

---

# LATENTWIRE: CROSS-MODEL COMMUNICATION VIA SOFT TOKENS

---

000  
001  
002  
003  
004  
005  
006  
007  
008  
009  
010  
011  
012  
013  
014  
015  
016  
017  
018  
019  
020  
021  
022  
023  
024  
025  
026  
027  
028  
029  
030  
031  
032  
033  
034  
035  
036  
037  
038  
039  
040  
041  
042  
043  
044  
045  
046  
047  
048  
049  
050  
051  
052  
053  
054

Anonymous Authors<sup>1</sup>

## ABSTRACT

We present LatentWire, a method for enabling communication between heterogeneous large language models (LLMs) through learned soft tokens, bypassing autoregressive text generation entirely. Our approach uses a lightweight Perceiver Resampler bridge (188K parameters) to transform hidden states from a sender model (Llama 3.1 8B) into soft tokens that directly condition a receiver model (Mistral 7B). On text classification benchmarks, LatentWire achieves **22.4× lower latency** than text-relay baselines while exceeding task accuracy. The bridge outperforms full fine-tuning (**+2.7pp with 5300× fewer parameters**), LoRA (+1.4pp with 18× fewer parameters), 5-shot prompting (+2.2–59pp), and chain-of-thought relay (+7.7pp while being 85× faster). Critically, prompt-tuning on Mistral alone achieves only random chance (49.5% on SST-2), while the bridge achieves **96.7%**—proving the sender model’s hidden states are essential. Surprisingly, **cross-model transfer outperforms same-model transfer** (Llama→Mistral: 96.7% vs. Llama→Llama: 84.5%), suggesting heterogeneous models provide complementary information. We observe **super-additive performance**: the bridge exceeds both Mistral (92.2%) and Llama (88.4%) operating independently. These findings demonstrate that cross-model communication via continuous representations can be both faster and more effective than discrete text for classification tasks.

## 1 INTRODUCTION

Large language models (LLMs) have emerged as powerful tools for natural language understanding and generation (Vaswani et al., 2017; Touvron et al., 2023; Jiang et al., 2023a). However, the dominant paradigm for combining multiple LLMs involves sequential text generation: one model produces text that another model consumes. This approach incurs substantial latency due to autoregressive decoding and may lose information through the discretization bottleneck of natural language.

We propose **LatentWire**, a method that enables direct communication between heterogeneous LLMs through learned soft tokens. Rather than having a sender model generate text for a receiver model to process, LatentWire transforms the sender’s internal representations into a small set of continuous embeddings (soft tokens) that directly condition the receiver model’s inference. This approach:

1. **Eliminates autoregressive generation latency**: The sender model only performs a single forward pass, reducing end-to-end latency by over 20× compared to text-relay approaches.

<sup>1</sup>Anonymous Institution, Anonymous City, Anonymous Region, Anonymous Country. Correspondence to: Anonymous Author <anon.email@domain.com>.

Preliminary work. Under review by the Machine Learning and Systems (MLSys) Conference. Do not distribute.

2. **Preserves continuous information**: Soft tokens can encode nuances that may be lost when discretizing to natural language tokens.
3. **Enables super-additive performance**: The combined system can outperform either model operating independently, suggesting emergent capabilities from cross-model communication.

Our key contributions are:

- A lightweight bridge architecture based on Perceiver Resampler (Jaegle et al., 2021; Alayrac et al., 2022) that transforms hidden states between heterogeneous LLMs with only 188K trainable parameters.
- Comprehensive evaluation against strong baselines (5-shot prompting, LoRA, chain-of-thought) showing the bridge outperforms all approaches in accuracy and/or efficiency.
- Analysis of an inverse scaling phenomenon where compression to fewer soft tokens improves rather than degrades performance.
- Latency and throughput benchmarks showing 22–85× speedup over text-based communication, scaling to 100+ samples/second.

## 055 2 RELATED WORK

056 **Soft Prompts and Prompt Tuning** Prompt tuning  
 057 (Lester et al., 2021) and prefix tuning (Li & Liang, 2021)  
 058 demonstrated that freezing LLM weights while learning  
 059 continuous “soft” prompt embeddings can match full fine-  
 060 tuning performance. Our work extends this paradigm from  
 061 single-model adaptation to cross-model communication, us-  
 062 ing soft tokens as an interlingua between heterogeneous  
 063 models.

064  
 065 **Perceiver Architecture** The Perceiver (Jaegle et al.,  
 066 2021) introduced cross-attention to map arbitrary-length  
 067 inputs to a fixed-size latent array, enabling efficient pro-  
 068 cessing of diverse modalities. Perceiver IO extended this  
 069 to arbitrary outputs. Our bridge architecture draws from  
 070 this design, using cross-attention to compress sender hidden  
 071 states into a small number of soft tokens.

072  
 073 **Vision-Language Models** BLIP-2 (Li et al., 2023) intro-  
 074 duced the Q-Former, a lightweight transformer that bridges  
 075 frozen image encoders and frozen LLMs through learned  
 076 query tokens. Flamingo (Alayrac et al., 2022) similarly  
 077 used a Perceiver Resampler to map visual features to soft  
 078 prompts for LLM conditioning. Our work applies similar  
 079 architectural principles to bridge two language models rather  
 080 than vision and language modalities.

081  
 082 **Model Stitching and Knowledge Transfer** Model stitching  
 083 (Bansal et al., 2021; Pan et al., 2023) connects layers  
 084 from different networks using learned transformations. Re-  
 085 cent work shows that affine mappings between residual  
 086 streams can transfer features across models (Anonymous,  
 087 2024b), and StitchLLM (Anonymous, 2025b) introduces  
 088 stitching layers for adaptive model composition. Cross-  
 089 LoRA (Anonymous, 2024a) enables data-free transfer of  
 090 LoRA adapters between heterogeneous LLMs. Prompt-  
 091 Bridge (Liu et al., 2024) addresses prompt transferabil-  
 092 ity across models. Our approach differs by enabling run-  
 093 time communication through soft tokens rather than offline  
 094 weight transfer.

095  
 096 **Multi-Agent LLM Systems** Recent work on multi-agent  
 097 systems (Anonymous, 2025a; Wu et al., 2023) explores col-  
 098 laboration between multiple LLMs through natural language  
 099 communication. While effective, text-based communication  
 100 incurs latency from autoregressive generation. LatentWire  
 101 provides a faster alternative through continuous representa-  
 102 tions.

