AN EXPERIMENTAL STUDY OF THERAPIST CHATBOT WITH COGNITIVE BEHAVIOR THERAPY FOR PEOPLE WHO ARE DIFFERENTLY ABLED WITH HEARING

SUNAYNA TALREJA
MASTERS IN AI AND ML (STUDENT_ID: 1140492)

RESEARCH PROPOSAL

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ABSTRACT

"Technology alone is not enough—it's technology married with the liberal arts, married with the humanities, that yields us the results that make our hearts sing." — Steve Jobs

Mental health is foundation of well being for humans but it is often neglected and seeking therapy is considered a sign of weakness or madness due to social perceptions. Also, currently healthcare systems are overburdened and resources available are limited and costly, so it is not accessible for everyone. Additionally, people who are differently abled with hearing often hesitate to ask for help. The research being proposed is to extend the support of an AI psychologist for people who are differently abled with hearing. The aim of the research is to provide an innovative solution by using a LLM based AI psychologist with 3D avatar designed to offer empathetic mental health support in sign language.

The research involves building a solution by fine tuning LLM for CBT conversations and creating a realistic 3D avatar to converse in sign language, brought together to provide a real life like experience. With the study the target is to build a solution which is capable of understanding emotions and providing emotional support to the user in a language which gives them a freedom to express and understand. The research proposal will focus on a thorough examination of various aspects of the study such as background information, problem statement, research questions, aim and objective, significance of the study, scope of the study, research methodology and other resources. Additionally, it provides a detailed plan for the implementation of the solution.

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LIST OF ABBREVIATIONS

LLM……...…. Large Language Model

GPT……..... Generative pre-trained

CBT……Cognitive Behavioral Therapy

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1. BACKGROUND

Mental health is often overlooked despite being essential for a calm and prosperous life. Individuals with diverse abilities often feel reluctant to seek assistance. This area currently has issues such as the high cost of therapy, limited access to qualified professionals, possessing limited skills in sign language communication and social stigma prevent many individuals from seeking the support they need.

With the rapidly changing technology, LLMs now possess capabilities to mimic real life conversations. But there still exists a challenge to understand and react to human emotion. Additional to the response being empathetic, the response needs to be relevant providing a resolution to the mental health issue of the conversing individual. Also, the response relevance needs to be effectively translated to a sign language ensuring the empathetic CBT interaction.

To overcome such challenges researchers have crafted multiple innovative solutions by leveraging the advancements in the realm of Artificial Intelligence and Machine Learning, for providing mental health support which is effective and cater to user's needs. A SAAC mental health chatbot to mimic a therapist to provide a personalized support and guidance with response tailored based on user conversations, it also maintains conversation history. (R et al., 2024) . In addition to the mental health support, it is extremely important to convey the empathetic response in a language which is understandable by the end user. With the use of integrated computer vision principles, this study aims to break the communication barriers for the deaf by creating a real time sign language translator (Jain et al., 2024). Additionally, it is also important to effectively communicate the solution which feels personal and replicates the environment of a patient and therapist CBT conversation. This study aims to communicate response using sign language avatar by calculating arm movement sequences of signs within a declared number of frames, or with a user defined shifting value per bone (M. Punchimudiyanse and R. G. N. Meegama, 2015) . Another approach to generate sign language videos is by using stable video diffusion, latent diffusion models are trained on 2D image synthesis which turns them into generative video models by inserting temporal layers and fine-tuning them on smaller set of high-quality video datasets. (Blattmann et al., n.d.).

The aim of the research is to explore advancements in the realm of AI and develop a LLM based, 3D avatar driven AI psychologist which facilitates sign language conversations. Human centered psychological principles blended with power of technology provide a solution which envisions a future of mental health being accessible to all.

