How Machine Learning Approach Is Being Deployed By The Studies On Prognosis Of Dementia: A Systematic Literature Review

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Introduction

- Research in Healthcare sector is valuable to society as it can lead to vital innovations like new treatments, tests, vaccines, prevention policies and other widespread advancements that affect healthcare and its dispensing to the common population. Modern healthcare experiences an increase of health information in terms of quantity, variety and accessibility, which indicates on the research's methodologies that require more compelling statistical techniques acceptable to use the best of this health data. Unique example of such robust procedures is machine learning.
- **Machine Learning:**

Machine Learning is a wide discipline that affects the insight and the construction of computer programs which demonstrate key aspects of intelligence. derivation of the word machine learning dates to 1950s along with its description given by Arthur Samuel as: "an area of study that offers computers the ability to learn without being explicitly programmed".

- **Machine Learning in Healthcare Prognosis:**

Prognosis in the medical loop serves the purpose of laying evidence – based interpretation for a person's chances of forming various results and further leads to information regarding the formation of interventions and strategies for betterment of diagnosing health concerns and managing patients. For constructing a reliable estimation of prognosis, a longitudinal perspective of the individuals ought to be taken into consideration, with various other factors, that sets strong foundation for the application of machine learning.

- **Dementia:**

Dementia is a convoluted illness that influences the brain's neurological system. It is highly prevalent amongst the aged population, liable for a radical cognitive deterioration severely chronic enough to affect the patient's regular operations and liberation. In order to address dementia prognosis in populations, additional prediction methods that have traditionally been used for population prediction should be included. So, machine learning innovative computing advancement which may aid the prognosis of dementia, its analysis and diagnostic decision making.

Rationale

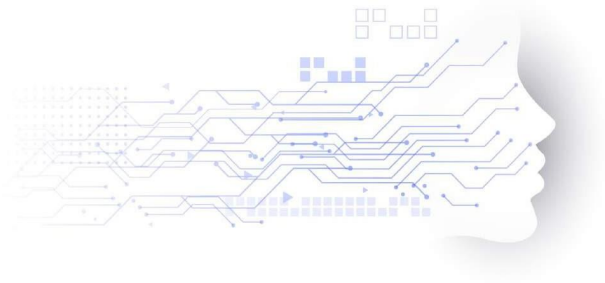
•This systematic literature review research on prognosis of dementia through machine learning was conducted since dementia requires multidisciplinary approach as it is a multifactorial illness. Also, very little is known regarding the whole fundamental procedures involved in the treatment of dementia. Therefore, this study presents the concept of machine learning in order to augment the human abilities for handling complicated issues, either through expanding the knowledge base or through revelation of new concepts for filling the gaps of previously conducted studies for uncovering associated benefits.

•Through this research we can also analyze various baseline attributes involved in the development of dementia and how machine learning can be deployed throughout the prognosis.

Study Outline

- This thesis is a framework based on 20 research articles that has been synthesized. The following is how the rest of this work is organized: Chapter 1 (introduction) introduces key concepts and background information for this work's motivation, as well as the thesis's research contexts. The overall and specific goals of this thesis are detailed in chapter 5 (Research Aims). Chapter 4 (Research context in prognosis: prediction of the onset of dementia in older people) provides similar information, but in the context of prognosis research. Chapter 10 (Discussion) discusses the major findings in relation to the research contexts and the work as a whole, while another chapter discusses threats to validity. The concluding reflections of the thesis work are included in chapter 12 (Conclusion); finally, chapter 14 (Future Work) offers proposals for prospective future investigations.

Study Context



- Dementia was a very prevalent condition with an unknown origin, limited palliative therapy, and a considerable social impact. The WHO has designated dementia as a public health priority, citing worrying rates of 7.5 million new cases per year. Dementia is a term used to describe a group of neurological illnesses that cause gradual cognitive decline and memory loss. As dementia progresses, the affected individuals experience an accumulation of disabilities and cognitive impairment to the point where it interferes with their social and professional functioning, and it can proceed to the point where they even lose their independence completely. Furthermore, little is known about its processes, and no approved symptomatic medication has been shown to be effective in addressing cognitive decline.
- Doing this prediction considering a time frame that is large enough for the application of interventions may lead to positive results as to prevent or delay the dementia onset. But, the challenge with this technique is that dementia is thought to be a complex condition, and some elements thought to impact its progression cannot be studied in typical SLR.

