

Exploring the Audio Modality in Persuasion Modeling for Social Deduction Games

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Based on “Werewolf Among Us: A Multimodal Dataset for Modeling Persuasion Behaviors in Social Deduction Games”

<https://arxiv.org/pdf/2212.08279>

Abstract

In this paper, we explore the role of audio modality in persuasion modeling within social deduction games. Building upon previous work that demonstrated the value of multimodal approaches combining text and video, we focus specifically on extracting persuasion strategies from audio data. We compare text-only BERT models with Whisper models that leverage both text and audio features. Our experiments show that Whisper-based models combining audio and text can outperform text-only models by 0.5% on average F1 score, suggesting that audio features capture beneficial signals for persuasion detection. Our findings indicate that much of the information gained by video modality can be explained by its audio component.

1 Introduction

Persuasion modeling is a critical component in understanding human communication dynamics and developing conversational agents. Previous research has primarily focused on analyzing persuasion strategies from textual dialogue, with recent advances incorporating visual signals to enhance performance. However, the specific contribution of audio modality in persuasion modeling remains largely unexplored.

Our research builds on the work by Lai et al. [1], who introduced a multimodal dataset for modeling persuasion behaviors in social deduction games. They demonstrated that visual cues can improve persuasion strategy prediction by approximately 0.8% on F1 score compared to text-only models. Our work addresses their call for future research to “explore the role of the audio modality in persuasion modeling and to investigate joint learning of multimodal representations for the social persuasion setting.”

We compare text-only models with audio-enhanced approaches, including BERT-based models and Whisper-based models that use both text and audio. Our models are designed to predict persuasion strategies such as Identity Declaration, Accusation, Interrogation, Call for Action, Defense, and Evidence. Through comprehensive experiments, we demonstrate that audio features provide beneficial signals for persuasion detection and can achieve nearly the same performance gains as those previously observed from video data, falling short by only a small margin.

2 Related Work

2.1 Persuasion Modeling

Research on computational modeling of persuasion has advanced significantly in recent years. Yang et al. [3] and Chen and Yang [4] introduced datasets focusing on persuasion strategies in online platforms. Chawla et al. [2] examined persuasion in simulated dialogue settings through crowdsourcing. However, these datasets predominantly consist of textual data without incorporating multimodal elements.

2.2 Multimodal Social Interaction Analysis

Multimodal approaches to social interaction analysis have gained traction with works like Xu et al. [5] and Li et al. [6] on multimodal sentiment analysis. Bai et al. [7] applied multimodal methods to predict debate outcomes from TV shows. The Ego4D Social benchmark [8] includes tasks for identifying

social interactions using video and audio. While these approaches incorporate multiple modalities, they typically do not focus specifically on persuasion strategies.

2.3 Audio Processing for Social Interaction

The Whisper model [9] represents a significant advancement in audio processing, demonstrating robust speech recognition capabilities across various domains. Recent work has begun exploring Whisper’s potential for social interaction understanding beyond simple transcription, though its application to persuasion modeling remains novel.

2.4 Computational Modeling of Deduction Games

Previous research has explored computational models for social deduction games, with Chittaranjan and Hung [10] developing a model for predicting Werewolf game outcomes based on speaking patterns. However, our work uniquely focuses on understanding persuasive strategies in such games from a multimodal perspective, specifically highlighting the audio component.

3 Method

We implement and compare several models to evaluate the contribution of audio modality in persuasion strategy prediction. This section details our model architecture, evaluation metrics, and experimental setup.

3.1 Architecture

Our models fall into two main categories: BERT-based text-only models and Whisper-based models that leverage both text and audio.

3.1.1 BERT-based Models

- **BERT Single-Task (ST):** We fine-tune separate binary classifiers for each persuasion strategy using the BERT-base-uncased model. Each classifier takes as input a prompt containing the strategy definition, previous utterances (context), and the target utterance.
- **BERT Multi-Task Binary-Label (MTBL):** Similar to the single-task model, but we train a single model that can predict any strategy based on the strategy mentioned in the prompt.
- **BERT Multi-Task Multi-Label (MTML):** We train a single model to predict all six persuasion strategies simultaneously. The input is only the previous utterances and target utterance, without any strategy-specific prompt.

The architectural details of these models are shown in Appendix A (Figures 1 and 2).

3.1.2 Whisper-based Models

- **Whisper Yes-No (YN) Models:** We fine-tune the Whisper-small model to generate a "yes" or "no" response to indicate whether the target utterance exhibits the strategy. We implement two variants:
 - **Single-Task (YN ST):** A separate model for each strategy.
 - **Multi-Task Binary-Label (YN MTBL):** A single model for all strategies, where the strategy is specified in the prompt.
- **Whisper Projection Models:** We extend the Whisper-small model with a projection layer that transforms the last token’s logits, followed by a dropout layer and a classification head. We implement three variants:
 - **Single-Task (Proj ST):** A separate model for each strategy.
 - **Multi-Task Binary-Label (Proj MTBL):** A single model for all strategies, where the strategy is specified in the prompt.

- **Multi-Task Multi-Label (Proj MTML):** A single model that predicts all strategies simultaneously without strategy-specific prompting.

All Whisper-based models are trained on both text and audio data, where the audio input corresponds to the utterances in the dialogue context. Detailed architecture diagrams for all Whisper-based models can be found in Appendix A (Figures 3, 4, and 5).

3.2 Evaluation Metrics

Following Chawla et al. [2] and Lai et al. [1], we report:

- F1 score for each persuasion strategy.
- Average F1 score across all strategies.
- Accuracy for each persuasion strategy.
- Average accuracy across all strategies.

3.3 Experimental Setup

We use the Werewolf Among Us dataset [1], which contains dialogue transcriptions and videos from YouTube of people playing the social deduction game "One Night Ultimate Werewolf."

3.3.1 Training Configuration

- Context size: 5 previous utterances (following the optimal setting from Lai et al.).
- BERT learning rate: 3e-5.
- Whisper learning rate: 1e-5, adam β_2 : 0.99, and warmup steps: 200 for stability.
- Training epochs: 10.
- Hardware: 8 TPUs.
- Implementation: JAX/Flax.

For each model configuration, we train with three different random seeds (12, 42, 87). We evaluate on the validation set every 2 epochs and select the checkpoint with the highest F1 score for final evaluation on the test set.

4 Results and Discussion

4.1 Performance Comparison

Tables 1 and 2 present the F1 scores and accuracy for all models, respectively, across the six persuasion strategies and on average.

Table 1: F1 scores (%) for each persuasion strategy and average across all strategies

Method	ID	ACC	INT	CA	DEF	EVI	Avg
BERT ST	80.9±1.0	64.7±1.3	90.0±0.7	75.3±1.3	41.9±1.7	58.5±1.3	68.5±0.5
BERT MTBL	83.2±0.4	67.7±1.3	90.5±0.1	76.5±1.3	42.3±3.5	60.1±1.1	70.4±0.4
BERT MTML	83.5±0.4	67.7±0.7	90.4±0.2	74.9±0.1	44.1±0.4	57.3±0.5	69.7±0.1
Whisper YN ST	82.8±1.5	64.1±1.5	89.8±0.6	77.2±0.6	47.2±0.5	57.7±1.0	69.8±0.1
Whisper YN MTBL	83.4±0.3	66.3±0.3	90.2±0.2	77.1±1.2	48.6±1.6	58.5±0.5	70.9±0.3
Whisper Proj ST	38.4±2.8	33.1±1.0	51.9±2.0	33.8±6.8	21.1±2.8	25.2±2.5	33.9±1.8
Whisper Proj MTBL	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
Whisper Proj MTML	34.0±1.2	29.2±1.5	51.0±1.5	28.3±2.1	24.2±1.3	21.9±2.0	31.5±0.4

ID: Identity Declaration, ACC: Accusation, INT: Interrogation, CA: Call for Action, DEF: Defense, EVI: Evidence

Table 2: Accuracy (%) for each persuasion strategy and average across all strategies

