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Noise And Cognitive Performance In Developing Brain Using Functional MRI: A scoping review protocol

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Abstract
This protocol aims to guide the process to conduct a scoping review on noise and cognitive performance in developing the brain using functional MRI. This review benefits future research by providing a clear mapping of evidence. This protocol adhered to Arksey and O'Malley's scoping review methodological framework. A Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) extension for Scoping Reviews (PRISMA-ScR) was implemented to report the full scoping review. This protocol facilitated a well-structured mapping of evidence. The findings from scoping review will be made public through conferences and journal publications.

Keywords: Scoping review protocol; Adolescents' cognitive performance; Noise; functional MRI.

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1.0 Introduction

Noise has been described as random fluctuations or unwanted sound that is annoying and disturbing in nature. Interestingly, emerging scientific evidence suggested that background noise in specific conditions has beneficial roles in cognitive performance, which is strongly associated with the quality of life (QOL) of a person, such as academic performance. Functional magnetic resonance imaging (fMRI) provides insight into understanding brain function and cognitive performance. A scoping review underpinning the previous findings on developing brain, functional MRI, and noise aims to report the types of evidence and examine the emerging studies that would benefit future research design. A protocol is a pre-planning strategy that provides conceptual clarity in identifying, defining, extracting, and summarising the relevant studies for evidence mapping. In this paper, a scoping review protocol is prepared as a guide to conduct the full scoping review.

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2.0 Literature Review

2.1 Human Developing Brain

Adolescence is a developing phase in humans that is robust and complex. This phase occurs between late childhood and early adulthood between ages 10 to 24 years (Sawyer et al., 2018). Most psychosocial and physiological aspects such as emotion, self-independence, social skills, and mental health are grounded at this phase before reaching maturity during adulthood. In addition, cognition development and brain maturity have undergone significant changes, especially in the prefrontal cortex area (Blakemore & Choudhury, 2006), the brain core for executive function. The executive function involved the decision-making process, working memory, attention, and cognitive abilities. Working memory consists of the ability to juggle information in daily life (Alloway & Gathercole, 2005), such as reading, writing, listening, comprehension, and logical reasoning. Cognitive performance is related to the working memory of the brain. The key function of working memory is the ability to retain information, encode the information and successfully retrieve the information successfully in a short duration of time (Othman et al., 2020). The working memory has been investigated using various imaging modalities, one of which is functional MRI.

2.2 Functional Magnetic Resonance Imaging

Functional MRI is an exclusive, non-invasive neuroimaging tool that provides a safe, zero-radiation, and sophisticated enough to detect brain activity patterns. The brain activity patterns are observed through an effect known as Blood Oxygenation Level Dependent (BOLD) contrast (Ogawa et al., 1990). BOLD is an endogenous MRI contrast activated when T2*-weighted gradient echo induced changes of the deoxyhemoglobin-related susceptibility effect. This individual magnetic susceptibility effect has altered the microscopic magnetic field gradients inside and surrounding the capillaries, veins, and venules. This contrast effect in functional MRI reflects the physiological variables driven by the combination of cerebral blood volume (CBV), cerebral blood flow (CBF)and the cerebral metabolic rate of oxygen (CMRO2) (Ogawa et al., 1990). Hence, as the blood flow increases due to brain activation, the oxygen metabolic rate decline and produce high signal intensity on the functional MR images. The activation course of the brain is also promoted by neural firing and axonal spiking.

The neural firing is supported by different chemical components, consisting of metabolites such as Gamma-AminoButyric Acid (GABA), hormones such as serotonin, dopamine, mineral, and ion channel, which are responsible for the action potential to occur for spiking and firing. Therefore, for the brain activation to become more pronounced in functional MR imaging, the design of experimental paradigm, experimental protocol, timing also stimulus delivery incorporated is essential. In functional MR imaging, the stimulus is a presentation of information given to the participant/subject in auditory or non-auditory/visual enveloped with the experimental task/design. Other than that, specific functional MRI experiments involved task-based and without any task to measure the brain activity. A well-design experimental task can assess the effects of noise on cognitive flexibility and capacity. The functional MRI images provide data on the brain activation area.The activation area relating to working memory includes the prefrontal cortex, Broadman's area, superior frontal gyrus and middle frontal gyrus. The prefrontal cortex is the last part of the brain to reach maturation (Arain et al., 2013). The developing brain undergoes gradual cell reorganisation until maturity is reached (Konrad et al., 2013). The well-being of the adolescent life relies on experience, exposure, and adaption with their surroundings and in this context is the noise.