Study Aim

•The main purpose of the prognosis research was to give prognostic estimates for older people in terms of whether or not they will develop dementia.

- The aim of the study was to give a systematic literature evaluation of the state of the art, trends, and gaps in dementia prognostic research using machine learning approaches.

Research Question and Objectives

"How Machine Learning approach is being deployed by the studies on Prognosis of Dementia: A Systematic Literature Review"

•**General Objective:** The aim of the literature review is to observe the articles from authors who have conducted primary studies on the employment of machine learning on prognosis of dementia, in order to discern some key aspects of application of machine learning in healthcare and to understand the major gaps of the previously conducted primary studies.

- **Specific Objectives:**

i) To identify most frequently used ML technique in the prognosis of dementia
ii) To study what data determinants are considered while applying ML technique
iii) To determine the aim of these studies which deploy ML technique for prognosis of dementia
iv) To ascertain the way in which censor data was handled
v) To understand whether these studies primarily focused on individual or population level

Literature Analysis

- With this literature review we can infer that there are many different proposed models of prognostic machine learning for predicting the progression of MCI into Dementia.
- Jussi Tohka *et al.* Study was based on two classification problems; Dementia and MCI (mild cognitive impairment), which further featured SVM based technique to predict the estimation of Dementia prognosis. Other Bo Cheng *et al.* proposes general domain transfer learning-based framework for the conversion of MCI prediction. The study was conducted using 202 ADNI subjects, the experimental study shows that the proposed method (SVM and DT) showcases better performance significantly than old methods of MCI converters.
- Some studies also predicted the progression through MRI screening, one study of Laura S. Symonds *et al.* presented superlative execution model merged an amalgamation of cognitive/functional indicators and morphometric MRI procedures projected estimated progression with 80% accuracy (83% sensitivity, 76% specificity, AUC = 0.87).

Literature Analysis…

- Many studies; Yash Liu *et al,* Asim Mubeen *et al* and Bencie Woll *et al* synthesized the results regarding the efficacy of tiered collaboration models for estimating the conversion from MCI to probable Dementia. The procedures executed in the study can be efficiently utilized for separating stable MCI patients from the ones who are at primary stage of dementia with high accurateness. The studies also demonstrated a new approach through multi-modal toolkit based on machine learning's automatic recognition.

- Majorly all studies focused on proportional result of performance of various ML methods, including support vector machine (SVM), Decision Tree (DT) and others when they are working in recognizing dementia from clinical database. It has been initiated that SVM performed relatively better than other methods. Also, a lot of studies stated 4-time windows of; 2, 3, 4 and 5 years. Then, a prognostic model was developed for each time window with the use of clinical and neuropsychological data. The result of the study revealed that Prognostic models utilizing time windows have more prominent presentation when prognosticating progression of dementia from MCI, in contrast to the general prognostic method which is frequently used in the literature er techniques.

Methodology

•A systematic literature review (SLR) recognizes, assesses and clarifies a considerable and symbolic sample of all the appropriate primary findings regarding the literature involving a dementia. SLRs perform a holistic examination followed by a predetermined approach which stipulates dedicated study questions, criteria for the assortment of articles and carry out the data extraction along with conclusion synthesis.

- Conducting a SLR embraces the subsequent steps:

(i) Ascertain the requirement for executing the SLR
(ii) Articulate research questions
(iii) perform a thorough search of the selected primary studies
(iv) Interpretation of the results
(v) Presenting the report on SLR

- An examination of various published quantitative and qualitative articles was done in this systematic literature review in order to critically analyze the perspective of various authors on prognosis of dementia through machine learning approach.

Methodology…

- **Search Strategy:**

PubMed, Google Scholar, Medline, ScienceDirect and to some extent lancet, all were used to carry out the search. The following search terms or search string was created keeping all the components of the research intact;

([“DEMENTIA” OR “DEMENTIA MORBIDITY” OR “ALZEIHEMER”] AND [“MACHINE LEARNING” OR “DECISION SUPPORT SYSTEM” OR “MACHINE LEARNING MODELS” AND [“PROGNOSIS” OR “PROGNOSTIC ESTIMATES”])

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Methodology…

- **Article Selection Strategy:**

The research was conducted from 1st April 2021 to 15th June 2021and included articles since 2013. Following figure explains the process of article selection for this study.

