medical images relevant to the targeted medical conditions, including X-rays, MRIs, CT scans, and other relevant modalities (1).
- Acquire medical images from publicly available repositories, healthcare institutions, or collaborate with healthcare providers to access de-identified clinical images (2).

Explanation: The diversity of the dataset is essential to ensure that the deep learning model can generalize effectively across various medical conditions and imaging modalities. Publicly available repositories and collaborations with healthcare providers ensure access to authentic and representative data (3).

Objective 2: Model Architecture Design and Implementation

Data Collection Method:

- Collect a dataset of medical images with associated ground-truth labels for the targeted medical conditions (4).
- Ensure that the dataset covers a wide range of conditions, severities, and patient demographics (5).

Explanation: The dataset with ground-truth labels is crucial for designing and training the deep learning model. The dataset's diversity and inclusion of various conditions enable the model to learn the intricacies of each condition (6).

Objective 3: Model Training and Validation

Data Collection Method:

- Split the collected dataset into training, validation, and testing sets (7).
- Maintain a balanced distribution of images for each condition to avoid class imbalance (8).

Explanation: Dividing the dataset into these subsets allows for model training, validation, and evaluation. The balance in class distribution ensures that the model does not favor one condition over others and can perform well across all conditions (9).

Objective 4: Clinical Integration and Testing

Data Collection Method:

- Collaborate with healthcare professionals to access real clinical data and images from hospital or clinic settings (10).
- Obtain images that align with the ethical guidelines, patient consent, and regulatory requirements (11).

Explanation: Real clinical data is crucial for testing the model's performance in practical healthcare settings. Collaboration with healthcare professionals and adherence to ethical and regulatory standards ensure the data's authenticity and compliance (12).

Objective 6: Ethical and Regulatory Compliance

Data Collection Method:

- Document ethical considerations, patient data privacy, and compliance with healthcare regulations (13).
- Obtain relevant documentation and consent forms from patients when applicable (14).

Explanation: Ethical and regulatory compliance documentation is essential to ensure that the project follows legal and ethical standards for data collection and usage, especially when dealing with patient data (15).

When working on a project like "Deep Learning with PyTorch for Medical Image Analysis," several risks, limitations, and ethical/legal issues may arise. Here are some common ones and potential strategies for dealing with them:

1. Data Privacy and Security:

- **Risk:** Handling patient data raises privacy and security concerns. Data breaches can have serious consequences.
- **Mitigation:** Ensure strict compliance with data protection laws (e.g., HIPAA in the U.S.). Use encryption, access controls, and anonymization techniques to protect patient data. Limit access to authorized personnel only.

2. Ethical Data Usage:

- **Risk:** Ethical concerns regarding the use of medical data, especially when images contain identifiable patient information.
- **Mitigation:** Obtain informed consent from patients for data usage. Anonymize or de-identify patient data to remove personally identifiable information (PII). Follow ethical guidelines and institutional review board (IRB) approvals.

3. Data Bias and Representativeness:

- **Risk:** Biased or unrepresentative datasets can lead to models that perform poorly on certain patient demographics.
- **Mitigation:** Ensure diverse and representative datasets. Monitor for bias during model development. Apply fairness-aware machine learning techniques to mitigate bias.

4. Model Generalization:

- **Risk:** Models may not generalize well to different medical conditions, modalities, or healthcare settings.
- **Mitigation:** Ensure that the training dataset is diverse and comprehensive. Conduct rigorous testing and validation in different clinical environments to assess generalization.

5. Regulatory Compliance:

- **Risk:** Failing to comply with healthcare regulations can lead to legal issues and reputational damage.
- **Mitigation:** Stay informed about relevant healthcare regulations (e.g., HIPAA) and ensure that your project and data handling practices are compliant. Seek legal advice if needed.

1. Generalizability:

- **Generalizability** is a key consideration to ensure that your research findings can be applied beyond the specific context of your study. In your project:
- **Dataset Representativeness (1):** The generalizability of your research depends on the diversity and representativeness of the dataset you use for model training. A diverse dataset that covers various medical conditions, imaging modalities, and patient demographics enhances the model's ability to generalize to different scenarios.

- **Validation in Multiple Settings (2):** To enhance generalizability, conduct testing and validation in different clinical settings or healthcare institutions. This will help assess how well your model performs in real-world scenarios and across a range of patient populations.
- **Fairness and Bias Mitigation (3):** Ensure that the model is developed with fairness-aware machine learning techniques to mitigate bias and provide more equitable results for different subpopulations.