2.3 Noise

Noise is often regarded as pervasive and poses adverse health effects such as increased heartbeats, taxing the mental workload, reduced cognitive performance (Basner et al., 2014) and sleep deprivation in young adults (Chraif, 2012). The effect of noise varies depending on the type of noise, for instance, occupational noise, exposure noise, or environmental noise (Basner et al., 2014). Noise can be further classified in terms of noise delivery, either intermittent noise continuous noise (Zhou et al., 2022), speech in noise (Manan et al., 2014), the intensity level of noise (Othman et al., 2020) and noise colours (Angwin et al., 2018). Several studies reported the adverse effects of noise on cognitive function (Chere & Kirkham, 2021). Other studies reported that noise improves learning performance in various population groups. For example, in children 10-16 years old (Söderlund et al., 2021), young adult group between age 18-24 years old (Othman et al., 2019) adult group from age 20 to 29 years old (Manan et al., 2012) and in older adult group 41-65 years old (Manan et al., 2014). They reported that this was mediated by the phenomenon known as stochastic resonance (SR). SR occurs because the brain is a linear system that could elevate its ability from the added random signal in a limited intensity level (Othman et al., 2020).

Most of this research pivots on either children or adults in general, and there is a scarce understanding of the effects of noise on adolescents' learning performance in detail. Nevertheless, the information and the evidence synthesis on brain development, especially in the working memory area between adolescence and adulthood, is still not well mapped (Andre et al., 2015). Based on an earlier search when preparing this protocol, there is a lack of literature discussing the effects of noise on the developing brain and its' cognitive performance. It was found that there is no previously published scoping review that provides a summary of the scientific literature and the robustness of existing evidence relating to the effect of broadband noise on the human developing brain using functional MRI.

2.4 Study Objectives

Prior to conducting the protocol for this scoping review, a prefatory search was performed using PubMed, PROSPERO, and MEDLINE to ascertain that no similar scoping review, systematic reviews, or narrative reviews on the proposed topic are underway. This protocol prepared a clear step-by-step guide to conducting a full scoping review for the benefits of knowledge synthesis revolving developing brain, functional MRI, and noise. The scoping review aims to determine the number of existing studies investigating the effects of noise on the cognitive performance of the adolescents' brain using functional MRI. Apart from that, this review helps to establish baseline data for the availability of the research. The purpose of this protocol is to provide preliminary planning to conduct a full scoping review. The aim is to

identify the research gap and the planning of future research regarding the cognitive science area. The scoping review synthesises the evidence by providing a clear mapping based on thematic values within the scope. Nevertheless, the full scoping review does not warrant to conduct and measure diagnostic accuracy of the magnetic resonance imaging or the effectiveness of the psychological battery test relating.

3.0 Methodology

3.0.1 Scoping Review Methodological Framework

The protocol for the scoping review is conducted according to Arksey and O'Malley's scoping review methodology framework (Arksey & O'Malley, 2005). Apart from the methodological process proposed by Arksey and O'Malley, an additional reference was also considered necessary for this protocol. A robust and updated framework that includes the detailed description to conduct the scoping review from Levac et al. (2010) was based on their previous experience conducting a scoping review based on the original Arksey and O'Malley framework. It is deemed important and necessary for this proposed review to include additional references for the methodological framework to enhance this scoping review process.

Arksey and O'Malley's original framework suggested a six-stage methodology to perform the scoping review. However, this protocol completed a plan to proceed with five out of the six stages, which are: (1) Identify the research question;(2) Identify relevant studies;(3) Eligible studies selection;(4) Data extraction and charting the data and (5) Collating, summarising, and reporting of the results. The optional stage 6, the consultation with stakeholders, is not included in this scoping review because it will require additional time to gather the feedback from the stakeholders and perform reviewing for new supplementary references. Besides, it is time-consuming to identify the potential stakeholder and their time and availability to contribute. Nevertheless, the finding from this scoping review will be informative for those conducting research on brain imaging, for instance, data scientists, healthcare providers, young researchers, and prospective graduate students utilising MRI per se. The protocol aims to include Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) extension for Scoping Reviews (PRISMA-ScR) to report the findings from the scoping review.

3.1 Protocol Design

3.1.1 Stage 1: Identify the research question

Formulating questions for scoping review is dissimilar from narrative synthesis and systematic reviews. The questions developed should address and examine the field's depth and breadth to prepare clear findings through evidence mapping to the readers. The review questions formulated will cover three essential aspects, which are (1) population, (2) concepts and (3) context of interest to broaden the number of kinds of literature included for the following methodological process. In this protocol, the reviewers prepared four research questions as follows.