2. PROBLEM STATEMENT OR RELATED RESEARCH OR RELATED WORK

In the era of life being a race, people are susceptible to depression, anxiety and other mental health disorders. With this change and advancements in technology gave birth to AI based chatbot solution which caters to needs of people seeking mental health support capable of understanding human emotions.(Shetty et al., 2023) (Asha et al., 2024) (R et al., 2024). The authors have used different approaches to provide the solution, one uses ISEAR dataset and Convolutional Neural Networks (CNNs) to identify the mood status of the user. A neural network-based model is created to identify emotions and generate responses from a predefined set of options. And other is utilizing libraries like spaCy and NLTK with TensorFlow and Keras for model building. This supports the creation of distinct yet interconnected models for intent recognition, emotion recognition and response generation. Third Author approached this buy building a SAAC chatbot which is text and voice enabled web based chatbot. SAAC chatbot makes use of Keras sequential deep learning model which serves as the core component responsible for understanding user input and generating appropriate responses.

Mental health issues are not just limited to working professionals or people with older age, it equally impacts students of any age or gender. The writer proposes a intelligent social therapy chatbot which classifies the text into emotion labels. The chatbot analyzes user input and determines the user's emotional state, such as depressed, stressed or normal. It calculates the positivity and negativity percentages of each chat based on the identified emotions. The chatbot tries to prevent negative thought process and build a constructive thought process. (Patel et al., 2019).

People with mental health issues seek hope and sometimes that hope can come from people who are also fighting the same thing. This Author build a platform to connect them together and share their struggles. (Rani et al., 2023). The Author has used Rasa, an open-source framework to build conversational AI chatbot. Rasa provides features for processing user input, managing conversations and connecting with external systems. With further advancements came the popularity of LLMs, LLMs support Human Computer Interactions mimicking Human to Human interactions. This Author harnesses abilities of pretrained GPT-2, to identify mental health patients. (Bookanakere et al., 2024)

Based on above researches, the Cognitive Behavior therapy can be performed effectively using LLMs. But the interactions are still text based and impersonal. For therapy to be effective Human like touch needs to be added. A Human touch for people with Hearing issues, sign language is the

language of communication. The Author suggest understanding and answering in ASL by a solutions which has a CNN-based architecture is chosen for feature extraction from ASL data. Deep learning sequence-to-sequence models are employed to facilitate bidirectional translation between ASL and natural language(Jain et al., 2024). The problem of communication is solved by above papers but still, the motion feel in above approaches is missing. To overcome that a diffusion-based generative model is proposed that generates motion sequences based on text transcripts. Since sign language is solely related to hand motion and facial expressions, author focuses on modeling the pose and the expression parameters on the canonical shape(Baltatzis et al., 2024).

Translations now solve the human touch problem to some extent but still don't mimic Human to Human interactions, but involvement of a 3D avatar can resolve this challenge. Aesthetics of a 3D avatar can add value to Human Computer Interactions. In this theoretical paper, author proposes visualizing 3D avatar on parameters of aesthetics, user experience and psychology. (Photiadis and Zaphiris, 2014) . Another author suggests the use of self-avatars by the use of Wonder World Creator app. "Wee Mee" a new app was introduced as a mobile application that lets you create an online character(Kang and Kim, 2020).

Now with human-to-human interactions available, a final touch of sign language is required for the solution to add convenience to the users with special ability with hearing. Many researchers have suggested avatars in different languages and solved problems using different approached. Sinhala Sign Language avatar is created by using MakeHuman software. The human model is exported in the (MHX) format, without a skeleton attached to the mesh and then imported into Blende. Blender's rigging process adds a bone Sign languagestructure to the avatar, with each bone assigned to a separate animation landmark details to follow(M. Punchimudiyanse and R. G. N. Meegama, 2015). ISL sign language avatar uses ISL generator to convert token using Transfer-based conversion, where source is converted to intermediate form. Another way of conversion is HamNoSys Generation Tool, which converts word to HamNoSys and then to SIGML for animation(Patel et al., 2020). Portugese Sign Language Avatar is created by using Unity app to animate the avatar, the data is collected using suit with sensors(Ribeiro et al., 2023). An application that converts multiple sign languages to Animations. A web based application is created that allows user to animate words in sign language. The app is built on the JASigning SiGML system. It contains a database of 4000 words in four supported sign languages which are French, British, Greek and German (Younes and Noussaima, 2024).