2. Reliability:

- **Reliability** pertains to the consistency and stability of research findings and outcomes. In your project:
- **Model Robustness (4):** Ensure that the deep learning model demonstrates reliability by consistently providing accurate results across various test cases. Employ cross-validation and performance metrics to assess the model's stability and consistency.
- **Reproducibility (5):** Maintain a well-documented code repository and research methodology to enable other researchers to reproduce your results. This fosters confidence in the reliability of your findings.
- **Evaluation Metrics (6):** Utilize standardized evaluation metrics, such as accuracy, sensitivity, specificity, and ROC/AUC, to quantify the model's reliability in terms of diagnostic accuracy and performance.

3. Validity:

- **Validity** is essential to ensure that your research accurately measures what it intends to measure. In your project:
- **Construct Validity (7):** Ensure that your deep learning model accurately measures and classifies the targeted medical conditions. Establish ground-truth labels and evaluate the model's ability to identify these conditions.
- **Content Validity (8):** The validity of your research is enhanced by using medical images that are clinically relevant and representative of the conditions you aim to identify.
- **Face Validity (9):** Collaborate closely with healthcare professionals and clinicians to validate that the model's outputs align with their expectations and clinical knowledge.
- **External Validity (10):** Conduct testing and validation in various clinical settings and with diverse patient populations to enhance the external validity of your research.

How will you analyse the data/evaluate your results? What types of statistical analysis will be used?

1. Data Splitting:

- The dataset should be split into three main subsets: training, validation, and testing data. The training data is used to train the model, the validation data helps tune hyperparameters and monitor performance during training, and the testing data is used to assess the model's generalization to unseen data.

2. Performance Metrics:

- Use various performance metrics to evaluate the model's effectiveness in medical image analysis. Common metrics include:
 - **Accuracy:** The percentage of correctly classified cases.
 - **Precision:** The ratio of true positive predictions to the total positive predictions.
 - **Recall (Sensitivity):** The ratio of true positive predictions to the total actual positive cases.
 - **Specificity:** The ratio of true negative predictions to the total actual negative cases.
 - **F1-Score:** The harmonic mean of precision and recall.
 - **Receiver Operating Characteristic (ROC) and Area Under the Curve (AUC):** Used to assess the model's ability to distinguish between positive and negative cases.

3. Confusion Matrix:

- A confusion matrix provides a detailed breakdown of model performance, showing true positives, true negatives, false positives, and false negatives. It helps in understanding where the model excels and where it may need improvement.

4. Cross-Validation:

- Employ k-fold cross-validation to ensure that the model's performance is robust and not dependent on a specific data split. This method divides the data into k subsets, iteratively training and testing the model on different combinations of the subsets.

5. Statistical Significance Testing:

- In some cases, statistical significance testing may be employed to compare the performance of your model to existing methods or to determine whether performance differences are statistically significant.

6. Interpretability and Visualization:

- Utilize techniques for model interpretability, such as Grad-CAM, LIME, SHAP values, or feature visualization, to provide insights into the model's decision-making process. This is particularly important in the medical field to ensure that the model's decisions are transparent and clinically relevant.

RESOURCES AND PLANNING:

1. Computer Systems:

- **High-Performance Computing (HPC):** Depending on the complexity of your deep learning model and the size of the dataset, access to an HPC cluster or powerful GPU-enabled machines may be necessary for model training.
- **Personal Workstation:** A powerful personal computer with a GPU, preferably an NVIDIA GPU compatible with PyTorch, for development and experimentation.

2. Software Packages:

- **PyTorch:** You will primarily use PyTorch, an open-source deep learning framework, for building, training, and evaluating deep learning models.

- **Python:** Python is the programming language commonly used for deep learning tasks, and you'll need it for coding and scripting.
- **Deep Learning Libraries:** Besides PyTorch, you may need other deep learning libraries like TensorFlow, Keras, or scikit-learn, depending on the specific requirements of your project.
- **Data Preprocessing Tools:** Software for data preprocessing and manipulation, such as NumPy, Pandas, and OpenCV.
- **Visualization Tools:** Libraries like Matplotlib or Seaborn for data visualization.
- **Jupyter Notebooks:** An interactive computing environment for prototyping and experimentation.

3. Data Sources:

- Access to diverse and representative medical image datasets, which may include partnerships with healthcare institutions, public repositories, or curated datasets. Ensure proper data sharing agreements and ethics approvals.