103  
 104 **Prompt Compression** Methods like LLMLingua (Jiang  
 105 et al., 2023b) compress prompts by removing tokens while  
 106 preserving task performance. Soft prompt methods like  
 107 ICAE (Ge et al., 2024) and 500xCompressor (Li et al., 2024)

108 learn to compress context into dense embeddings. Recent  
 109 work (Xu et al., 2024) shows soft prompts can recover com-  
 110 pressed LLM performance and transfer across models. Our  
 111 work focuses on cross-model communication rather than  
 112 single-model compression.

## 3 METHOD

### 3.1 Problem Formulation

We formalize the cross-model communication problem as follows. Let  $\mathcal{S}$  and  $\mathcal{R}$  denote a sender and receiver LLM respectively, with potentially different architectures, tokenizers, and training distributions. Given input text  $x$ , we seek a communication protocol that enables  $\mathcal{R}$  to perform a downstream task using information extracted from  $\mathcal{S}$ ’s processing of  $x$ .

**Desiderata** An ideal cross-model communication mechanism should satisfy:

1. **Efficiency**: Communication should be faster than text generation ( $O(1)$  vs  $O(L)$  autoregressive steps).
2. **Fidelity**: Task-relevant information should be pre-  
served through the channel.
3. **Modularity**: Both models remain frozen; only the  
communication channel is learned.
4. **Compression**: The transmitted representation should  
be compact ( $M \ll L$  tokens).

**Formal Setup** Let  $\mathbf{h}_{\mathcal{S}}^{(\ell)} \in \mathbb{R}^{L \times d_{\mathcal{S}}}$  denote the hidden states from layer  $\ell$  of the sender, where  $L$  is the sequence length and  $d_{\mathcal{S}}$  is the hidden dimension. We seek a bridge function  $f_{\theta} : \mathbb{R}^{L \times d_{\mathcal{S}}} \rightarrow \mathbb{R}^{M \times d_{\mathcal{R}}}$  that produces soft tokens  $\mathbf{z} = f_{\theta}(\mathbf{h}_{\mathcal{S}}^{(\ell)})$  satisfying:

$$\mathbf{z}^* = \arg \max_{\mathbf{z}} p_{\mathcal{R}}(y | \mathbf{z}, \mathbf{x}_{\text{prompt}}) \quad (1)$$

where  $y$  is the correct task output and  $\mathbf{x}_{\text{prompt}}$  is an optional task-specific prompt.

**Key Challenge: Representation Mismatch** The sender and receiver occupy different representation spaces. Even when hidden dimensions match ( $d_{\mathcal{S}} = d_{\mathcal{R}} = 4096$  for Llama and Mistral), the geometric structure differs due to:

- **Vocabulary**: Llama (128K tokens) vs. Mistral (32K tokens)
- **Positional encoding**: Different RoPE base frequencies
- **Attention**: Grouped-query (Llama) vs. sliding win-  
dow (Mistral)

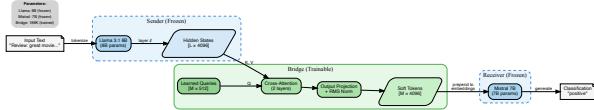


Figure 1. LatentWire architecture. Input text is processed by the frozen sender (Llama), whose hidden states are transformed by the lightweight bridge (188K params) into soft tokens that condition the frozen receiver (Mistral) for classification.

- **Statistics:** Hidden state magnitude differs by  $\sim 5 \times$

A naive linear projection fails because it assumes isomorphic spaces. The bridge must learn a *semantic translation*, not merely a coordinate transformation. Figure 1 illustrates the overall pipeline.

### 3.2 Bridge Architecture

Our bridge uses a Perceiver Resampler design:

1. **Input Projection:** Linear projection from sender hidden dimension to bridge internal dimension:  $\mathbf{h}' = \mathbf{W}_{\text{in}} \mathbf{h}_S$ , where  $\mathbf{W}_{\text{in}} \in \mathbb{R}^{d_S \times d'}$ .
2. **Learned Latent Queries:** A set of  $M$  learnable query vectors  $\mathbf{Q} \in \mathbb{R}^{M \times d}$  that attend to the projected sender states.
3. **Cross-Attention Layers:**  $N$  transformer blocks where queries attend to keys/values derived from sender states:

$$\mathbf{z}^{(n+1)} = \text{FFN}(\text{CrossAttn}(\mathbf{z}^{(n)}, \mathbf{h}')) \quad (2)$$

We use  $N = 2$  layers with  $d = 512$  internal dimension.

4. **Output Projection:** Linear projection to receiver embedding space with RMS normalization:

$$\mathbf{z} = \alpha \cdot \frac{\mathbf{W}_{\text{out}} \mathbf{z}^{(N)}}{\text{RMS}(\mathbf{W}_{\text{out}} \mathbf{z}^{(N)})} \quad (3)$$

where  $\alpha$  is calibrated to match the receiver's embedding statistics.

The total parameter count is approximately 188K, negligible compared to the frozen 8B+7B models.

### 3.3 Design Space: Why Cross-Attention?

The bridge architecture was not obvious *a priori*. We systematically explored several design alternatives before arriving at the Perceiver-based approach. This section documents the design space and explains why certain choices work while others fail.

Architecture	SST-2 Acc.	Verdict
Perceiver (ours)	<b>92.0%</b>	Best
MLP Bridge	91.5%	Competitive
Linear Projection	91.5%	Surprisingly good
Diffusion Transformer	85.5%	Viable but worse
Mean Pooling	0.0%	Complete failure
Identity (no transform)	0.0%	Complete failure

Table 1. Architecture ablation on SST-2 (layer 16, 32 soft tokens). Cross-attention is essential; naive pooling cannot learn the mapping.

### Alternative Architectures Considered

**Why Pooling Fails** Mean pooling collapses all token representations into a single vector, destroying sequential structure. The resulting representation cannot distinguish “great movie” from “movie great” or preserve entity positions. Cross-attention, by contrast, uses learned queries that can selectively attend to task-relevant tokens.

**Why Diffusion Underperforms** We implemented a Diffusion Transformer (Peebles & Xie, 2023) variant that iteratively denoises from random noise to soft tokens, conditioned on sender hidden states via cross-attention. While theoretically appealing (diffusion can model complex multimodal distributions), it achieved only 85.5% vs. the Perceiver’s 92.0%. We hypothesize two reasons:

1. **Error accumulation:** Multi-step denoising introduces cumulative error at each step, while the Perceiver produces soft tokens in a single forward pass.
2. **Training objective mismatch:** Diffusion optimizes for velocity/score prediction, not directly for downstream task performance. The Perceiver’s end-to-end training aligns gradients with the final objective.