Method	ID	ACC	INT	CA	DEF	EVI	Avg
BERT ST	97.7±0.2	89.4±0.4	96.1±0.2	96.2±0.2	83.1±0.6	92.8±0.3	92.6±0.1
BERT MTBL	98.1±0.1	89.5±0.8	96.3±0.0	96.4±0.3	84.5±1.4	92.6±0.2	92.9±0.3
BERT MTML	98.0±0.0	90.0±0.1	96.3±0.1	96.2±0.1	83.5±0.7	92.3±0.1	92.7±0.6
Whisper YN ST	98.1±0.2	89.1±0.1	96.0±0.2	96.6±0.1	84.4±0.6	93.0±0.2	92.9±0.1
Whisper YN MTBL	98.1±0.0	89.9±0.2	96.2±0.1	96.6±0.1	85.5±0.1	92.4±0.1	93.1±0.0
Whisper Proj ST	94.5±0.3	82.4±0.7	83.6±0.5	92.4±0.4	83.5±0.3	88.4±1.1	87.5±0.4
Whisper Proj MTBL	94.1±0.0	84.7±0.0	80.7±0.0	92.3±0.0	85.7±0.0	90.4±0.0	88.0±0.0
Whisper Proj MTML	94.2±0.1	81.8±0.7	83.6±0.3	92.2±0.2	83.5±0.2	89.4±0.3	87.5±0.4

ID: Identity Declaration, ACC: Accusation, INT: Interrogation, CA: Call for Action, DEF: Defense, EVI: Evidence

4.2 Key Findings

- **Audio improves persuasion detection:** The Whisper Yes-No Multi-Task Binary-Label model achieves the best average performance with 70.9% average F1 score and 93.1% average accuracy, outperforming the best BERT F1 and accuracy models (BERT MTBL and BERT MTML) by 0.5% average F1 score and 0.2% average accuracy, respectively.
- **Audio vs. Visual modality:** In the original paper by Lai et al., incorporating visual features improved average F1 score by 0.8%. Our results suggest that much of this improvement can be attributed to the audio component.
- **Multi-task learning effectiveness:** Both for BERT and Whisper models, multi-task approaches generally outperform single-task models, indicating that joint learning across strategies is beneficial.
- **Strategy-specific insights:** Audio features seem particularly helpful for "Defense" strategy detection, with a 6.3% gain in F1 score compared to the best BERT model (48.6% vs. 44.1%).
- **Projection approach limitations:** The Whisper Projection models performed poorly compared to the Yes-No models. This is likely because Whisper is fundamentally a generative model, and adapting it for classification with a projection layer requires significantly more training data and careful hyperparameter tuning than our experimental setup provided. The Yes-No approach better leverages Whisper’s generative capabilities without requiring extensive architectural modifications.

4.3 Training Convergence Analysis

We tracked the training progression of all models using Weights & Biases (wandb), which allowed us to monitor key metrics such as training loss, evaluation loss, evaluation F1 score, and evaluation accuracy throughout the training process. Figure 6 shows the convergence graph for our best-performing BERT model (MTBL), while Figure 14 shows the same for our best-performing Whisper model (YN MTBL).

The convergence graphs reveal several interesting patterns:

- The Whisper Yes-No models generally reached optimal performance more quickly than their BERT counterparts, suggesting that incorporating audio features may help the model converge faster.
- For difficult strategies like "Defense" and "Evidence," the Whisper-based models showed more stable learning curves, with fewer fluctuations in evaluation metrics during training compared to text-only BERT models.
- The Whisper Projection models exhibited unstable training behavior, with highly fluctuating evaluation metrics, which aligns with our earlier observation about their poor overall performance.

A comprehensive collection of convergence graphs for all model variants and strategies is provided in Appendix C.

4.4 Analysis

The improved performance of the Whisper Yes-No models indicates that audio features capture important cues for persuasion detection. These cues might include tone, emphasis, pauses, and other paralinguistic features that are absent in text-only representations. The particularly strong improvement for the "Defense" strategy suggests that audio features may be especially relevant when people are defending themselves or others, as emotional cues in voice can signal credibility and conviction.

The poor performance of the Whisper Projection models highlights the challenges in adapting generative pre-trained models for classification tasks. Whisper was primarily trained for speech recognition in a generative manner, and repurposing it for classification through projection layers requires retraining parts of the model architecture. In contrast, the Yes-No approach fits more naturally with Whisper's generative training objective, as it simply requires the model to generate a specific token ("yes" or "no"). Future work could explore more extensive pretraining and optimization strategies for the projection-based approaches.

5 Future Work

Future research could explore several promising directions:

5.1 Improved Audio Representation Learning

The Whisper Projection models performed poorly, suggesting room for improvement in how audio representations are used for classification tasks. Future work could investigate:

- Pre-training specialized audio encoders on persuasion-specific tasks.
- Exploring alternative fusion mechanisms between audio and text features.
- Using contrastive learning to align audio and text representations in a shared embedding space.

5.2 Fine-grained Audio Feature Analysis

A detailed analysis of which audio features contribute most to persuasion strategy detection could provide insights into the mechanism behind the performance of such models. This might involve:

- Ablation studies on different audio features (pitch, energy, speech rate).
- Attention visualization to identify when the model attends to audio versus text.
- Probing experiments to understand what persuasion-relevant information is encoded in different layers.

5.3 Cross-domain Application

Testing the audio-enhanced persuasion models on other domains could help understand their generalizability:

- Political debates.
- Sales negotiations.
- Therapeutic conversations.

6 Limitations & Broader Impact

6.1 Limitations

- **Dataset specificity:** Our models are trained and evaluated on the Werewolf Among Us dataset, which features a specific game setting that may not generalize to other conversational contexts.
- **Hyperparameter tuning:** The Whisper Projection models might perform better with extensive hyperparameter tuning, which was beyond the scope of this study.

- **Computational requirements:** Training Whisper-based models requires significant computational resources, making thorough hyperparameter optimization and architecture search prohibitively expensive. This limits our ability to fully explore potential modifications that might improve performance.

6.2 Broader Impact

- **Positive applications:** Models that detect persuasion strategies from multimodal inputs could enhance communication training, assist negotiation coaching, and improve conversational agents’ authenticity.
- **Potential risks:** The same technology could be misused for manipulation detection avoidance, targeted persuasion, and more. Careful ethical guidelines should accompany deployment of such models.
- **Privacy considerations:** Audio analysis raises privacy concerns beyond text analysis, as voice contains biometric information and potentially sensitive paralinguistic cues.
- **Bias and fairness:** Persuasion strategies vary across cultures and demographics, and models may perform differently across speaker groups, potentially reinforcing biases if deployed without consideration for diverse populations.

6.3 Ethical Considerations

As noted by Lai et al., persuasion skills can be used for both beneficial and harmful purposes. Our research aims to understand human behavior in social settings rather than to encourage deception or manipulation. Applications of this technology should be subject to ethical review and appropriate safeguards.

References

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A Model Architectures

This appendix contains detailed figures of the model architectures used in our experiments.

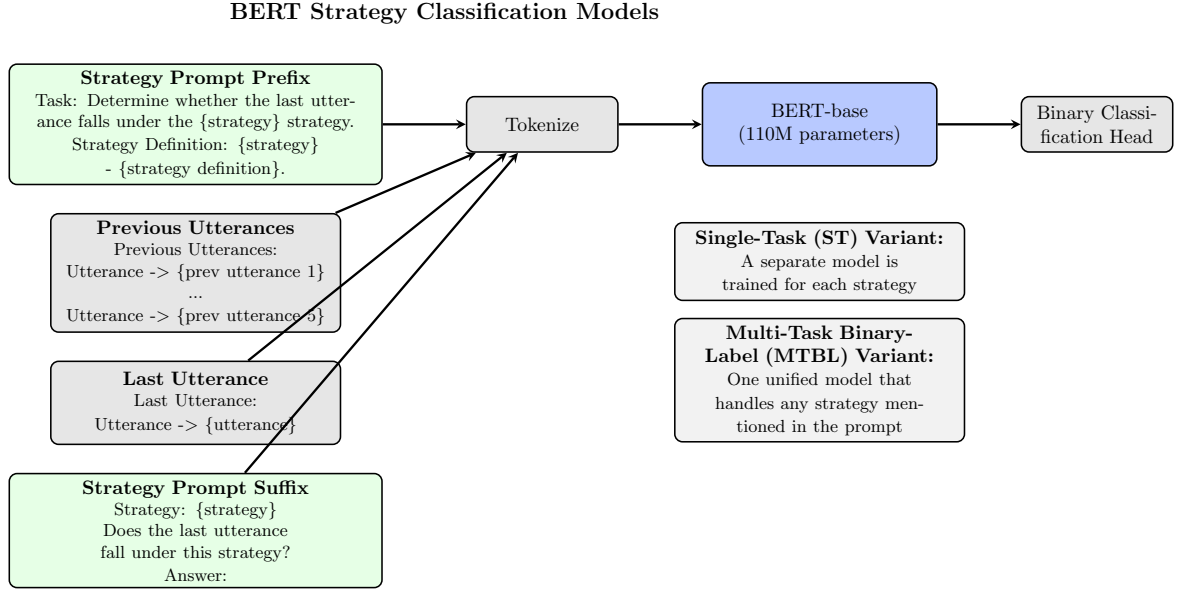


Figure 1: Architecture of the BERT Single-Task (ST) and Multi-Task Binary-Label (MTBL) models. The ST variant uses a separate model for each of the six persuasion strategies, while the MTBL variant uses a single model that handles all strategies based on which one is specified in the prompt.