With above used technologies a sign language based chatbot can be created effectively. But recent advancements have introduced a more human like avatar called MetaHuman. Author has suggested

use of metahuman rigging with sign language(Nakirikanti et al., 2024). ISL signs are captured using Unreal Engine's depth sensing and motion capture features. These actions are mapped to words, phrases, or sentences in Unity3D, creating a library of ISL gestures. The Android app interface enables an immersive communication experience, where user input (spoken or text) triggers corresponding ISL actions through Metahuman avatars.

A 3D avatar can also be generated by utilizing the features of latest technology of stable video diffusion. It provides a strong 3D multiview, which can be used as a base to further fine tune to generate multiple objects. (Blattmann et al., n.d.). Image diffusion models have been previously used to generate 3D avatars, they were created by using a text or image inputs. The latent diffusion models were fine tuned with image conditioning to solve image generation (Kolotouros et al., 2024).

In psychology, the ability of a human to express is a foundation of cognitive behavior therapy. However, current techniques in technology often fall short in providing an meaningful experience for patients who are differently abled with hearing. This is where the involvement of Large Language Models (LLMs) and 3D avatars when brought together, can alter the prospects of psychology.

Human computer Interactions can be enhanced to mimic human to human conversations and result in cultivating deeper connections and better therapy outcomes by combining capabilities of LLMs with 3D avatars

3. RESEARCH QUESTIONS

How can AI therapy chatbots be helpful in providing mental health support?

How beneficial would be the communication between 3D avatar and a differently abled with hearing humans?

What would be the ethical implications in using AI based therapy and how different it can be from human-human sign language conversations?

4. AIM AND OBJECTIVE

This study begins by examining the background of cognitive behavioral therapy (CBT) and its challenges for individuals who are differently abled in hearing. It will analyze the advantages and

limitations of large language models (LLMs) for combining these models into therapy applications. The study also examines how a 3D avatar can contribute to successful virtual therapy. By drafting targeted research questions, the aim to understand how tools like GPT-4, Diffusion models, Blender and Metahuman etc. tools and libraries can be integrated to provide a human like therapy experience for users.

The objectives of this study are as follows:

- To identify the abilities LLMs in understanding human emotions and providing relevant cognitive behavioral therapy (CBT).
    - Assess LLMs capabilities to understand emotions and psychological problems faced by a human.
    - Calculate the accuracy of the empathetic responses provided.
    - Assess LLMs ability to retain context of therapy conversations and provide response on the memory created.
- To assess the abilities of 3D avatars to read human emotions and provide authentic human-like conversational support.
    - Assess the capabilities of emotion detection algorithms, using the facial expression, body language and textual conversion of the sign language conversation.
    - Assess the abilities of 3D avatar mimicking human gestures.
    - Assess abilities of 3D avatars to express the targeted emotion, for the conversation to be realistic.
- To develop a solution by combining 3D avatar and LLM based solution which is capable of understanding and responding in sign language
    - Measure the accuracy of the system in reading human emotions, body language, sign language together to understand the challenges faced by the individual.
    - Measure the accuracy of the returned response on parameters like emotional intelligence, Cognitive Behavioral therapy response relevance based on the context of entire conversation.
    - Measure the accuracy of the effective delivery of the returned response in sign language effectively to provide the emotional support sought by individual.

5. SIGNIFICANCE OF THE STUDY

Due to social taboos or personal barriers, many people with special abilities find it difficult to seek help. The aim of this study is to offer a safe, environment where people may openly express themselves without having a fear of being judged or ridiculed. The suggested solution will make

mental health resources more widely available. This method provides people who are specially abled with Hearing, a human like conversations from the comfort of their homes by utilizing large language models (LLMs) and 3D avatars, ensuring ease and confidentiality.

6. SCOPE OF THE STUDY

This study will focus on delivering Cognitive Behavioral Therapy (CBT) in sign language. by using large language models (LLMs), with a particular preference on using GPT-4. Range of innovative techniques and methodologies will be examined for flawless integration of LLMs with 3D avatars which will enhance the usefulness of Cognitive Behavioral Therapy (CBT).

Out of scope :

- **Behavioural :**
  - Other forms of therapy like psychoanalysis, mental health disorder identification, group therapy will be out of scope
  - Focuses only on sign language accessibility, other areas in accessibility are not targeted.
  - Long term clinical trial will not supported as part of the project.
  - No integration to any existing healthcare system will be provided.
  - The solution will be limited to Indian Sign Language only. Future scope can be to extent for other languages and sign languages.