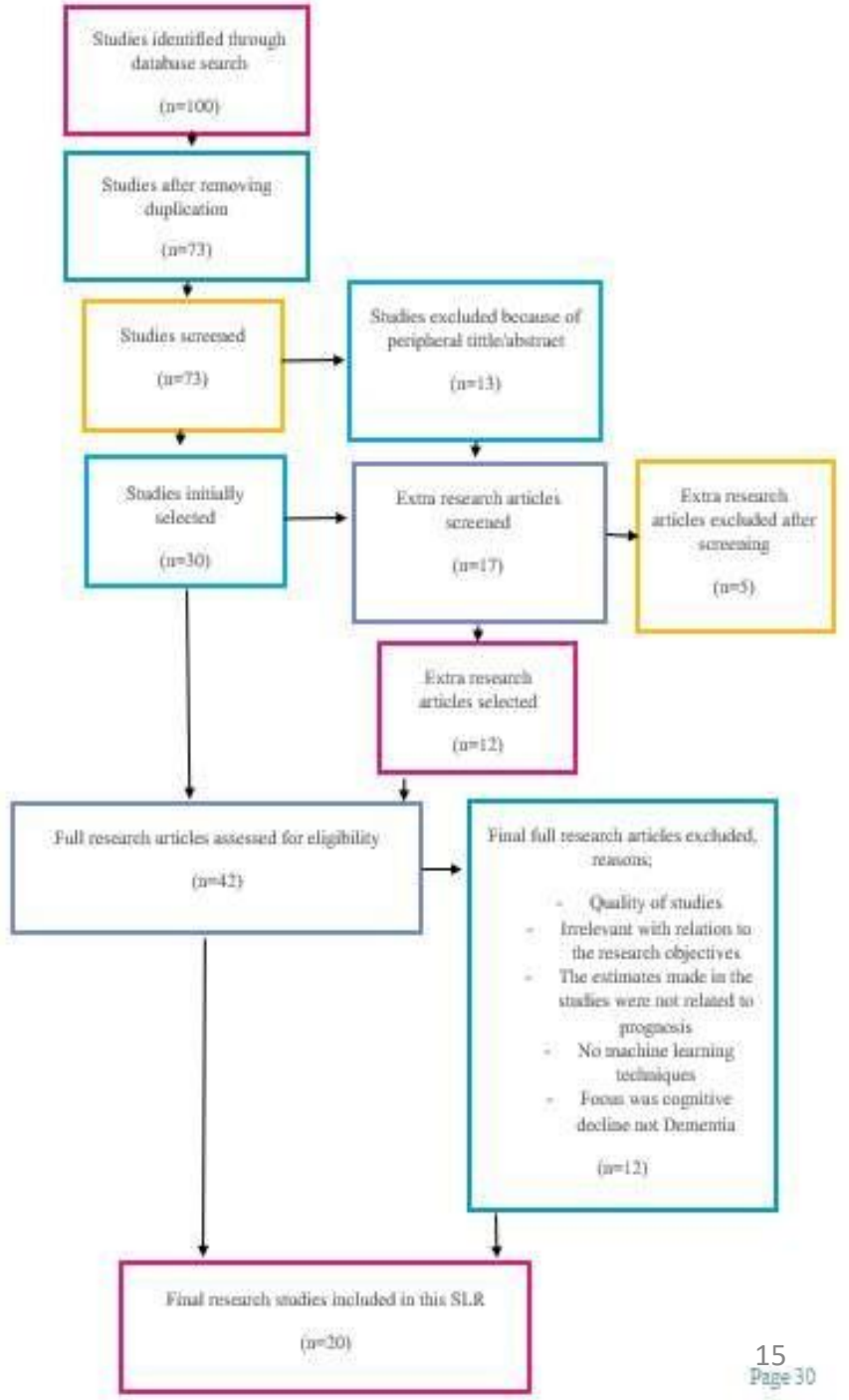
•100 study articles were found to be relevant for the SLR but, due to time constraints exclusion and inclusion criteria was decided for conflict resolution which brought down the search to 20 articles which were thoroughly read and assessed. The ones which effectively accepted through the created criteria were specified as pertinent and relevant for data extraction.