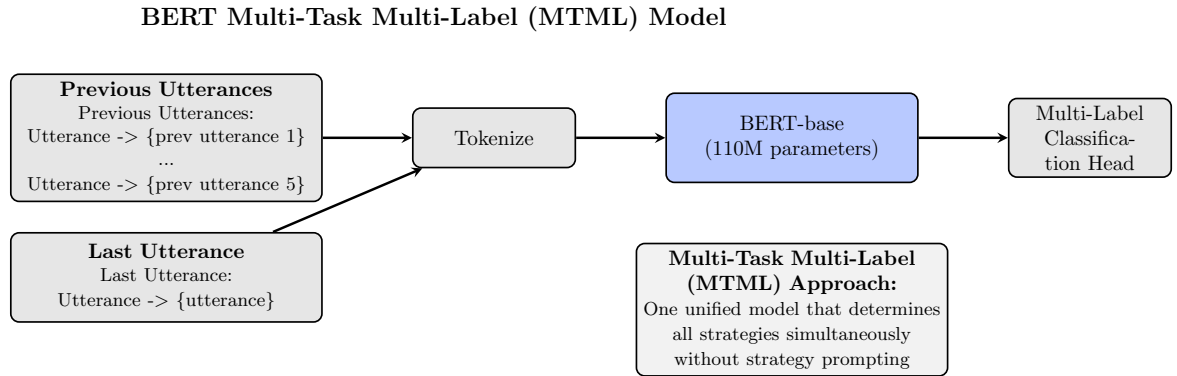


Figure 2: Architecture of the BERT Multi-Task Multi-Label (MTML) model. A single model simultaneously predicts all six strategies without strategy-specific prompting.

Whisper Yes/No Strategy Classification Models

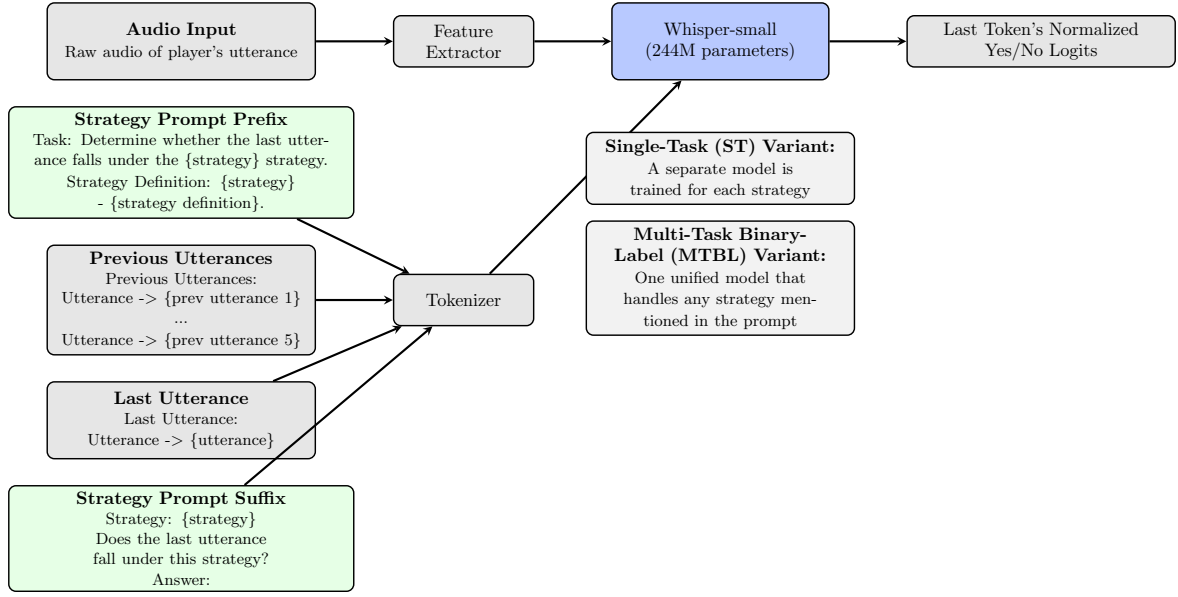


Figure 3: Architecture of the Whisper Yes-No Single-Task (YN ST) and Multi-Task Binary-Label (YN MTBL) models. These models process both audio and text inputs and use the last token's normalized yes/no logits to predict strategy presence.

Whisper Projection Strategy Classification Models

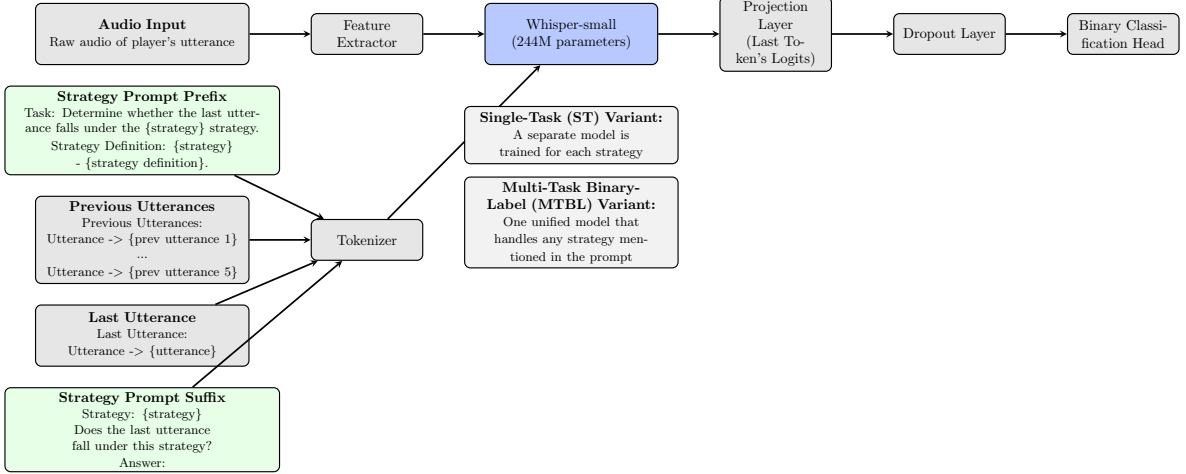


Figure 4: Architecture of the Whisper Projection Single-Task (Proj ST) and Multi-Task Binary-Label (Proj MTBL) models. These models extend Whisper with additional layers: a projection layer operating on the last token's logits, a dropout layer, and a binary classification head.

Whisper Projection Multi-Task Multi-Label (MTML) Model

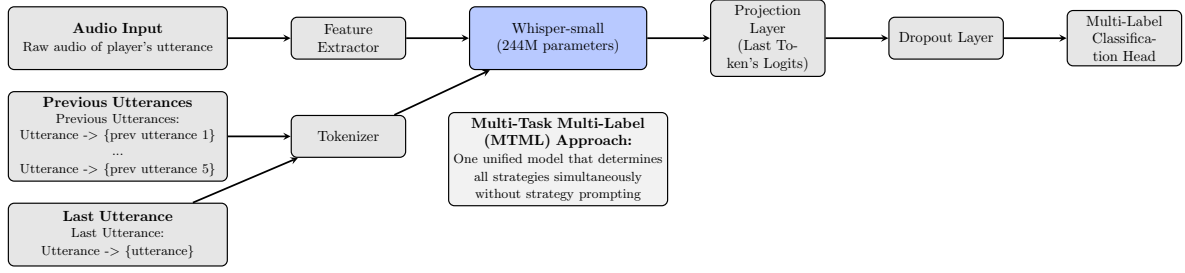


Figure 5: Architecture of the Whisper Projection Multi-Task Multi-Label (Proj MTML) model. This model simultaneously predicts all strategies without strategy-specific prompting, using a multi-label classification head.

B Code and Resources

This section provides information about the code repository, dataset, and other resources used in this research.