- **Technical:**
  - The project will not focus on creation of new tools for 3D avatar generation, existing tools like blender, metahuman or fine tune only existing diffusion models to create 3D avatar.
  - No new core LLM architectures will be developed.

7. RESEARCH METHODOLOGY

The research methodology involves building backend and frontend of the sign language psychology chatbot. Backend involves identification of fitting LLM (Preferably GPT-4) and fine tuning it with Cognitive Behavioral Therapy conversations. Front end of the solution involves reading and identifying Indian sign language words and alphabets, and conveying the response in

sign language by a 3D avatar. The avatar for the front end would be explored in 2 approaches and implement the best approach. Below are the approaches for 3D avatar.

Approach 1 - Animation using the Blender Python (bpy) API or metahuman APIs.

Approach 2 – Fine tuning video diffusion models to generate a video having sign language with a realistic human like avatar.

a) **Data Collection:** Data to build an effective solution, we would require datasets which are based on sign language and CBT therapist conversations. Below datasets would solve our problems.
   - **Data set:** Below datasets will be used for fine tuning purposes.

     Indian Language Signed Animated Videos (Contains alphabets and numbers of ISL)

     ISL Dataset (Contains ISL Library of all possible words) (Sridhar, 2020)

     nlp-mental-health-conversations (Mental health consultation conversations)

     isear-dataset (Emotion relation to the sentence)

b) **Data pre-processing:** Data preprocessing would be performed in 2 flows. One would be for psychological conversations and second would be to extract sign language data from the sign language video dataset mentioned above. Below are the steps required for preprocessing of both the flows.

   Psychological conversations:
   - **Data Cleaning:** The data cleaning needs to be performed by removing irrelevant, duplicate or incomplete entries from the dataset.

   - **Text Pre-processing:**
     - **Stop words Removal:** The stop words need to be removed as they do not add value to the conversations.
     - **Special Token Handling**: Special tokens or symbols may not be recognized by the language model. E.g., comments, string literals and special characters would require special preprocessing.
     - **Tokenization:** Transformation of raw conversations into a sequence of tokens recognizable by the LLM needs to be done.
     - **Stemming and Lemmatization:** The words need to be reduced to their base form.
     - **Context Retention**: Conversational context needs to be preserved for LLM fine-tuning.
     - **Sentiment Analysis**: Conversations need to be annotated with emotional tags for sentiment analysis.

- **Data Augmentation:** Data augmentation techniques would be applied to increase the data in the training set using modified copies of existing data.
- **Feature Extraction:** The meaningful features need to be extracted from text.
- **Dataset Split:** The dataset needs to be divided into training, validation and test data sets.
- **Normalization and Scaling:** The data needs to be normalized for numerical features to a standard range to avoid model biasing.

Sign Language:

- **Video Processing:** For detecting facial expressions and hand gestures, preprocessing of videos needs to be done using libraries like OpenCV, mediapipe to detect facial landmarks and hand landmarks.
- **Feature Extraction:** Extract facial emotion vectors for visuals.
- **Normalization:** Normalization of features needs to be done to calculate emotional intensity scores.

c) Design and Development:

- Design a framework for combining LLMs (preferably GPT-4) with 3D avatars.
  - **Large Language Models LLMs (GPT4):** The LLM would be fine-tuned on CBT therapy conversations and it will act as the backend conversational agent, providing the empathetic support for cognitive behavior therapy conversations. The LLM will maintain a memory of the therapy conversation and would be responsible for feeding the information to the avatar.

  - **3D avatar:** The 3D avatar will be the front end of the application, and will be used in conveying the response in sign language. Avatar would be rigged using the ISL sign language video data set with the help of apis present for Blender or Metahuman or a video diffusion models would be fine-tuned to generate sign language content to convey the response. Both approaches would mimic the human emotion and gesturing to provide a realistic human like response.