Inclusion Criteria	Exclusion Criteria
Should be a validated study in English; AND	Published before 2013; OR
Should have been published within the last 8 years; AND	Studies published in language other than English; OR
Address the prognosis associated to at least one machine learning technique; AND	Studies that don't address at least one machine learning technique; OR
Prognosis related to dementia and its comorbidities	Articles focuses on cognitive impairment rather than Dementia
Variable	Definition
Attribute studied	Which dementia disease is being studied to determine a prognosis
Dataset used in the study	Name and origin of the data source utilized to calculate the dementia prognosis
Database categories	The data units were classified into classes
Handling Censored data	The manner in which censored data was handled is described.
Analysis technique	The prognostic models were built using machine learning techniques.
Variable Model	The variables that were used to create the prognostic models
Study Goals	The built-in prognostic models' purpose
Focus of the research	If the created prognostic models target individual or population-level predictions.

Result

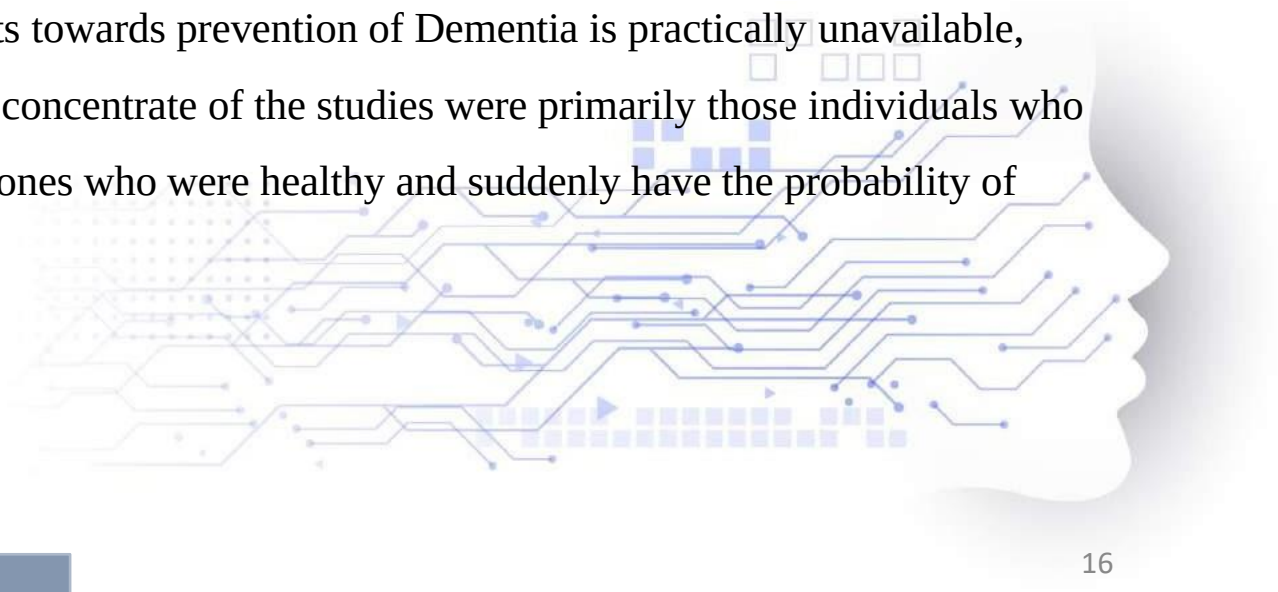
•The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart was used to define the assortment of the studies. At first 100 studies were selected and from these 42 full research articles were assessed for SLR eligibility, where 20 final articles were selected to be inculcated in the SLR, rest of the studies were excluded as they were found to be out of the threshold of the quality assessment, for not being in relevance with the research objective, some were not a prognostic estimation studies, some were excluded because they didn't use proper machine learning technique and one criteria for exclusion was for those studies who emphasizes on overall cognitive decline, but not dementia in particular.

•Most frequently mentioned technique in the articles were SVM (Support Vector Machines) and Decision Trees.



Result. . .