B.1 Code Repository

Our implementation is available on GitHub at <https://github.com/alonbechuk/PersuasionGames>. The repository contains all the code necessary to reproduce our experiments, including the BERT and Whisper model implementations, training scripts, and evaluation code.

B.2 Dataset

We used the Werewolf Among Us dataset, which is available on Hugging Face at <https://huggingface.co/datasets/bolinlai/Werewolf-Among-Us>. This dataset contains multimodal recordings of social deduction games with annotations for persuasion strategies, allowing us to train and evaluate our models on real-world persuasion behaviors.

B.3 Implementation Details

The implementation is our original work, with inspiration, ideas, and some code snippets adapted from:

- The original Werewolf Among Us GitHub repository (github.com/SALT-NLP/PersuasionGames), from which we forked our project.
- Hugging Face Transformers Flax examples ([github.com/huggingface/transformers/examples/flax](https://github.com/huggingface/transformers/tree/main/examples/flax)), which provided templates for implementing efficient JAX/Flax-based models.

We used Weights & Biases (wandb) for experiment tracking, visualization of learning metrics, and telemetry throughout our training process, which helped us monitor model performance and compare different approaches.

C Convergence Graphs

This section presents the training convergence graphs for our models, captured using Weights & Biases. Each graph shows the progression of training loss, evaluation loss, evaluation F1 score, and evaluation accuracy throughout the training process.

C.1 BERT Models

C.1.1 Multi-Task Models

Bert Multi-Task Binary-Label

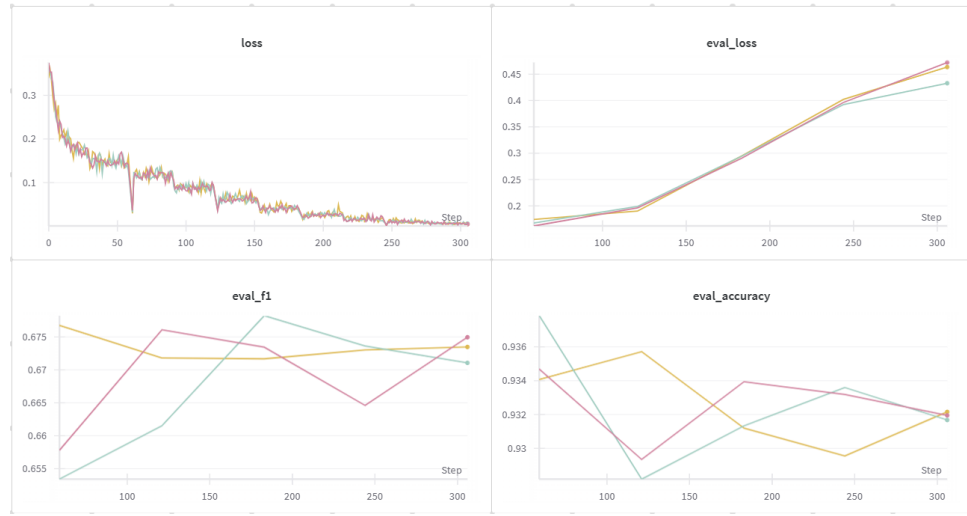


Figure 6: Convergence graph for BERT Multi-Task Binary-Label model.

Bert Multi-Task Multi-Label

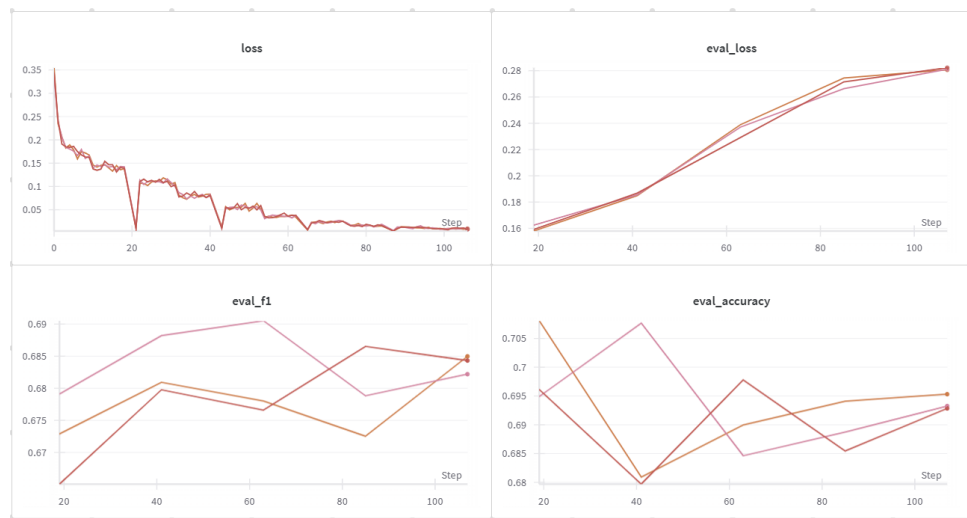


Figure 7: Convergence graph for BERT Multi-Task Multi-Label model.

C.1.2 Single-Task Models by Strategy

Bert Identity Declaration

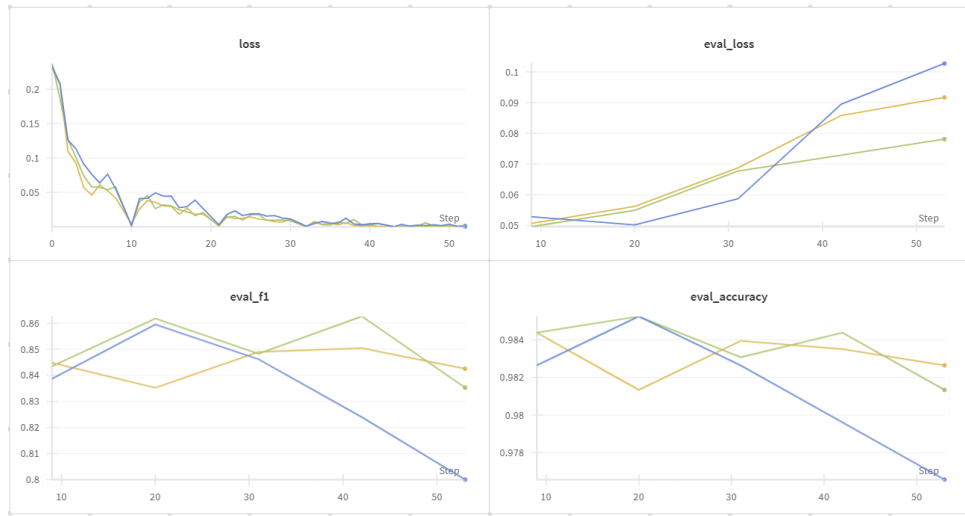


Figure 8: Convergence graph for BERT Single-Task Identity Declaration model.

Bert Accusation

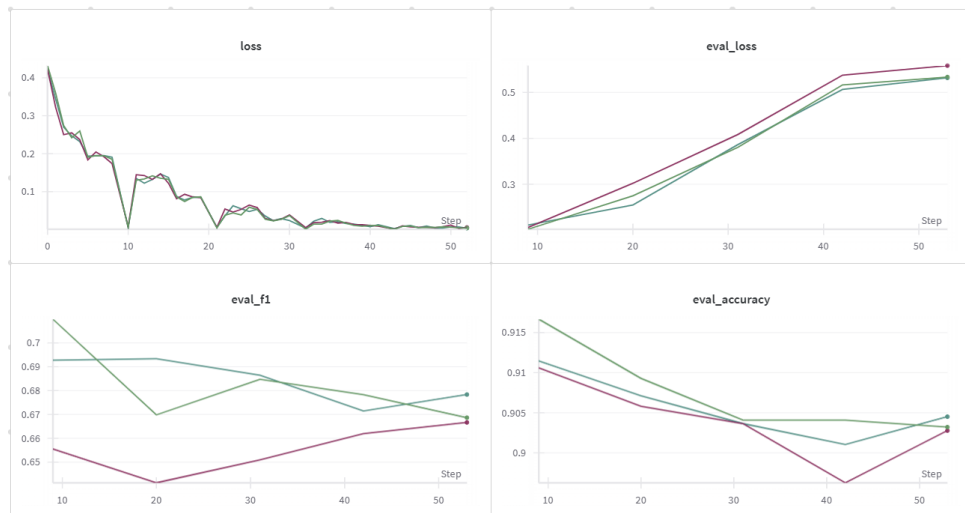


Figure 9: Convergence graph for BERT Single-Task Accusation model.