- The aim would be to implement a user-friendly interface for interaction between end users and 3D avatar capable in providing response in sign language.

d) Experimental Setup: Create scenarios and case studies to test the AI system's ability to deliver CBT. Incorporate diverse user profiles to evaluate the system’s adaptability and effectiveness across different demographics.

e) Implementation: Implement algorithms and methodologies for combining LLMs into the 3D avatar. Figure 1 below shows the basic architecture diagram.

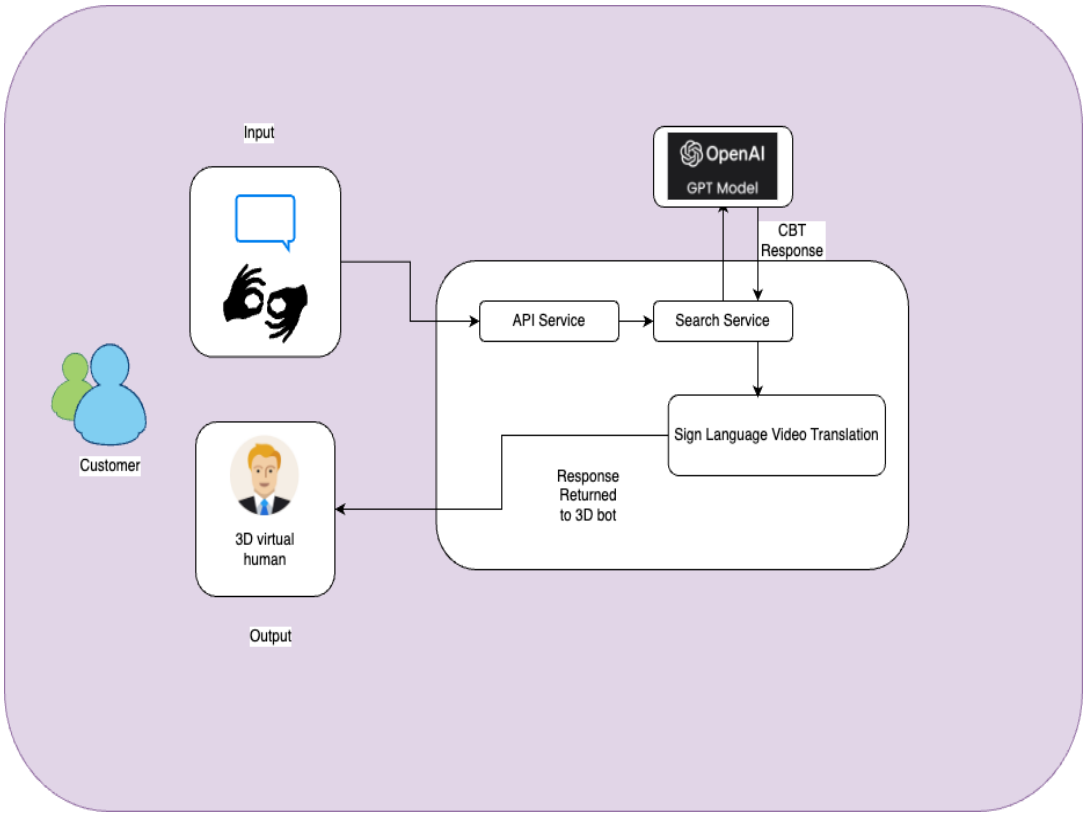

Figure 1: Basic Architecture of LLM integration with a 3D Avatar

f) Evaluation Metrics: Evaluation of the generated CBT response would be done based on below metrics

- **Perplexity:** To evaluate the efficacy of a language model in predicting a given text sample.
- **BLEU Score:** This evaluates the quality of generated text by comparing it with other reference translations.
- **Accuracy:** Accuracy will provide the ratio of accurately generated outputs with respect to the total number of samples.
- **Human Evaluation:** Human evaluation requires human verification of the generated text.

g) **User Testing:** Feedback would be gathered by using trials that replicate real-world therapy sessions. Feedback would also be gathered through surveys, interviews etc to understand user experience.

h) **Empirical Analysis:** Analysis of the data collected from user testing needs to be evaluated to check the effectiveness of the integrated system. With the gathered data identify advantages, limitations and areas of improvement required in the solution.

i) **Ethical Considerations:** Address key ethical concerns such as data privacy, confidentiality and the psychological impact of AI-based therapy on users.

j) **Iterative Refinement:** Use findings from evaluations and user feedback to refine the system's design, interaction model and therapeutic strategies.

k) **Conclusion and Reporting:** Summarize findings, highlight the potential impact and provide recommendations for future research and development in AI-driven therapy.