1. What are the purposes and characteristics of the studies (noise presentation, level of the noise intensity, colour of noise) investigating the adolescents' brain?
2. Where is the activated area (prefrontal cortex/ parietal lobe) significantly affected by the background noise?
3. What is type of experimental designs, task selection/implementation, imaging sequence/protocol were used for the functional MRI imaging?
4. Do previous studies include any cognitive test and/or neuropsychological battery test for assessing cognition functioning? If yes, what are they tested for (executive function or default mode network)?

These questions are the preliminary step to explore more searchable literature or any reported studies on the public domain databases. The questions developed for this review would provide a clear purpose and direction to conduct the search for relevant literature. The following stage in this review is expanded on by defining the population (adolescent), concepts (functional MRI) and the context of interest (noise).

3.1.2 Stage 2: Identification of relevant studies.

A search strategy is an integral part when performing scoping reviews to ensure only relevant studies are collected in this current review to reflect the inclusion criteria derived. The search strategy in this review will be conducted using online databases easily accessible by the authors. The databases chosen to perform the search in this protocol contain publishers or journals that published relevant articles on neuroimaging/cognitive sciences/psychology. It should have desirable data/findings/literature on functional MRI and the human brain. Hence, all the reviewers will perform a literature search using Pubmed, BrainMap, Scopus databases, and grey literature. It is crucial to set the correct time range when conducting the literature search because the numbers of literature on neuroimaging, particularly the emerging functional MRI, has started to gain interest by groups of researchers in the 1990s (Bandettini, 2012) (Stephan & Roebroeck, 2012) (Biswal, 2012). Nonetheless, the period deemed relevant for the literature search for this review is between 1998 and 2021. This scoping review will perform searches on literature published in the English language only. This review also seeks to include the search terms and syntax. The keywords that will be are in combination in 4 sets which involved words as in set 1: "functional magnetic resonance imaging" or "functional MRI" or" fMRI" or "Magnetic Resonance Imaging"; Set 2: "teens" or "adolescent" or "adolescence" or" developing brain"; Set 3: "noise" or "environmental noise" or “broadband noise”, Set 4: "working memory" or "cognition" or "cognitive performance" with the Boolean operator AND between the set. The literature/studies will be included in the data extraction using the following inclusion criteria.

1. The study will choose studies that include a sample or subgroup of the population, which comprises adolescents aged from 10 years to 23 years, including females and males.
2. Studies should consist of functional MRI as a main investigative tool or additional/comparative tool.
3. Studies reported their findings to consist of cognitive functioning, particularly executive function and working memory area.
4. Analytic study design (observational, experimental, cross-sectional), meta-analysis (seed-based, activation likelihood estimation), systematic review, literature review.
5. Grey literature (thesis, abstract).

The exclusion criteria derived for this protocol comprised of literature published for conference abstracts, reviews of books, commentaries from the editors' articles, personal views, reviews, and experimental reports on occupational noise and industrial noise, which is deemed irrelevant for this scoping review themes. This review will also exclude studies that focus on neuroimaging studies other than functional MRI, such as positron emission tomography (PET) and magnetoencephalography (MEG). The initial preliminary plan for this scoping review protocol was that a reviewer seeks consultation with two librarians to learn using online databases for literature sourcing affectively, preparing the search string. Based on the search string prepared, the list of references/works of literature will be imported and stored in reference management software, the Mendeley reference manager v2.65.0. The reviewer will prepare a dedicated folder to complete the full reporting of this scoping review. This folder will be shared among other reviewers for data screening and selection.

3.1.3 Stage 3: Studies Selection

Selecting pertinent studies suitable for the review's scope and serving the main purpose is crucial. For this reason, adhering to the research questions developed to capture only the relevant studies is vital (Sargeant & O'Connor, 2020) for a well-structured scoping review. Therefore, all reviewers achieved a consensus to screen the cited references and reference list from the review papers to explore further the searches. Screening the suitable studies using well-formulated inclusion criteria require discussion with other reviewers to reach a consensus regarding the feasibility of the studies selected and rejected. Reviewers will need to inform and provide reason/s for the rejection using thematic analysis and classification of the criteria prepared in the folder. Furthermore, as the screening process is still ongoing, the pre-planned search strategy developed in this proposed review possibly revised whilst selecting the relevant studies (Levac et al., 2010).