Bert Interrogation

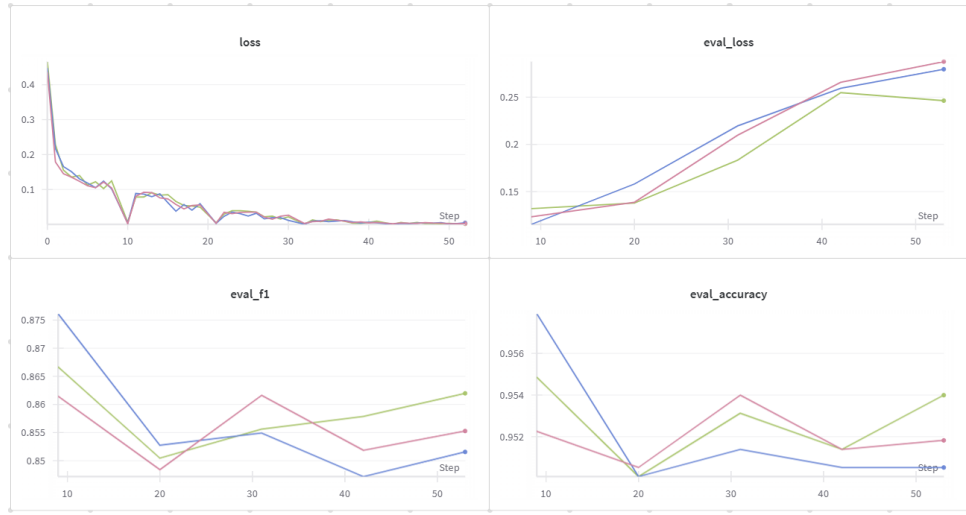


Figure 10: Convergence graph for BERT Single-Task Interrogation model.

Bert Call for Action

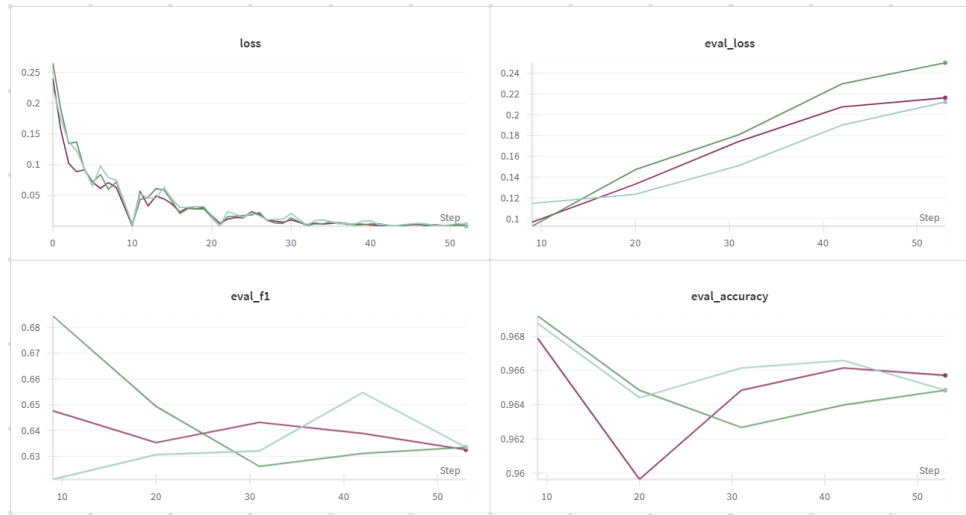


Figure 11: Convergence graph for BERT Single-Task Call for Action model.

Bert Defense

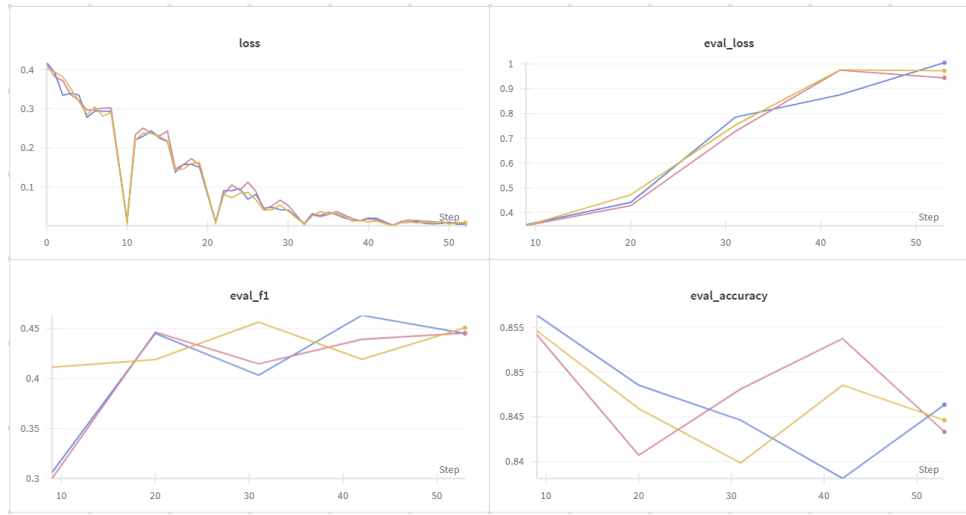


Figure 12: Convergence graph for BERT Single-Task Defense model.

Bert Evidence

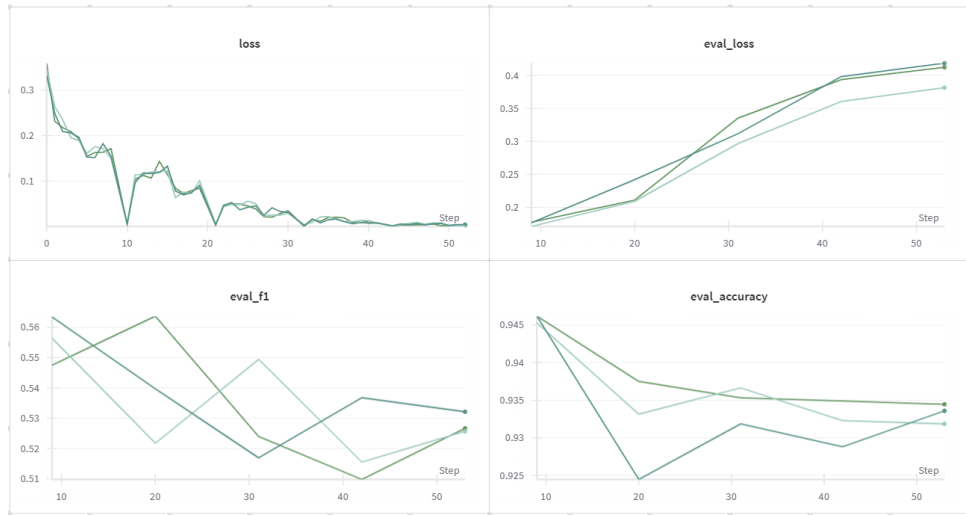


Figure 13: Convergence graph for BERT Single-Task Evidence model.

C.2 Whisper Yes-No Models

C.2.1 Multi-Task Model

Whisper Yes-No Multi-Task Binary-Label

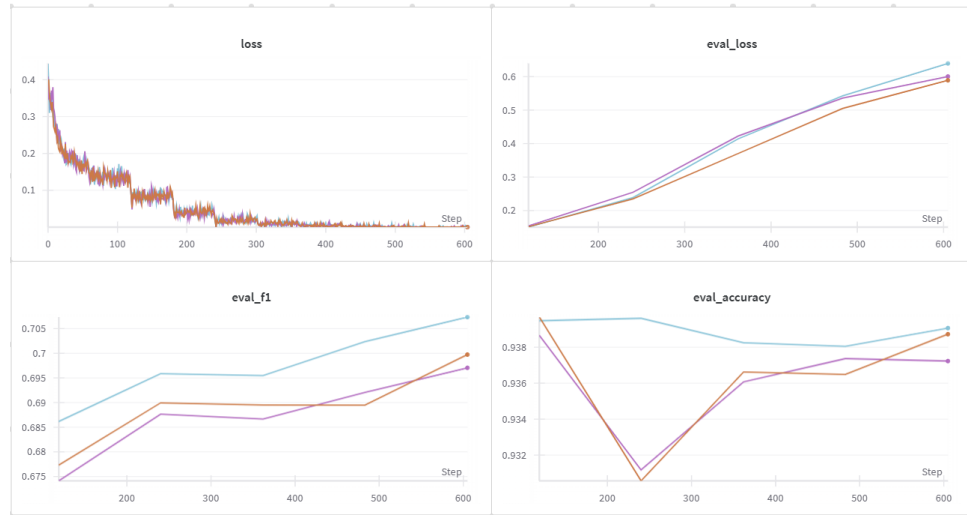


Figure 14: Convergence graph for Whisper Yes-No Multi-Task Binary-Label model.