8. REQUIREMENTS RESOURCES

Hardware Requirement

- **CPU or GPU**: High performing multicore CPU or GPUs, so that high performing deep learning frameworks like mediapipe, OpenCV, TensorFlow and PyTorch can efficiently utilise for accelerated training and animation.
- **RAM**: LLMs usually require significant memory resources to store model parameters.
- **Hardware Accelerators**: TPUs for faster training of models.

Software Requirement

- **Deep learning frameworks**: Deep learning frameworks: Deep learning frameworks like **OpenCV** or **Mediapipe** will be used for getting landmark data from ISL sign language video datasets. **TensorFlow**, **PyTorch** or similar frameworks will be used for training models.
- **Data processing**: **Pandas** will be used handle therapy conversation data. **Flask** will serve as lightweight frameworks for building APIs.
- **LLMs**: Models like GPT4 for supporting CBT conversations.

- **Diffusion Models**: Video diffusion models like stability video diffusion model will be used in generation of 3D avatar.
- **Animation tools**: Tools like Blender or Unreal engine 5 for metahuman for generation of 3D avatar.
- **Version control system:** GIT, SVN, AWSCodeCommit, BitBucket or similar tools required for tracking code changes.
- **Docker or Singularity** to create reproducible environments for model training. Tools like **Kubernetes** would be good to have to support scalability.

9. RESEARCH PLAN

Below is the 22 weeks plan starting from 23rd October 2024(Date of topic approval)

- **Week 1-2: Research Proposal Development**
  - **Week 1:** Define research objectives, scope and methodology which emphasizes on bringing together GPT4 or similar with 3D avatars for delivering CBT based sign language chatbot solution.
  - **Week 2:** Initiate the drafting of the research proposal including a detailed literature review on LLMs and 3D avatars with a basic outline of the framework.

- **Week 3-4: Proposal Review and Revision**
  - **Week 3:** Proposal to be reviewed by advisors or peers on the parameters of clarity, feasibility and relevance to mental health solutions.
  - **Week 4:** Based on the provided feedback, change the proposal and finalize it for approval, making sure it aligns with ethical guidelines and research goals.

- **Week 5-8: Development Setup**
  - **Week 5:** Perform Literature search and Literature review for effective solution building
  - **Week 6:** Fine-tuning of GPT-4 or similar using therapist conversations data and designing of the front-end 3D avatar either using Blender's bpy API or fine tuning of video diffusion models would be performed.
  - **Week 7:** A prototype will be created by combining GPT-4 with the 3D avatar which is capable of replicating the CBT conversations between patient and a therapist.
  - **Week 8:** Prototype would be tested against the initial requirement and feedback would be gathered to later refinement.

- **Week 9-12: Trials and Feedback Collection**
    - **Week 9-10:** Conduct trials involving case studies and replicated therapy sessions with diverse user profiles. Collect data on user engagement, emotional connection and system performance.
    - **Week 11-12:** Refine the prototype based on trial outcomes and gather additional feedback through surveys or interviews.

- **Week 13-16: Data Analysis and Report Drafting**
    - **Week 13-14:** Analyze the result data for measuring the effectiveness of the system.
    - **Week 15-16:** Draft the results section of the research report showing the findings.

- **Week 17-18: Report Writing and Revision**
    - **Week 17**: Draft the discussion and conclusion sections and highlighting the findings for therapist chatbot.
    - **Week 18**: Refine the complete research report based on feedback from advisors or peers.

- **Week 19-22: Preparing Presentation and Finalizing the Report**
    - **Week 19:** Draft a presentation to communicate the result findings along with a functional demo of the solution.
    - **Week 20:** Practice the presentation for delivering at seminars or conferences.
    - **Week 21-22:** Present the findings at conferences or seminars. Refine the report based on the provided feedback and submit it for assessment.