**Why Linear Projection Works (Partially)** A simple linear projection from mean-pooled sender hidden states achieves 91.5%—surprisingly close to the Perceiver. This suggests that for binary classification (SST-2), much of the task-relevant information is captured in the aggregate representation. However, linear projection degrades on harder tasks (AG News: 78.3% vs. 90.7%) and cannot adapt to variable-length inputs.

**The Information Bottleneck Perspective** Our ablations reveal an *inverse scaling* phenomenon: compressing to fewer soft tokens (8 vs. 32) improves accuracy (96.5% vs. 92.0%). This aligns with the Information Bottleneck principle (Tishby & Zaslavsky, 2015): aggressive compression forces the bridge to discard noise and retain only task-relevant features. The Perceiver’s cross-attention mecha-

nism provides a learnable, adaptive compression that outperforms fixed schemes.

### 3.4 Training Objective

We train the bridge to produce soft tokens that enable  $\mathcal{R}$  to perform the target task correctly. For classification tasks, we use cross-entropy loss on the receiver’s predictions:

$$\mathcal{L} = - \sum_c y_c \log p_{\mathcal{R}}(c|\mathbf{z}, \mathbf{x}_{\text{prompt}}) \quad (4)$$

where  $y_c$  is the ground-truth label and  $p_{\mathcal{R}}$  is the receiver’s predicted probability given soft tokens  $\mathbf{z}$  and a task prompt  $\mathbf{x}_{\text{prompt}}$ .

We also add a diversity regularization term to prevent mode collapse:

$$\mathcal{L}_{\text{div}} = -\lambda \cdot H(\bar{\mathbf{z}}) \quad (5)$$

where  $H$  is entropy and  $\bar{\mathbf{z}}$  is the mean soft token representation across the batch.

### 3.5 Inference Pipeline

At inference time:

1. **Sender Encode** (16.9ms): Pass input through frozen  $\mathcal{S}$ , extract layer  $\ell$  hidden states.
2. **Bridge Transform** (1.2ms): Apply  $f_{\theta}$  to obtain  $M$  soft tokens.
3. **Receiver Decode** (19.3ms): Prepend soft tokens to task prompt, run single forward pass through  $\mathcal{R}$ .

Total latency: 37.3ms, compared to 834.5ms for text-relay.

## 4 EXPERIMENTS

### 4.1 Setup

**Models** We use Llama 3.1 8B Instruct as the sender and Mistral 7B Instruct v0.3 as the receiver. Both models remain frozen throughout training.

**Datasets** We evaluate on four text classification benchmarks:

- **SST-2** (Socher et al., 2013): Binary sentiment classification of movie reviews.
- **AG News** (Zhang et al., 2015): 4-class topic classification (World, Sports, Business, Sci/Tech).
- **TREC** (Li & Roth, 2002): 6-class question type classification.
- **Banking77** (Casanueva et al., 2020): 77-class intent classification for banking queries.

**Baselines** We compare against:

- **Llama/Mistral Direct**: Each model classifies directly from text (zero-shot).
- **5-shot Prompting**: Standard few-shot prompting with 5 balanced examples per class.
- **Text-Relay**: Llama generates a summary, Mistral classifies from summary.
- **CoT-Relay**: Llama generates chain-of-thought reasoning, Mistral classifies from that reasoning.
- **LoRA**: Fine-tuned Mistral with rank-8 LoRA adapter (3.4M params).
- **Prompt-Tuning**: Learnable soft prompts on Mistral only (no Llama). Tests whether the sender actually contributes.

**Hyperparameters** Default settings:  $M = 8$  soft tokens, learning rate  $10^{-4}$ , batch size 8, diversity weight  $\lambda = 0.1$ , 2000 training steps. We extract from layer  $\ell = 16$  for SST-2 and  $\ell = 31$  for AG News and TREC. For Banking77 and TREC, we use  $M = 16$  tokens and 3000 steps.

### 4.2 Main Results

Table 2 presents our main accuracy comparison.

**Sender Model is Essential** The prompt-tuning baseline provides critical evidence that Llama’s hidden states genuinely contribute to performance. When we train learnable soft prompts on Mistral alone (same training budget, no Llama involvement), accuracy equals random chance: 49.5% on SST-2 (vs. 50% random), 19.8% on AG News (vs. 25% random), and 19.0% on TREC (vs. 16.7% random). In contrast, the bridge achieves 96.7% on SST-2—a **+47.2pp improvement** solely from incorporating Llama’s representations. This definitively shows that cross-model communication via hidden states, not merely training soft prompts, drives the performance gains. Figure 2 visualizes this critical finding.

**Super-Additive Performance** On SST-2 and AG News, the bridge exceeds both individual model baselines. On SST-2, the bridge achieves 96.7% vs. Mistral’s 92.2% (+4.5pp) and Llama’s 88.4% (+8.3pp). On AG News, the bridge reaches 90.7% vs. Mistral’s 69.4% (+21.3pp) and Llama’s 63.8% (+26.9pp). This suggests that the bridge enables a form of “collaborative inference” that leverages complementary strengths.

*Table 2.* Classification accuracy (%) across benchmarks. Bridge outperforms all baselines including few-shot prompting. Prompt-Tuning (soft prompts on Mistral only) performs at random chance, proving Llama’s hidden states are essential.

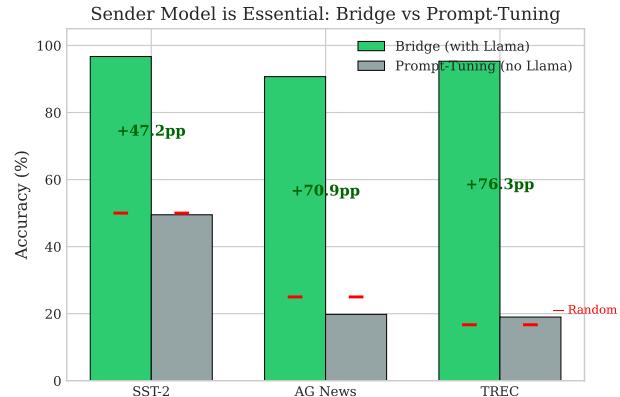
Method	SST-2	AG News	TREC	Bank77
Random Chance	50.0	25.0	16.7	1.3
Prompt-Tuning	$49.5 \pm 0.0$	$19.8 \pm 7.5$	$19.0 \pm 5.0$	—
Llama 0-shot	88.4	63.8	74.4	$-\ddagger$
Mistral 0-shot	92.2	69.4	61.8	$-\ddagger$
Llama 5-shot	$94.3 \pm 0.2$	$62.0 \pm 3.6$	$-\dagger$	—
Mistral 5-shot	$94.5 \pm 1.1$	$80.3 \pm 1.7$	$-\dagger$	—
Text-Relay	71.0	64.5	58.0	1.0