C.2.2 Single-Task Models by Strategy

Whisper Yes-No Identity Declaration

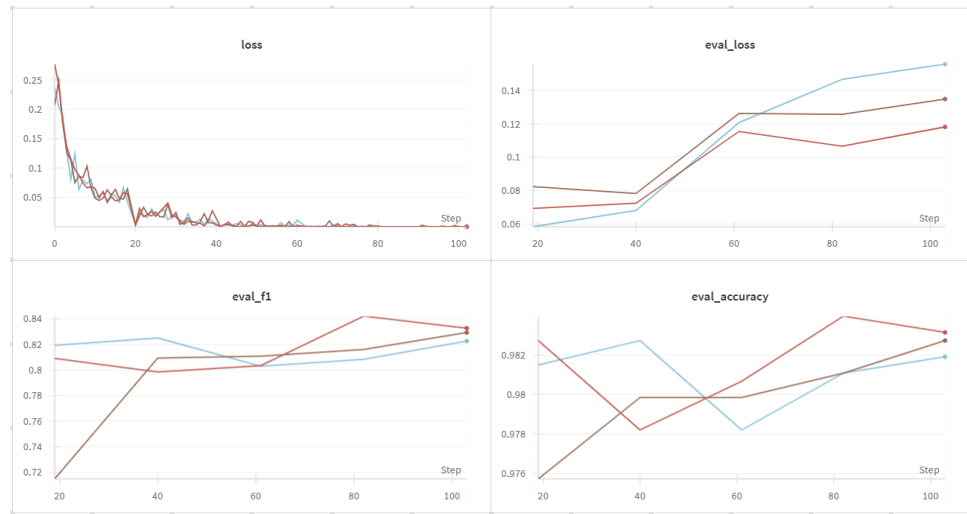


Figure 15: Convergence graph for Whisper Yes-No Single-Task Identity Declaration model.

Whisper Yes-No Accusation

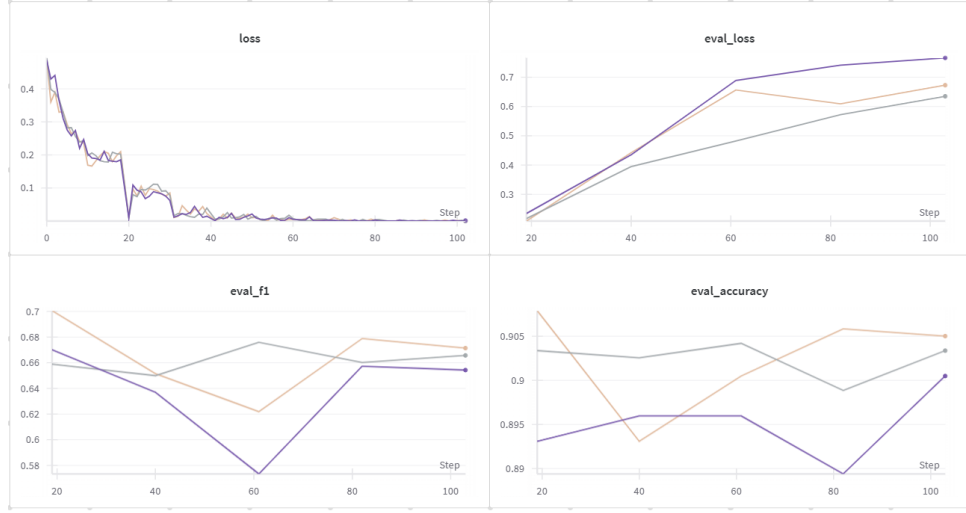


Figure 16: Convergence graph for Whisper Yes-No Single-Task Accusation model.

Whisper Yes-No Interrogation

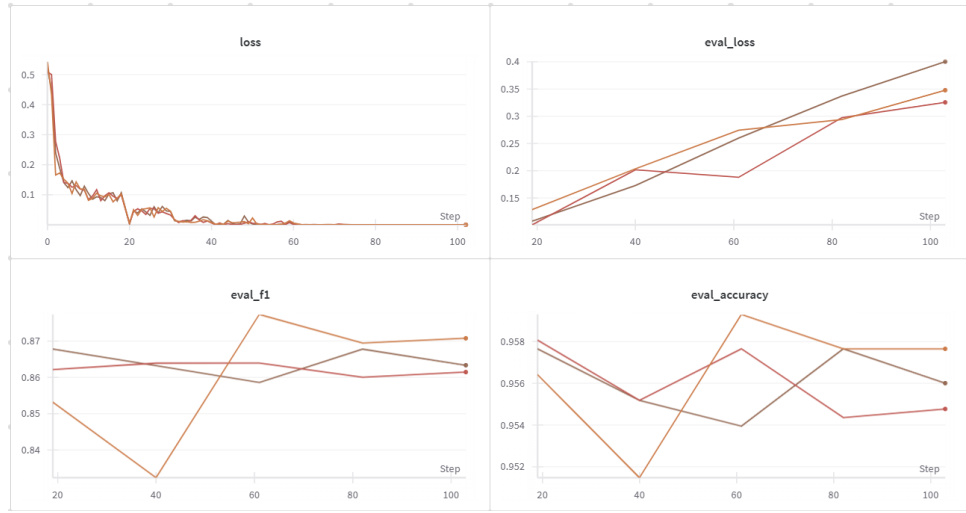


Figure 17: Convergence graph for Whisper Yes-No Single-Task Interrogation model.

Whisper Yes-No Call for Action

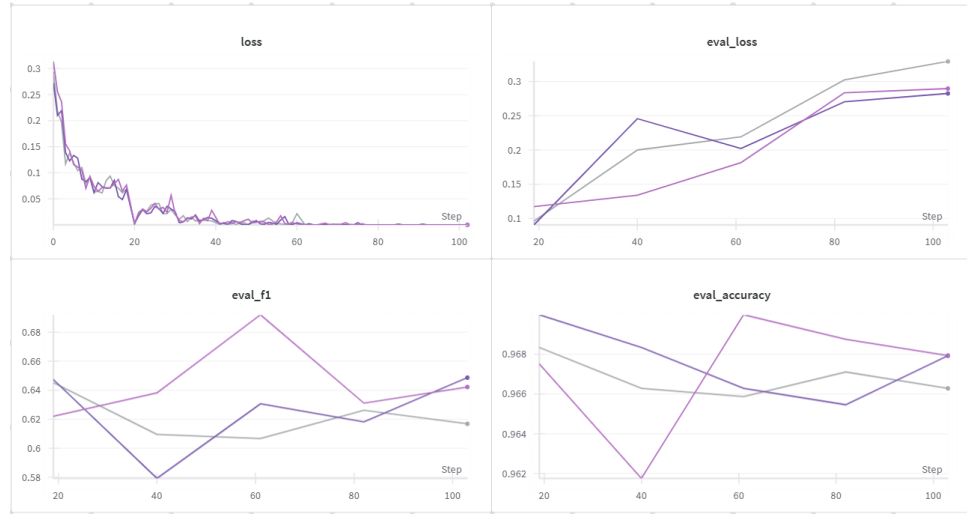


Figure 18: Convergence graph for Whisper Yes-No Single-Task Call for Action model.

Whisper Yes-No Defense

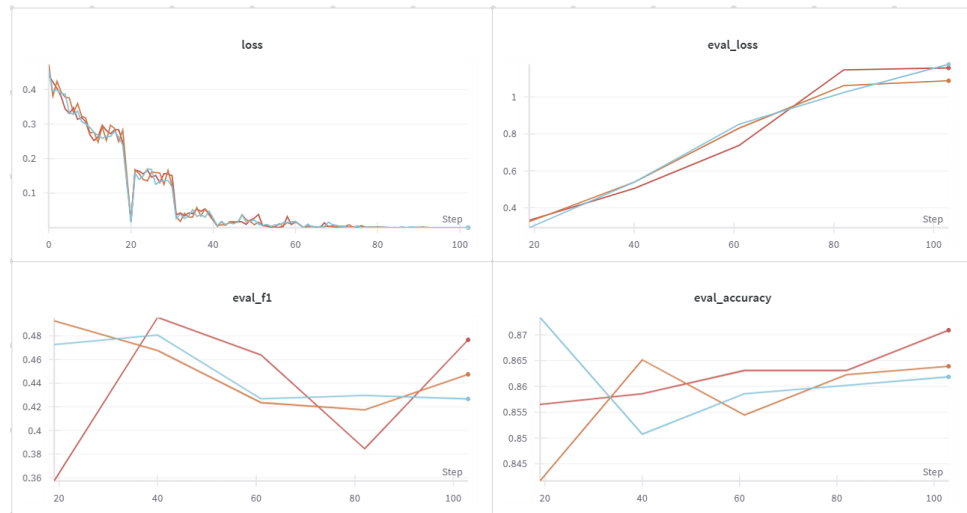


Figure 19: Convergence graph for Whisper Yes-No Single-Task Defense model.