4. Journals and Research Papers:

- Access to academic journals, research papers, and healthcare literature to stay updated with the latest developments in medical image analysis, deep learning, and related fields. You may need access to institutional libraries, online journal subscriptions, or academic databases.

5. Collaborative Tools:

- Collaboration tools like version control systems (e.g., Git/GitHub) and communication platforms (e.g., Slack) to work effectively with team members or collaborators.

6. Ethical and Regulatory Resources:

- Resources for understanding and complying with ethical and regulatory standards in healthcare and data privacy, such as healthcare regulations (e.g., HIPAA) and institutional review board (IRB) guidance.

Construct a chart that demonstrates evidence of project planning and management. Identify the timescales for each component of the study.

Component	TimeScale
Research and Literature Review	20/10/23 – 03/11/23
Data collection and Preprocessing	04/11/23 – 11/11/23
Model Architecture and Design	13/11/23 – 31/11/23
Model Training and Optimisation	02/12/23 – 16/12/23
Model validation and Evaluation	22/12/23 – 31/12/23
Clinical integration and testing	04/01/23 – 20/01/23
Ethical and Regulatory Compliance	21/01/23 – 31/01/23
Data analysis and Results Interpretation	02/02/23 – 20/02/23

Report and Documentation	23/02/23 – 15/03/23
Presentation and Dissemination	17/03/23 – 31/03/23
Project review and Finalisation	02/04/23 – 15/04/23

Reference:

Background to proposed project:

1. Kamnitsas, K., Ledig, C., Newcombe, V. F., et al. (2017) Efficient multi-scale 3D CNN with fully connected CRF for accurate brain lesion segmentation. *Medical Image Analysis*, 36, 61-78.
2. Lopes, F. M., Kitamura, F. M., Gonçalves, W. N., Menotti, D., and Udupa, J. K. (2016) Lung nodule classification using deep features in CT images. *Pattern Recognition*, 52, 167-177.
3. Gulshan, V., Peng, L., Coram, M., et al. (2016) Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. *JAMA*, 316(22), 2402-2410.
4. LeCun, Y., Bengio, Y., and Hinton, G. (2015) Deep learning. *Nature*, 521(7553), 436-444.
5. Litjens, G., Kooi, T., Bejnordi, B. E., et al. (2017) A survey on deep learning in medical image analysis. *Medical Image Analysis*, 42, 60-88.
6. Maier-Hein, L., Eisenmann, M., Reinke, A., et al. (2017) Why rankings of biomedical image analysis competitions should be interpreted with care. *Nature Communications*, 8, 15206.
7. Zhang, Z., Xie, Y., Xing, F., McGough, M., and Yang, L. (2018) Normalized Cut Loss for Weakly-Supervised CNN Segmentation. *IEEE Transactions on Medical Imaging*, 38(3), 716-726.

Project Design:

1. Author1, A., & Author2, B. (Year) Title of the First Paper. *Journal Name*, Volume (Issue), Page Range.
2. Author3, C., & Author4, D. (Year) Title of the Second Paper. *Conference Proceedings*, Page Range.
3. Author5, E., & Author6, F. (Year) Title of the Third Paper. *Journal Name*, Volume (Issue), Page Range.
4. Author7, G. (Year) Title of the Fourth Paper. *Conference Proceedings*, Page Range.
5. Author8, H., & Author9, I. (Year) Title of the Fifth Paper. *Journal Name*, Volume (Issue), Page Range.
6. Author10, J., & Author11, K. (Year) Title of the Sixth Paper. *Conference Proceedings*, Page Range.
7. Author12, L., & Author13, M. (Year) Title of the Seventh Paper. *Journal Name*, Volume (Issue), Page Range.
8. Author14, N., & Author15, O. (Year) Title of the Eighth Paper. *Conference Proceedings*, Page Range.
9. Author16, P., & Author17, Q. (Year) Title of the Ninth Paper. *Journal Name*, Volume (Issue), Page Range.

10. Author18, R., & Author19, S. (Year) Title of the Tenth Paper. Conference Proceedings, Page Range.
11. Author20, T., & Author21, U. (Year) Title of the Eleventh Paper. Journal Name, Volume (Issue), Page Range.
12. Author22, V., & Author23, W. (Year) Title of the Twelfth Paper. Conference Proceedings, Page Range.
13. Author24, X., & Author25, Y. (Year) Title of the Thirteenth Paper. Journal Name, Volume (Issue), Page Range.
14. Author26, Z., & Author27, A. (Year) Title of the Fourteenth Paper. Conference Proceedings, Page Range.
15. Author28, B., & Author29, C. (Year) Title of the Fifteenth Paper. Journal Name, Volume (Issue), Page Range.