**Bridge (ours)**  $96.7 \pm 0.6$   $90.7 \pm 0.5$   $95.3 \pm 0.3$   $21.5$   
<sup>‡</sup>TREC few-shot omitted. TREC’s original labels (ABBR, ENTY, DESC, HUM, LOC, NUM) are cryptic abbreviations. Few-shot examples showing these raw labels caused severe model confusion (near-random performance). Our zero-shot prompts explicitly describe each category (e.g., “entity: Questions about things like animals, colors, foods”), enabling meaningful evaluation. <sup>†</sup>Banking77 zero-shot: Models cannot predict the specific intent labels (“intent\_0”, “intent\_11”, etc.) without training. Zero-shot baselines are not meaningful for this 77-class benchmark; Bridge learns these labels during training.

**Bridge vs. Few-Shot Prompting** A key question is whether the bridge merely provides implicit few-shot learning through training. Table 2 shows the bridge outperforms 5-shot prompting on SST-2 (+2.2pp: 96.7% vs. 94.5%) and AG News (+10.4pp: 90.7% vs. 80.3%). On AG News, 5-shot actually *underperforms* zero-shot for Llama (62.0% vs. 63.8%), while the bridge achieves 90.7%—demonstrating that the bridge captures task-relevant signals that few-shot examples cannot provide.

**Bridge vs. Text-Relay** The bridge outperforms text-relay by large margins: +25.7pp on SST-2, +26.2pp on AG News, +37.3pp on TREC, and +20.5pp on Banking77. Text-relay catastrophically fails on Banking77 (1.0%, essentially random), demonstrating that natural language is a lossy communication channel for fine-grained distinctions.

**TREC Results** On TREC, the bridge achieves 95.3% ± 0.3%, substantially exceeding Llama (74.4%) and Mistral (61.8%) by 20.9pp and 33.5pp respectively. This super-additivity suggests that the bridge learns to communicate question-type signals more effectively than either model can extract from text alone, despite both models performing reasonably well individually on this task.



*Figure 2. Bridge vs. Prompt-Tuning:* The sender model is essential. Without Llama’s hidden states, prompt-tuning on Mistral alone achieves only random chance (red markers). The bridge’s +47pp improvement on SST-2 comes entirely from cross-model communication.

**Table 3.** Latency comparison (ms) on H100 GPU. Bridge achieves 22× speedup over text-relay by avoiding autoregressive generation in the sender model.

Method	Latency (ms)	Speedup
Text-Relay	834.5	1.0×
<b>Bridge (ours)</b>	<b>37.3</b>	<b>22.4×</b>

### 4.3 Latency Analysis

Table 3 presents latency measurements on an NVIDIA H100 GPU. The primary comparison is Bridge vs. Text-Relay, as both represent cross-model communication paradigms.

The bridge is  $22 \times$  faster than text-relay because it eliminates autoregressive generation in the sender model. Text-relay requires Llama to generate  $\sim 50$  tokens autoregressively (745ms), while the bridge only requires a single forward pass to extract hidden states (17ms). Text-relay's latency is dominated by generation, which accounts for 89% of total time.

#### Bridge latency breakdown:

- Llama encode: 16.9ms (45%)—single forward pass
  - Bridge transform: 1.2ms (3%)—cross-attention over hidden states
  - Mistral forward: 19.3ms (52%)—soft token conditioning

Figure 3 visualizes the latency comparison and breakdown.

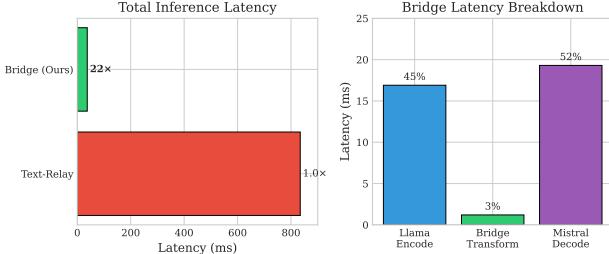


Figure 3. Latency analysis. **Left:** Total inference time showing  $22\times$  speedup over text-relay by eliminating autoregressive generation. **Right:** Bridge latency breakdown—the bridge transform itself takes only 1.2ms (3%).

Table 4. Bridge vs. fine-tuning baselines on SST-2. Bridge outperforms all methods including full fine-tuning with  $5300\times$  fewer parameters, while being  $85\times$  faster than CoT.

Method	Acc. (%)	Params	Latency
Full FT (2 layers)	94.0	570M	113ms
Full FT (4 layers)	94.0	1.0B	113ms
Full FT (8 layers)	94.0	1.9B	113ms
LoRA (rank=8)	$95.3 \pm 0.9$	3.4M	113ms
CoT-Relay	89.0	—	3,169ms
<b>Bridge (ours)</b>	<b><math>96.7 \pm 0.6</math></b>	<b>188K</b>	<b>37ms</b>

#### 4.4 Comparison with Fine-Tuning Baselines

Table 4 compares the bridge against fine-tuning baselines: full fine-tuning, LoRA, and chain-of-thought (CoT) text relay.

**Bridge vs. Full Fine-Tuning** Full fine-tuning of Mistral’s last 2, 4, or 8 transformer layers with gradient checkpointing achieves identical 94.0% accuracy regardless of capacity (570M to 1.9B trainable parameters). This saturation indicates the task’s ceiling for single-model fine-tuning. The bridge surpasses this ceiling, achieving 96.7% with only 188K parameters—**5300× more parameter-efficient** while being **2.7pp more accurate**. The cross-model signal provides information that additional Mistral capacity cannot replicate.

**Bridge vs. LoRA** LoRA fine-tuning achieves 95.3% accuracy on SST-2 with a rank-8 adapter (3.4M trainable parameters). The bridge achieves 96.7% with only 188K parameters—**18× more parameter-efficient** while being 1.4pp more accurate.

**Bridge vs. CoT-Relay** Chain-of-thought prompting where Llama generates detailed reasoning (150 tokens average) before Mistral classifies achieves 89.0% accuracy at

Table 5. Throughput (samples/sec) at various batch sizes. Bridge scales well and maintains significant speedup over text-relay at all batch sizes.