Whisper Yes-No Evidence

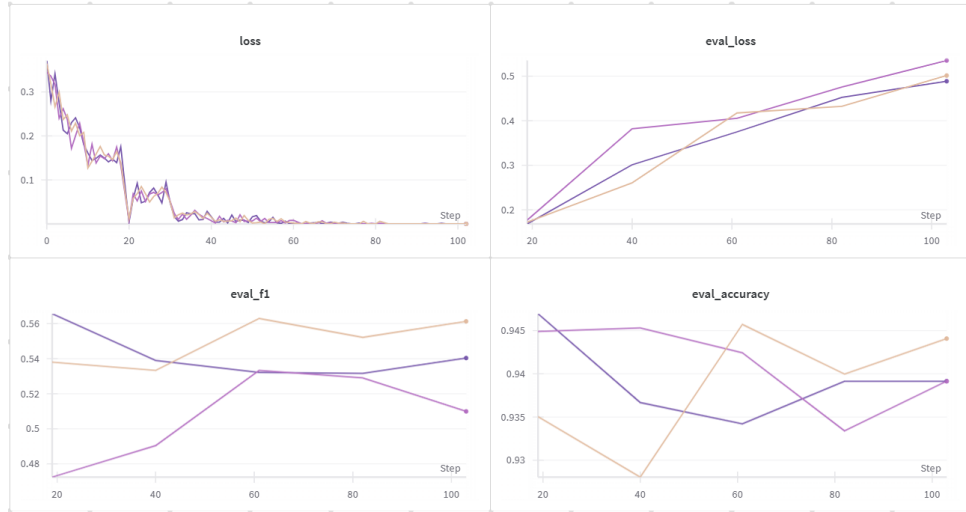


Figure 20: Convergence graph for Whisper Yes-No Single-Task Evidence model.

C.3 Whisper Projection Models

C.3.1 Multi-Task Models

Whisper Projection Multi-Task Binary-Label

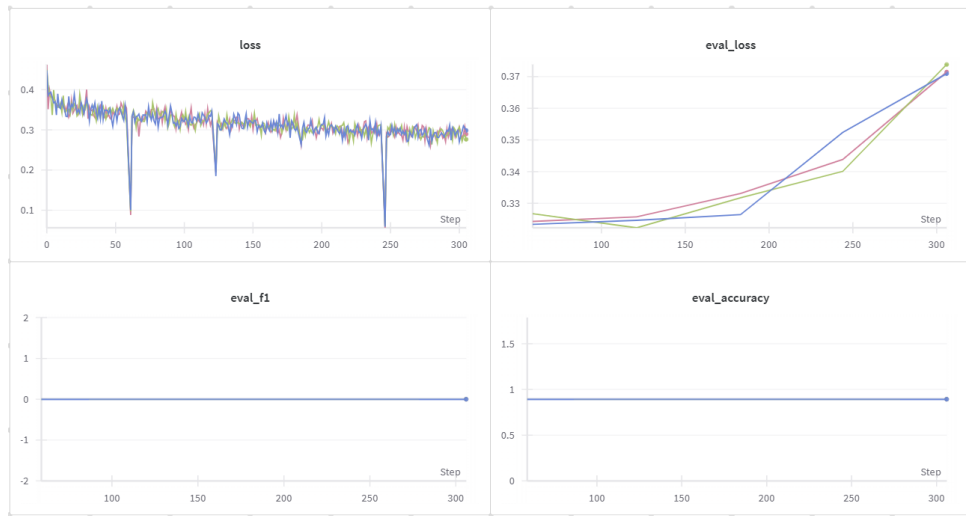


Figure 21: Convergence graph for Whisper Projection Multi-Task Binary-Label model.

Whisper Projection Multi-Task Multi-Label

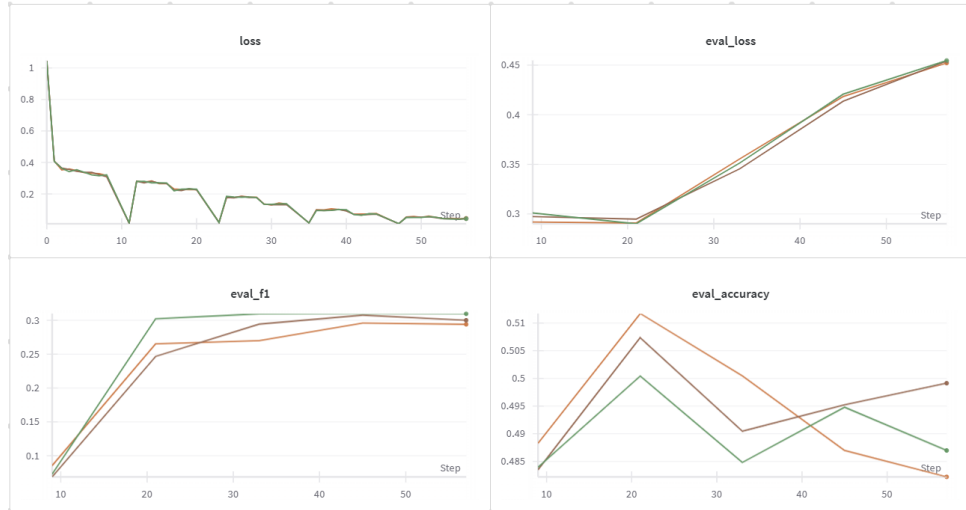


Figure 22: Convergence graph for Whisper Projection Multi-Task Multi-Label model.

C.3.2 Single-Task Models by Strategy

Whisper Projection Identity Declaration

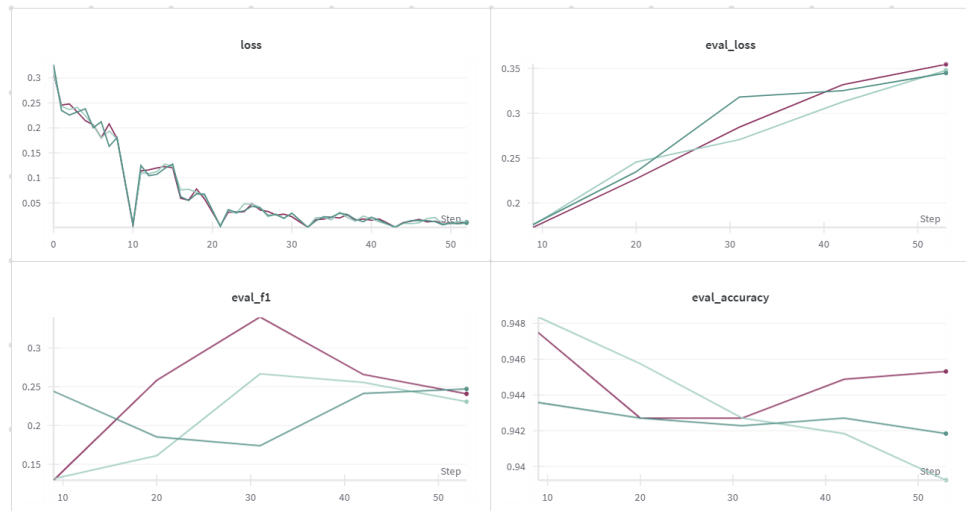


Figure 23: Convergence graph for Whisper Projection Single-Task Identity Declaration model.