Figure 2 below shows the gantt chart of project timeline

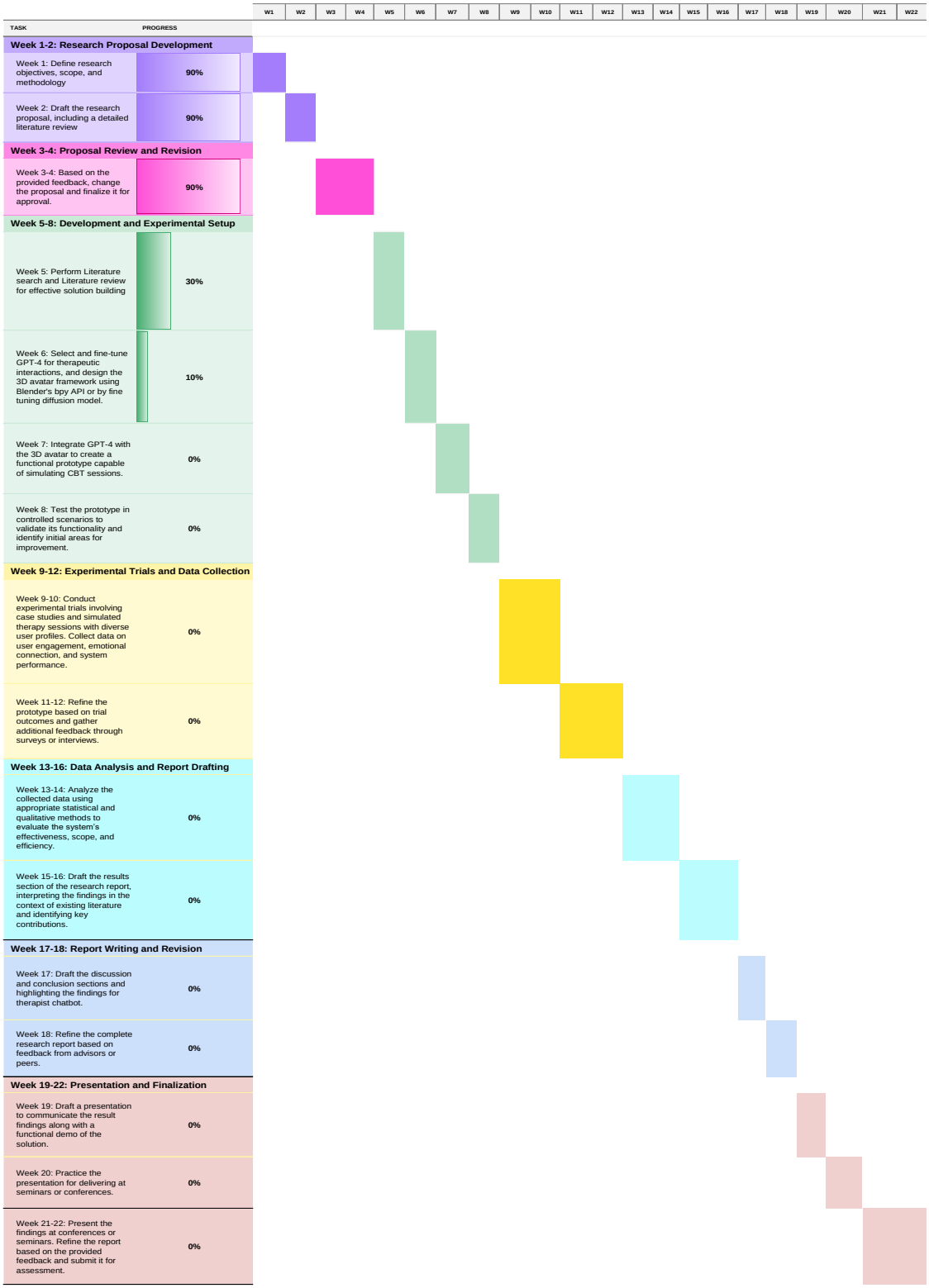

Figure 2: Project Plan

This plan provides a 22-week detailed structured timeline for each phase of the research process. It ensures each step has an adequate time for proposal development, data collection, analysis, writing, presentation, and finalization.

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