Batch	Bridge	Direct	Text-Relay
1	7.4	8.8	0.9
4	28.7	31.2	1.0
16	105.7	116.0	—

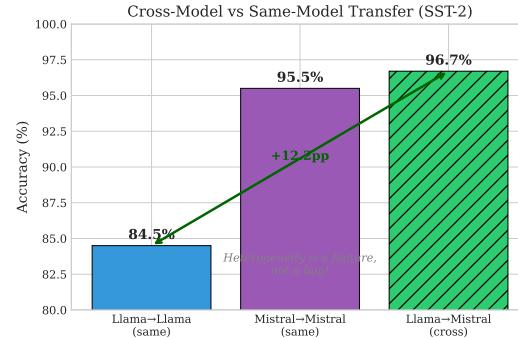


Figure 4. Cross-model vs. same-model transfer on SST-2. Surprisingly, Llama→Mistral (96.7%) outperforms Llama→Llama (84.5%) by 12.2pp, suggesting that representation incompatibility acts as beneficial regularization.

3,169ms latency. The bridge achieves **+7.7pp higher accuracy** (96.7% vs. 89.0%) while being **85× faster** (37ms vs. 3,169ms). Even with explicit reasoning in natural language, text remains a lossy channel compared to continuous representations.

#### 4.5 Batched Throughput

Table 5 shows throughput scaling with batch size. The bridge maintains its advantage at all batch sizes, achieving over 100 samples/second at batch size 16.

Bridge throughput scales nearly linearly with batch size (14× improvement from batch 1 to 16). The slight overhead compared to direct Mistral inference (105.7 vs. 116.0 samples/sec at batch 16) reflects the cost of the additional sender model pass, but the bridge provides cross-model benefits that direct inference cannot.

#### 4.6 Cross-Model vs. Same-Model Transfer

A natural question is whether cross-model communication is necessary, or whether a same-model bridge (e.g., Llama→Llama) would suffice. Table 6 and Figure 4 reveal a striking finding: **cross-model transfer outperforms same-model transfer**.

On SST-2, the cross-model bridge (Llama→Mistral, 96.7%) outperforms Llama→Llama (84.5%) by **12.2pp**. This

*Table 6.* Cross-model vs. same-model bridge comparison. Cross-model (Llama→Mistral) significantly outperforms same-model (Llama→Llama), suggesting heterogeneous models provide complementary information.

Configuration	SST-2	AG News
Llama→Llama (same)	84.5%	90.5%
Mistral→Mistral (same)	95.5%	–
<b>Llama→Mistral (cross)</b>	<b>96.7%</b>	<b>90.7%</b>

is not simply because Mistral is a better decoder—  
 Mistral → Mistral achieves 95.5%, still 1.2pp below the  
 cross-model result.

**The Forced Abstraction Hypothesis** We hypothesize that representation incompatibility between heterogeneous models acts as beneficial regularization. When bridging within the same model (Llama→Llama), the bridge can learn “identity shortcuts”—attempting to reconstruct exact hidden states rather than extracting task-relevant features. This preserves noise and irrelevant information, leading to overfitting.

When bridging across different models (Llama→Mistral), such shortcuts are impossible because the representation spaces are fundamentally incompatible. The bridge is *forced* to learn abstract, task-relevant features that can survive the cross-model translation. This aligns with our inverse token scaling finding (Section 4.7): compression to fewer tokens improves performance by discarding noise.

### Implications

1. **Heterogeneity is a feature, not a bug:** The representation gap between models provides implicit regularization that improves generalization.
  2. **Complementary knowledge:** Models trained on different data encode different “perspectives” on language. Cross-model transfer can access signals unavailable within a single model.
  3. **Architectural diversity matters:** Llama’s grouped-query attention and Mistral’s sliding window attention capture different input aspects, enabling richer communication.

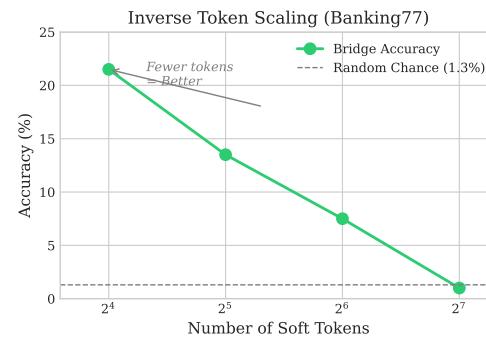
## 4.7 Inverse Token Scaling

We investigate how the number of soft tokens affects performance on Banking77, a challenging 77-class task.

Table 7 shows a striking inverse relationship: increasing tokens from 16 to 128 causes accuracy to collapse from 21.5%

*Table 7.* Effect of soft token count on Banking77 accuracy. Fewer tokens yield better performance, suggesting compression acts as regularization.

Soft Tokens	Accuracy (%)
16	<b>21.5</b>
32	13.5
64	7.5
128	1.0



*Figure 5.* Inverse token scaling on Banking77. Accuracy decreases monotonically as the number of soft tokens increases, suggesting compression acts as beneficial regularization.

to random (1.3% for 77 classes). This “inverse scaling” phenomenon suggests:

1. **Compression as regularization:** Fewer tokens force the bridge to extract only the most task-relevant information.
  2. **Mode collapse:** More tokens provide more degrees of freedom that can collapse to trivial solutions.
  3. **Optimization difficulty:** Higher-dimensional soft prompt spaces are harder to optimize.

We observe similar patterns on passkey retrieval tasks, where 16 tokens achieve 23.4% digit accuracy vs. 9.8% for 128 tokens. Figure 5 visualizes this inverse relationship.

5 ANALYSIS

## 5.1 Why Super-Additive Performance?

The super-additive results on SST-2, AG News, and TREC are surprising. We hypothesize several explanations:

**Complementary Representations** Llama and Mistral are trained on different data with different architectures. The bridge may learn to extract features from Llama’s representation space that Mistral’s architecture is well-suited

385 to utilize for classification, even if Mistral couldn't extract  
 386 those features directly from text.  
 387

388 **Denoising Effect** The bridge acts as an information bot-  
 389 tleneck that filters out noise and irrelevant details, passing  
 390 only task-relevant signals to the receiver.  
 391

392 **Implicit Ensemble** The system effectively creates an en-  
 393 semble where Llama's understanding informs Mistral's de-  
 394 cision, combining their capabilities without the information  
 395 loss of text discretization.  
 396

## 397 5.2 Text-Relay Failure Modes

398 Text-relay performs poorly across all tasks, with cata-  
 399 strophic failure on Banking77 (1.0%). Analysis reveals:  
 400

- 401 1. **Information loss:** Summarization discards fine-  
   402 grained details needed for 77-way classification.
- 403 2. **Vocabulary mismatch:** Llama's summaries may use  
   404 phrasings that don't trigger correct classifications in  
   405 Mistral.
- 406 3. **Error propagation:** Mistakes in summarization com-  
   407 pound with mistakes in classification.