- Outcome of the final synthesis of 20 articles presented in this study revealed the perspective of the dementia prognosis through machine learning approach, along with recognizing the disparities among various perspectives presented in these papers. Findings from the studies outlines that the concentration of the whole research of the prognosis of Dementia was on the utilization of prediction model for estimating progression of Dementia, in order to forecast the Dementia cases from MCI.
- Through this research it was also inevitable that the attempts towards prevention of Dementia is practically unavailable, further this analysis of various articles laid out that the key concentrate of the studies were primarily those individuals who were possessing some sort of cognitive relapse and not the ones who were healthy and suddenly have the probability of developing dementia in future.



Result. . .

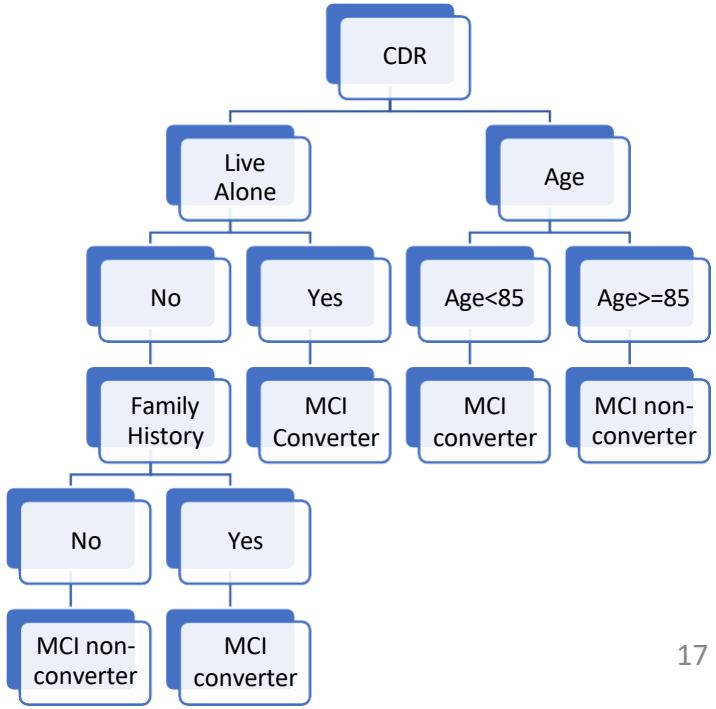
1. Identified Machine Learning Technique

On the Subject of ML techniques, the generation of the extricated data indicates that the extremely frequent used ML methods were Support Vector Machines (SVM) (15 articles) and Decision Trees (DT) (5 articles). In terms of the SLR findings, SVMs were found in 20/37 papers, in some proposed models, and are by far the most often utilized machine learning technology in dementia prognostic research.

A Decision Tree (DT) is a classification technique that represents learned knowledge as a tree structure that can be translated into if-then rules. The recursive learning process of DT begins with a test of each input variable to see how well it can classify the labelled instances on its own.

Technique Modifications	Featuring study in SLR
SVM	1-15
Radial basis function SVM	17, 13-15
Relevance Vector Machines	7
Domain Transfer SVM	7
Other approaches of SVM	7

Technique Modifications	Featuring study in SLR
Random Forests	17
Decision Trees	16-20
Boosted Trees	18,19



Result. . .

2. Characteristics of The Data Used in The Models

Distinct characteristic variables termed as; neuroimaging, neuropsychological, genetic variable, lab testing and demographical variables are included in the articles which were studied. Also, there were certain articles which contributed more than once for the subcategories but, the input to categories was only counted once. Thus, resulting in smaller number for categories than overall sum of numbers of the subcategories.

Category of Variable	Subcategory of Variable	No. Of Studies	Studies, featuring variable category
Neuroimaging	MRI, PET, Neural-based models	9	2, 5, 6, 9, 14, 15, 17, 19, 20
Cognitive measures	Dementia assessment scale	1	12
Genetics	Family history, Hierarchical medical history	5	7,8,10,12,16
Lab Tests	Clinical tests	4	1,6,10,12
Demographics	Age	1	7

Result. . .

3. The Objectives of Dementia Prognostic Studies

The accumulated gathered information reveals that most of the studies, meant to scrutinize the progression of MCI to Dementia. The identified articles mention the need for the Dementia prognosis and suggested patterns for the prediction, generally amid 8 to 36 months till growth. In certain study articles, there were also variation of the goal. In these studies, the aim was the prediction of Alzheimer and not Dementia from MCI. Further, some studies use patient's prolonged informational records to design the predictive model based on course of action of Dementia with regards to its cerebral operations.