3.1.4 Stage 4: Data extraction and charting the data

The data screening and extraction will be performed by two reviewers to assess the eligibility of the literature retrieved. MS Excel spreadsheet (version Microsoft 365) will be deployed as a medium to tabulate all the studies and screen for inclusion criteria for each abstract and/or full paper. The included items for the screening will be outlined and prepared in the table. It is hoped that this would help to provide a clear mapping of the decision made on the evidence. The data extraction framework is prepared following as shown in Table 1.

Table 1: The proposed data extraction framework

Main Category	Description
Author	Name of all the author(s)
Title	-
Journal	-
Year of publication	-
Purpose(s) of the study	Explained the objective(s)
Types of review	Describe if the literature is systematic review, experimental reporting etc
Number of studies included	Specify the numbers of literature.
Number of participants	Describe the number of subjects involved in the study
Condition of the population	Either healthy subject of with certain mental condition ie; autism, neuropsychiatric.
Type of the studies included	Indicate the design; cross sectional, longitudinal studies
Experimental task	Description of the fMRI task
Types of stimulus (noise)	Intensity level and colour of noise
Types of cognitive test used	Description of the cognitive test used to measure the performance
Area of brain activation	Determine the brain activation area

The information from each article, such as the standard bibliographical details such as the authors, title, journal, and year of the publication, will be delineated clearly. Despite that, this proposed review will include the study design, the number of participants, effects and/or adverse effects of noise, types of mental assessments used will be tabulated. The proposed items will undergo a pilot test to secure

the framework prepared in this review is consistently applied. Reviewers will revise the categories and items if it requires framework modification. All the extracted data will be prepared and collected after the screening process, and it should be based on the items and categories outlined in this protocol. The discussion between the reviewers will be conducted to discern any discrepancy regarding the eligibility of the study/literature until consensus is achieved. Hence, this review planned to measure the inter-rater agreement using Cohen's Kappa (κ).

3.1.5 Stage 5: Collating, summarising, and reporting the results.

All the information extracted from the suitable literatures will be collected and saved in another MS Excel folder. This folder will only contain accepted and relevant literature for this scoping review. The information from each reported study or review will be collated into charts and text for the potential readers to grasp the description of the literature available. The information that will be included is the area for brain activation, the experimental tasks, the type, colour and intensity level of the noise and including the measurement used for the cognitive performance presented. The process of presenting the summary from this review will be delineated based on the research question derived.

4.0 Ethics and Dissemination

The methodology of collecting and synthesising the materials will be conducted using public online databases from the university libraries, and ethical approval is unnecessary. Even so, this scoping review protocol is related to a research study in which ethical approval has been granted from the Universiti Kebangsaan Malaysia Ethics Committee with the reference number (UKM PPI/111/8/ JEP-2020-082). The findings in the scoping review will be shared through scientific journals at conferences or health sciences-related seminars.

5.0 Strength and Limitation

With the guidelines prepared based on this protocol, the scoping review aims to provide well-structured mapping evidence synthesis based on generating an overview of the findings from previous studies. The strength of this full scoping review is the mapping of existing evidence on the effects of noise on the developing brain using functional MRI. This scoping review would be the first step for other investigators to embark on contributing findings and robust studies in the future. For that reason, this scoping review aims to provide a clear but broad scope. The limitation is that the focus of the language is on the English language only. Other languages, such as Japanese or German, could be reported on functional MRI and adolescents' cognitive. Still, it is feasible for the reviewers to conduct language translation for each piece of literature and perform the screening. The concern here is that it could affect the proportion of evidence searched. This review will consider articles published in scientific journals but is not limited to experimental design research only. Another limitation from the perspective of time management is that to complete this review is; there will be no consultation with stakeholders to collect their opinion on the evidence and go through additional references to add to the findings. However, the quality of this protocol will be examined by librarians from two libraries to avoid confirmation bias when completing the scoping review. To date, no review has been conducted to assess the number of works of literature investigating noise and its effects on the brain using functional MRI. Advertently, the full scoping review has no intention to provide changes to the existing healthcare policy or provide health guidelines to policymakers.

6.0 Conclusion

This scoping review protocol aims to provide clear guidance to conduct a scoping review. Therefore, the scoping review focus to provide a clear depiction of the research/literature gap involving studies relating to noise affecting the developing brain using functional MRI. Once the full scoping review is completed, this protocol will be cited and included in the paper to increase the awareness that a protocol initially guided the full review.

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Paper Contribution to Related Field of Study

This scoping review protocol will guide the reviewers to prepare and conduct a full scoping review in future. This paper also will alert other researchers and stakeholders to conduct the different scope of literature on functional MRI.

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