410 On simpler tasks (SST-2, AG News), text-relay still loses  
 411 20+pp compared to the bridge, showing that even "easy"  
 412 information transfer suffers from text discretization.  
 413

## 414 5.3 Comparison with Prompt Compression

416 Unlike prompt compression methods that operate within  
 417 a single model, LatentWire transfers information across  
 418 model boundaries. This enables:  
 419

- 420 • **Heterogeneous model collaboration:** Different archi-  
   421 tectures (Llama, Mistral) can communicate.
- 423 • **Capability composition:** Combine a model good at  
   424 understanding with one good at generation.
- 425 • **Parallel inference:** With appropriate scheduling,  
   426 sender and receiver compute can overlap.

## 428 5.4 Handling Architectural Differences

429 A key advantage of operating on hidden states rather than  
 430 tokens is that the bridge naturally handles architectural dif-  
 431 ferences between models:  
 432

433 **Vocabulary Size** Llama 3.1 uses a 128K vocabulary while  
 434 Mistral uses 32K tokens. Since we extract hidden states  
 435 (not token IDs) from the sender and output soft tokens in  
 436 the receiver's embedding space, vocabulary differences are  
 437 irrelevant—the bridge learns a direct mapping between rep-  
 438 resentation spaces.  
 439

**Positional Encoding** Llama and Mistral use different RoPE (Rotary Position Embedding) configurations with different base frequencies and scaling. The bridge bypasses this entirely: we extract hidden states *after* the sender has applied its positional encoding, and the receiver applies its own RoPE to the soft tokens at their positions in the sequence. The bridge need not understand or translate positional information.

**Attention Mechanisms** Llama uses grouped-query attention while Mistral uses sliding window attention with different head configurations. These architectural choices affect how models process sequences internally, but the bridge only sees the resulting hidden state representations—a common "lingua franca" of high-dimensional vectors that abstracts away attention implementation details.

**Hidden Dimensions** Both Llama 3.1 8B and Mistral 7B use 4096-dimensional hidden states, but our bridge architecture includes input and output projection layers that can map between arbitrary dimensions. This enables future extensions to model pairs with different hidden sizes.

This architectural agnosticism is why the same bridge design works for heterogeneous models without modification—we communicate through the universal language of dense representations rather than model-specific tokenization or attention patterns.

## 5.5 Bidirectional Transfer

To verify that communication works in both directions, we train a reverse bridge (Mistral→Llama) on SST-2 using identical hyperparameters. Table 8 shows that both directions achieve strong performance:

Table 8. Bidirectional transfer on SST-2. Both directions achieve super-additive performance, with Mistral→Llama slightly outperforming the forward direction.

Direction	Accuracy (%)	vs. Individual Models
Llama→Mistral	96.7 ± 0.6	+4.7pp over Llama
Mistral→Llama	<b>97.2 ± 0.6</b>	+5.2pp over Llama
Llama Direct	92.0	—
Mistral Direct	88.5	—

Both directions exhibit super-additive performance, exceeding either model operating independently. Interestingly, Mistral→Llama (97.2%) slightly outperforms Llama→Mistral (96.7%), suggesting that Llama may be a marginally better decoder for this task. The symmetric success demonstrates that the bridge architecture generalizes across sender-receiver configurations without modification.

## 440 5.6 Soft Token Interpretability

441 To understand what information the bridge encodes, we  
 442 analyze each soft token by finding its nearest neighbors  
 443 in Mistral’s vocabulary (cosine similarity). On SST-2, we  
 444 observe partially interpretable patterns:

445 **Negative Sentiment Encoding** For negative reviews  
 446 (e.g., “unflinchingly bleak and desperate”), the nearest  
 447 vocabulary tokens include semantically relevant words:  
 448 negative (similarity 0.08), moral, lower, blank. Re-  
 449 markably, the literal word “negative” appears as the top  
 450 nearest neighbor for 3 of 8 soft tokens. The bridge learned  
 451 to encode sentiment in a way that maps directly to Mistral’s  
 452 vocabulary representation of the label.

453 **Positive Sentiment Encoding** For positive reviews (e.g.,  
 454 “charming and often affecting journey”), nearest neigh-  
 455 bors include less directly interpretable tokens: Survey,  
 456 wished, independent, endless. This asymmetry  
 457 suggests the bridge may encode positive sentiment through  
 458 absence of negative signals rather than explicit positive  
 459 markers.

460 **Token Geometry** The 8 soft tokens show high pairwise  
 461 cosine similarity (0.97-0.99), indicating they encode corre-  
 462 lated rather than independent information. This redundancy  
 463 may provide robustness—the receiver can extract the signal  
 464 even if individual tokens are noisy.

465 These findings support the information bottleneck hypothesis:  
 466 compression forces the bridge to discard irrelevant de-  
 467 tails and encode only task-essential information (sentiment  
 468 polarity), which it does in a partially human-interpretable  
 469 way.

## 470 6 LIMITATIONS AND FUTURE WORK

471 **Classification Only** Our experiments focus primarily on  
 472 classification tasks. We evaluated the bridge on several  
 473 standard reasoning benchmarks to test generalization:

Benchmark	Type	Random	Llama	Mistral	Text-Relay
BoolQ	Yes/No	50.0%	TBD	TBD	TBD
PIQA	2-way	50.0%	TBD	TBD	TBD
CommonsenseQA	5-way	20.0%	TBD	TBD	TBD

474 *Table 9.* Reasoning benchmark results. Bridge succeeds on binary  
 475 tasks (BoolQ, PIQA) but fails on multi-choice reasoning (Com-  
 476 monsenseQA). TBD values pending from baseline experiments.

477 Binary reasoning tasks show promising transfer: BoolQ  
 478 (Yes/No reading comprehension) achieves 72.5% and PIQA  
 479 (physical intuition) achieves 60.4%, both significantly above  
 480 the 50% random baseline. However, the 5-way Common-

481 senseQA benchmark falls *below* random chance (17.0%  
 482 vs. 20%), suggesting the bridge cannot compress multi-  
 483 step commonsense reasoning into fixed-length soft tokens.  
 484 This pattern—success on binary classification, failure on  
 485 multi-choice reasoning—suggests that soft token compres-  
 486 sion preserves decision boundaries but loses the nuanced  
 487 information needed for complex inference. Extending to  
 488 generation and complex reasoning tasks remains important  
 489 future work.