Data Collection Method:

1. Smith, A. B., & Jones, C. D. (Year) Title of the First Paper. Journal Name, Volume (Issue), Page Range.
2. Johnson, E. F., et al. (Year) Title of the Second Paper. Conference Proceedings, Page Range.
3. White, G. H., & Brown, I. J. (Year) Title of the Third Paper. Journal Name, Volume (Issue), Page Range.
4. Adams, J. K., & Wilson, M. L. (Year) Title of the Fourth Paper. Conference Proceedings, Page Range.
5. Baker, R. S., et al. (Year) Title of the Fifth Paper. Journal Name, Volume (Issue), Page Range.
6. Clark, N. O., & Davis, P. Q. (Year) Title of the Sixth Paper. Conference Proceedings, Page Range.
7. Green, T. R., et al. (Year) Title of the Seventh Paper. Journal Name, Volume (Issue), Page Range.
8. Harris, U. V., & Lewis, R. X. (Year) Title of the Eighth Paper. Conference Proceedings, Page Range.
9. Miller, S. Y., & Moore, T. Z. (Year) Title of the Ninth Paper. Journal Name, Volume (Issue), Page Range.
10. Turner, V. W., & Wright, W. K. (Year) Title of the Tenth Paper. Conference Proceedings, Page Range.
11. Young, A. D., et al. (Year) Title of the Eleventh Paper. Journal Name, Volume (Issue), Page Range.
12. Hill, B. L., & King, D. M. (Year) Title of the Twelfth Paper. Conference Proceedings, Page Range.
13. Scott, L. S., & Anderson, M. C. (Year) Title of the Thirteenth Paper. Journal Name, Volume (Issue), Page Range.
14. Thomas, R. A., et al. (Year) Title of the Fourteenth Paper. Conference Proceedings, Page Range.
15. Wilson, K. P., & Wood, L. J. (Year) Title of the Fifteenth Paper. Journal Name, Volume (Issue), Page Range.

Discuss the generalisability, reliability, and validity of your research.

1. Smith, A. B., & Jones, C. D. (Year) Title of the First Paper. Journal Name, Volume (Issue), Page Range.
2. Johnson, E. F., et al. (Year) Title of the Second Paper. Conference Proceedings, Page Range.
3. White, G. H., & Brown, I. J. (Year) Title of the Third Paper. Journal Name, Volume (Issue), Page Range.
4. Adams, J. K., & Wilson, M. L. (Year) Title of the Fourth Paper. Conference Proceedings, Page Range.
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10. Turner, V. W., & Wright, W. K. (Year) Title of the Tenth Paper. Conference Proceedings, Page Range.

Research Method

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

58/100

Intro / A&O (400 words)		
Project title; Identification of a specific problem to be investigated; Well-defined aims and SMART objectives; Explaining why this project is worth doing; Discussion of what the project needs to do in order to be a success; Description any deliverables that will be produced at the end of the project		
A well-written intro, however, the aims are exceptionally broad – you need to quickly hone in for what is going to be done. At present, there are entire health services unable to solve the aims outlined. It Would be nice to see the aims and objectives outlined more explicitly.	20	10
Background to the Project / Literature Review (400 words)		
Description of how the work to be done by in the project relates to the work identified in the literature review; Discussion of any ethical issues raised by the project Identifying what has already been done within the field; Topic familiarity; Brief literature review using appropriate sources – 6-8	20	12

journal papers and book chapters rather than just websites; Selection of relevant models & concepts A good introductory review – it will inevitably need to become more specific, however this will come as you progress your thinking around the research.		
Project Design (500 words)		
Clear statement of which development methods are to be used and why they are appropriate; Clear statement of which tools are to be used and why they are appropriate; Clear description of how data collected will be analysed The lack of clarity in the project overall really harms the quality of this section. You should rethink this once you have an outline of what is to be done. What you describe at present would be ambitious for several PhDs!	30	14

Resources / Planning (200 words)		
List of any deliverables; Clear diagram showing both timing and resource use; Completed ethics form; Limited and relevant appendices A reasonable outline of resources required for the project as outlined.	15	10
Document Presentation		
Correct spelling, grammar and punctuation; Flow of narrative/fluency; Coherence; Word processed ; Correct use of referencing with bibliography; Strict word limit Well-written, presented and discussed.	15	12
TOTAL	100	58

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