Whisper Projection Accusation

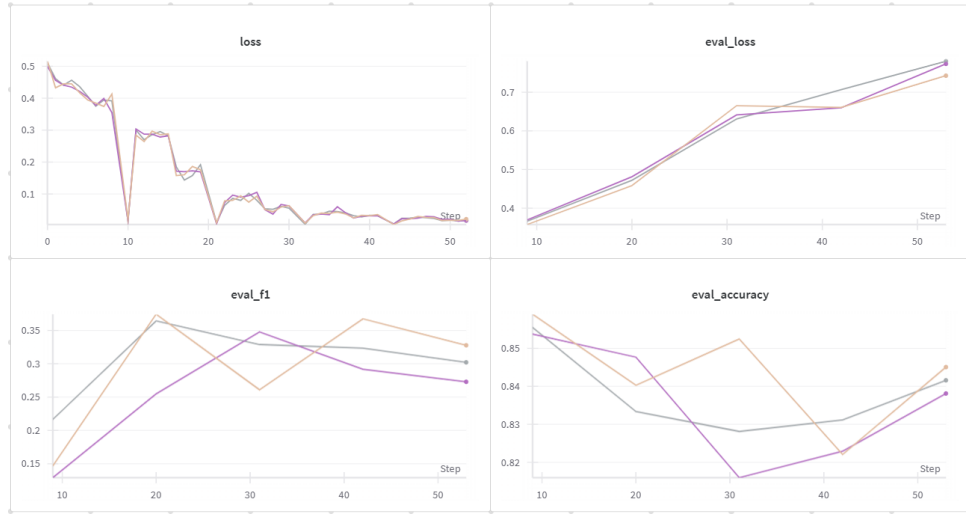


Figure 24: Convergence graph for Whisper Projection Single-Task Accusation model.

Whisper Projection Interrogation

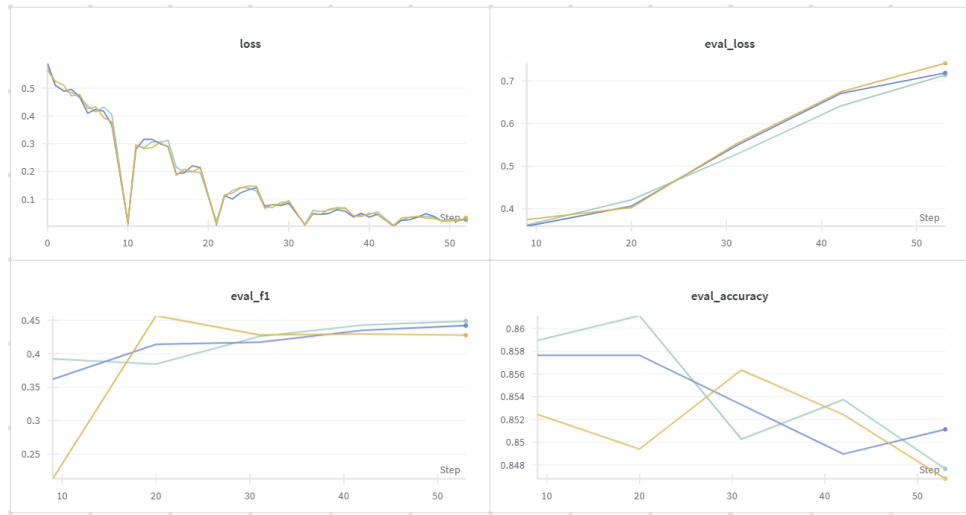


Figure 25: Convergence graph for Whisper Projection Single-Task Interrogation model.

Whisper Projection Call for Action

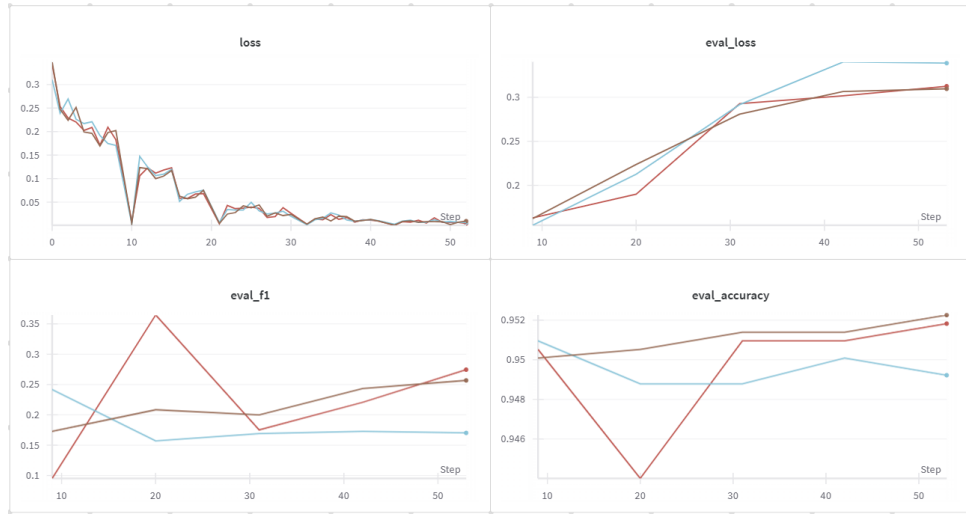


Figure 26: Convergence graph for Whisper Projection Single-Task Call for Action model.

Whisper Projection Defense

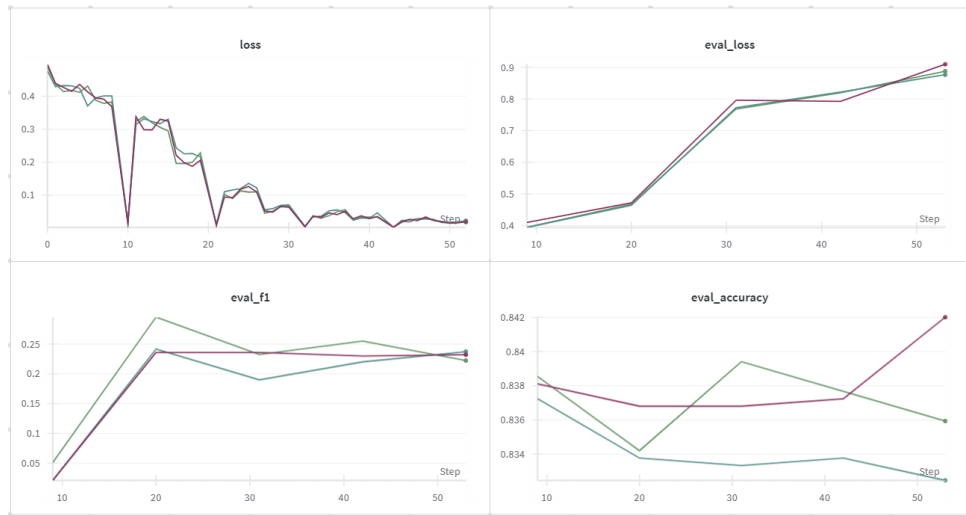


Figure 27: Convergence graph for Whisper Projection Single-Task Defense model.

Whisper Projection Evidence

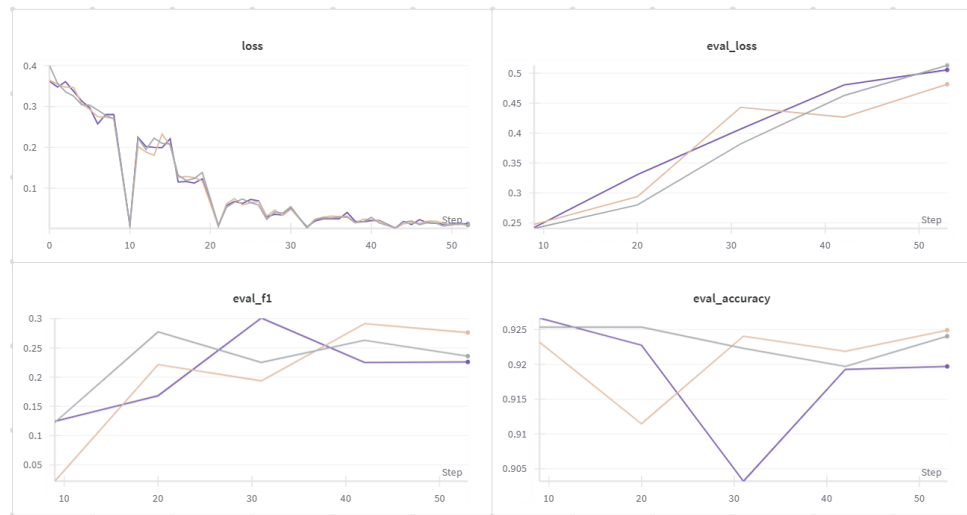


Figure 28: Convergence graph for Whisper Projection Single-Task Evidence model.