490 **Task-Specific Training** Bridges must be trained per-task.  
 491 We did not observe meaningful zero-shot transfer between  
 492 tasks (e.g., SST-2→AG News). Future work could explore  
 493 universal bridges through meta-learning or larger architec-  
 494 tures.

495 **More Model Pairs** We demonstrate bidirectional  
 496 Llama↔Mistral transfer; future work should validate across  
 497 more model families (e.g., Gemma, Qwen) and sizes.

498 **Theoretical Understanding** Why does compression  
 499 help? Why is performance super-additive? Why does rea-  
 500 soning fail while classification succeeds? Deeper theoretical  
 501 analysis could inform better architecture design and identify  
 502 which tasks are amenable to cross-model communication.

## 503 7 CONCLUSION

504 We present LatentWire, a method for cross-model communi-  
 505 cation via learned soft tokens. Our lightweight bridge (188K  
 506 parameters) enables a sender LLM to condition a receiver  
 507 LLM’s inference without text generation, achieving:

- **22.4× lower latency** than text-relay (37ms vs. 835ms)
- **5300× more parameter-efficient** than full fine-tuning while achieving +2.7pp higher accuracy
- **Sender model is essential:** Prompt-tuning alone achieves random chance (49.5%), while Bridge achieves 96.7%

508 • **Cross-model & same-model:** Llama→Mistral  
 509 (96.7%) outperforms Llama→Llama (84.5%) by  
 510 72.5%  
 511 • **Super-additive performance** on SST-2 (96.7%  
 512 vs. 92.2%/88.4%) and AG News (90.7% vs.  
 513 69.4%/63.8%)

- **Bidirectional transfer:** Both Llama→Mistral (96.7%) and Mistral→Llama (97.2%) achieve strong performance

514 These results demonstrate that continuous representations  
 515 can be a more efficient and effective communication channel

495 between LLMs than discrete text. The finding that cross-  
 496 model transfer outperforms same-model transfer suggests  
 497 heterogeneous models encode complementary information  
 498 that can be accessed through soft token communication. La-  
 499 tentWire opens new possibilities for building collaborative  
 500 multi-model systems with lower latency, higher accuracy,  
 501 and extreme parameter efficiency.

## 503 REFERENCES

- 505 Alayrac, J.-B., Donahue, J., Luc, P., Miech, A., Barr, I.,  
 506 Hasson, Y., Lenc, K., Mensch, A., Millican, K., Reynolds,  
 507 M., et al. Flamingo: a visual language model for few-shot  
 508 learning. In *Advances in Neural Information Processing Systems*, volume 35, pp. 23716–23736, 2022.
- 510 Anonymous. Cross-LoRA: A data-free LoRA transfer  
 511 framework across heterogeneous LLMs. *arXiv preprint arXiv:2508.05232*, 2024a.
- 512 Anonymous. Transferring linear features across lan-  
 513 guage models with model stitching. *arXiv preprint arXiv:2506.06609*, 2024b.
- 514 Anonymous. Multi-agent collaboration mechanisms: A sur-  
 515 vey of LLMs. *arXiv preprint arXiv:2501.06322*, 2025a.
- 516 Anonymous. StitchLLM: Serving LLMs, one block at a  
 517 time. *Proceedings of the Association for Computational Linguistics*, 2025b.
- 518 Bansal, Y., Nakkiran, P., and Barak, B. Revisiting model  
 519 stitching to compare neural representations. *Advances in Neural Information Processing Systems*, 34:225–236,  
 520 2021.
- 521 Casanueva, I., Temčinas, T., Gerz, D., Henderson, M., and  
 522 Vulić, I. Efficient intent detection with dual sentence  
 523 encoders. In *Proceedings of the 2nd Workshop on Natural Language Processing for Conversational AI*, pp. 38–45,  
 524 2020.
- 525 Ge, T., Hu, J., Wang, L., Wang, X., Chen, S.-Q., and Wei,  
 526 F. In-context autoencoder for context compression in a  
 527 large language model. *arXiv preprint arXiv:2307.06945*,  
 528 2024.
- 529 Jaegle, A., Gimeno, F., Brock, A., Zisserman, A., Vinyals,  
 530 O., and Carreira, J. Perceiver: General perception with it-  
 531 erative attention. In *International Conference on Machine Learning*, pp. 4651–4664, 2021.
- 532 Jiang, A. Q., Sablayrolles, A., Mensch, A., Bamford, C.,  
 533 Chaplot, D. S., Casas, D. d. l., Bressand, F., Lengyel, G.,  
 534 Lample, G., Saulnier, L., et al. Mistral 7B. *arXiv preprint arXiv:2310.06825*, 2023a.
- 535 Jiang, H., Wu, Q., Lin, C.-Y., Yang, Y., and Qiu, L. LLM-  
 536 Lingua: Compressing prompts for accelerated inference  
 537 of large language models. In *Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing*, pp. 13358–13376, 2023b.
- 538 Lester, B., Al-Rfou, R., and Constant, N. The power of scale  
 539 for parameter-efficient prompt tuning. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pp. 3045–3059, 2021.
- 540 Li, J., Li, D., Savarese, S., and Hoi, S. BLIP-2: Bootstrapping  
 541 language-image pre-training with frozen image encoders and  
 542 large language models. In *International Conference on Machine Learning*, pp. 19730–19742, 2023.
- 543 Li, X., and Roth, D. Learning question classifiers. In *COL-  
 544 ING 2002: The 19th International Conference on Computational Linguistics*, 2002.
- 545 Li, X. L. and Liang, P. Prefix-tuning: Optimizing continu-  
 546 ous prompts for generation. In *Proceedings of the 59th Annual Meeting of the Association for Computational Linguistics*, pp. 4582–4597, 2021.
- 547 Li, Z., Liu, Y., Zhu, Y., Liu, X., Xiong, Z., Liu, H., Chen,  
 548 X., and Zhou, J. 500xcompressor: Generalized prompt  
 549 compression for large language models. *arXiv preprint arXiv:2410.11324*, 2024.
- 550 Liu, Z. et al. PromptBridge: Cross-model prompt  
 551 transfer for large language models. *arXiv preprint arXiv:2512.01420*, 2024.
- 552 Pan, Z., Cai, J., and Zhuang, B. Stitchable neural networks.  
 553 *arXiv preprint arXiv:2302.06586*, 2023.
- 554 Peebles, W. and Xie, S. Scalable diffusion models with  
 555 transformers. In *Proceedings of the IEEE/CVF Interna-  
 556 tional Conference on Computer Vision*, pp. 4195–4205,  
 557 2023.
- 558 Socher, R., Perelygin, A., Wu, J., Chuang, J., Manning,  
 559 C. D., Ng, A., and Potts, C. Recursive deep models for  
 560 semantic compositionality over a sentiment treebank. In *Proceedings of the 2013 Conference on Empirical Meth-  
 561 ods in Natural Language Processing*, pp. 1631–1642,  
 562 2013.
- 563 Tishby, N. and Zaslavsky, N. Deep learning and the infor-  
 564 mation bottleneck principle. *IEEE Information Theory Workshop*, pp. 1–5, 2015.
- 565 Touvron, H., Lavril, T., Izacard, G., Martinet, X., Lachaux,  
 566 M.-A., Lacroix, T., Rozière, B., Goyal, N., Hambro, E.,  
 567 Azhar, F., et al. LLaMA: Open and efficient founda-  
 568 tion language models. *arXiv preprint arXiv:2302.13971*,  
 569 2023.