Goal of the Studies	Study Count	Measures Studied	Type of Data Analysis	Featuring Studies
Mild Cognitive Impairment can be used to predict the onset of Dementia disease.	17	Dementia Disease, MCI	ML	1,2, 5-14, 16-20
Model illness stage using the score from the FDG-PET imaging	2	Dementia Disease	ML	3,15
Modeling illness progression based on events	1	MCI Conversion	ML	4

Result. . .

4. Addressing Data that has been Censored

When some individuals are unaware of their own personal time to the event of interest, data censoring occurs. This can happen when data on the time to event is unavailable due to a lack of follow-up or when the outcome event does not occur before the trial ends. Only two of the 20 studies included in this SLR explicitly addressed censored data. Participants who did not acquire very mild or mild dementia during the follow-up were statistically censored, while in the latter study the researchers and data censoring is addressed as a danger to validity, stating that for shorter follow-ups, there may be patients labelled as MCI with an MRI pathological pattern who have not yet acquired Dementia. The other papers considered in this review made no specific remarks about data censoring.

5. Focus of the Studies

The last objective of the SLR was to analyze the focus of the studies included in this research, and it was discovered that all the 20 studies sincerely focused on prognosis of dementia at an individual level and no study focused on population level.

Discussion

In order to tackle an issue like dementia which is sensitive, it is very significant that the interpretability and performance of prognosis must be thoroughly deemed. In the earlier conducted studies this arbitration was taken care of. Most importantly it is a matter of consideration that dementia is a mental cognitive disorder which eventually leads to severely grave outcomes for the individual who has it plus their families, as due to this illness a person tends to lose their basic mobility and daily functionality of performing routine activities, offering poorest of health markers with time.

The key outcomes after this Systematic literature review are abridged below:

(i) Almost all the studies mentioned, utilizes predictive modals for forecasting the occurrence of dementia from MCI, with the use of different data reserve

(ii) Evaluations are generally rendered for about 36 months prior to the onset of dementia

(iii) Behavioral and social attributes were missing or neglected in the evaluated presented models

(iv) The locus of the whole thesis was based on individual level and not on population level

Limitations of the Study & Recommendations

•The issue of whether a suitably large representative sample of all potentially relevant studies was included in the final set is the major limitation of this SLR.

•To address the problem, a more inclusive selection approach was implemented. This means that in articles where the inclusive criteria were not clearly stated in the title or abstract, the study's substance was examined further for prospective inclusion or exclusion.

•Clinical studies should be the focus of future research in order to validate and examine the results acquired by estimating models developed in research contexts of the SLR in clinical trials, which should be the next step in the process of transferring discoveries to clinical practice.

•The findings of this SLR revealed current trends and gaps in dementia prognostic research that should be addressed in the future. Further study should be conducted based on these findings to investigate other combinations of ML approaches, employing a multivariable approach that encompasses the indicated data qualities as well as lifestyle and social aspects.

Conclusion

•The dissertation followed an approach of SLR which aimed at examining the machine learning's application in healthcare domain through its deployment in the field of prognosis of dementia. As the application of machine learning contemplates it as a modern healthcare technique, which can be utilized as the solution to peculiar applied issues.

•In the research concept of prognosis of dementia, prognostic assessments were attempted to be examined and it was found that the required sufficient evident results reflected that the focus of most of the studies laid on the prediction models of MCI using ML techniques for patients who develop dementia, in usually 36 months, by the significant use of neuroimaging.

•The 20 studies included in the SLR summarized the focus on the prognosis of dementia through the usage of ML technology, it executed various attributes including frequency in the type of ML technique, variables and aim of the various studies. There were only limited number of sets of data which were being utilized and most notably.

Threats to Validity

- The validity threats determination will be deliberated in the following with regards to external validities in the encompassed articles of this dissertation, laterally with tasks involved in order to mitigate the threat.

•External Validity explains the extent of achieved synthesized results as generalizable. The SLR of the studies included in this thesis are executed in a systematic manner along with defining the inclusive criteria, so to an extent we can mitigate the risk of external validity and consider the research to be generalizable.


Thank you!

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