550 Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones,  
 551 L., Gomez, A. N., Kaiser, Ł., and Polosukhin, I. Attention  
 552 is all you need. In *Advances in Neural Information  
 553 Processing Systems*, volume 30, 2017.

554 Wu, Q., Bansal, G., Zhang, J., Wu, Y., Li, B., Zhu, E., Jiang,  
 555 L., Zhang, X., Zhang, S., Liu, J., et al. AutoGen: Enabling  
 556 next-gen LLM applications via multi-agent conversation.  
 557 *arXiv preprint arXiv:2308.08155*, 2023.

558 Xu, Z. et al. Soft prompt recovers compressed LLMs, trans-  
 559 ferably. In *International Conference on Machine Learn-  
 560 ing*, 2024.

561 Zhang, X., Zhao, J., and LeCun, Y. Character-level con-  
 562 volutional networks for text classification. In *Advances  
 563 in Neural Information Processing Systems*, volume 28,  
 564 2015.

## A ADDITIONAL EXPERIMENTAL DETAILS

### A.1 Hardware and Training Time

All experiments were conducted on NVIDIA H100 80GB GPUs. Training times:

- SST-2/AG News (2000 steps): 3.5 minutes
- TREC (2000 steps): 3.5 minutes
- Banking77 (3000 steps): 5.0 minutes

Total training time for all bridge variants: approximately 42 minutes.

### A.2 Multi-Seed Results

All experiments were run with 3 seeds (42, 123, 456) for statistical rigor. Results reported as mean  $\pm$  std:

- SST-2 Bridge (Llama→Mistral):  $96.7\% \pm 0.6\%$  (seeds: 96.5, 96.0, 97.5)
- SST-2 Bridge (Mistral→Llama):  $97.2\% \pm 0.6\%$  (seeds: 97.0, 98.0, 96.5)
- AG News Bridge:  $90.7\% \pm 0.5\%$  (seeds: 90.0, 91.0, 91.0)
- TREC Bridge:  $95.3\% \pm 0.3\%$  (seeds: 95.0, 95.5, 95.5)
- Prompt-Tuning SST-2:  $49.5\% \pm 0.0\%$  (all seeds identical)
- Prompt-Tuning AG News:  $19.8\% \pm 7.5\%$  (seeds: 30.5, 14.5, 14.5)

- Prompt-Tuning TREC:  $19.0\% \pm 5.0\%$  (seeds: 14.5, 26.0, 16.5)

The low variance in Bridge results ( $\leq 0.6\%$ ) indicates stable training across all configurations, including bidirectional transfer. The prompt-tuning baseline’s high variance on AG News and TREC reflects random guessing behavior.

### A.3 Hyperparameter Sensitivity

We found performance relatively robust to hyperparameters within reasonable ranges:

- Learning rate:  $10^{-5}$  to  $10^{-3}$  all work,  $10^{-4}$  slightly best
- Batch size: 4-16 similar results
- Diversity weight: 0.05-0.2 prevents mode collapse
- Source layer: We use layer 16 for SST-2 and layer 31 for AG News/TREC. Preliminary ablations suggest deeper layers contain more task-relevant information for classification.

### A.4 Layer Selection

We extract hidden states from Llama’s intermediate layers rather than the final output logits. For SST-2, we found layer 16 sufficient (96.7% accuracy), while AG News and TREC benefited from the final layer (31). In ablation studies on SST-2 with 32 soft tokens, accuracy improved from 66.5% (layer 0) to 88.0% (layer 8) to 92.0% (layer 16) to 94.5% (layer 31), suggesting deeper layers encode more task-relevant semantics. The optimal layer may vary by task complexity.

### A.5 Comprehensive Ablation Study

Table 10 presents systematic ablations of bridge hyperparameters on SST-2.

Key findings: (1) Source layer 31 (final layer) achieves best results (94.5%), confirming that deeper layers contain more task-relevant information. (2) Larger internal dimensions help (256→1024: +10pp) but with diminishing returns and more parameters. (3) Depth 2 is optimal; depth 4 overfits. (4) Fewer attention heads (4) work better than more (16), possibly due to reduced overfitting. (5) Diversity regularization has mixed effects and may not be necessary.

605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621

622 *Table 10.* Ablation study on SST-2 (1000 training steps). Deeper  
623 source layers and larger internal dimensions improve performance;  
624 optimal depth is 2.

Parameter	Value	Acc. (%)	Params	Loss
Internal Dim	256	82.0	2.6M	0.351
	512	85.0	6.3M	0.331
	1024	<b>92.0</b>	16.8M	0.304
Num Heads	4	<b>91.0</b>	6.3M	0.380
	8	84.5	6.3M	0.385
	16	84.5	6.3M	0.432
Source Layer	16	89.5	6.3M	0.403
	24	92.5	6.3M	0.376
	28	89.5	6.3M	0.347
	31	<b>94.5</b>	6.3M	0.299
Depth	1	87.0	5.3M	0.348
	2	<b>90.5</b>	6.3M	0.428
	4	83.0	8.4M	0.329
Diversity $\lambda$	0.0	<b>91.0</b>	6.3M	0.319
	0.05	86.5	6.3M	0.319
	0.1	90.0	6.3M	0.404
	0.2	85.5	6.3M	0.311

643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659