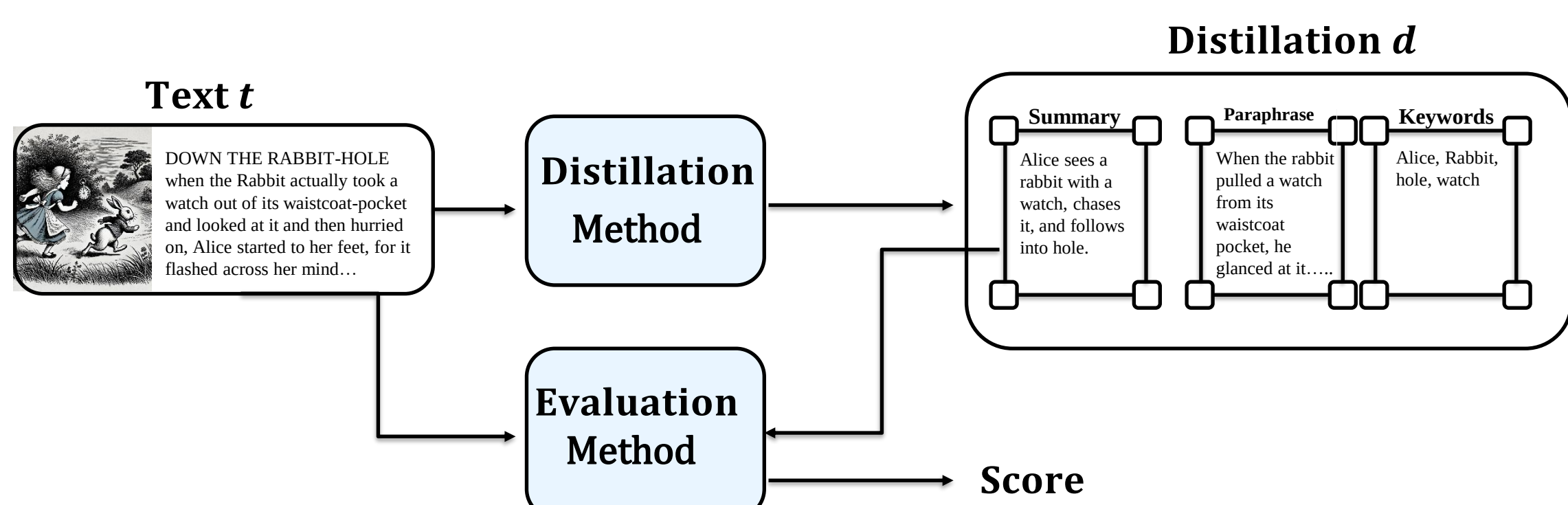


Guided Word Guessing with Language Models and Information-Theoretic Content Distillation

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1. Overview

- Content distillation challenges: text summarization, paraphrasing, keyword extraction,...



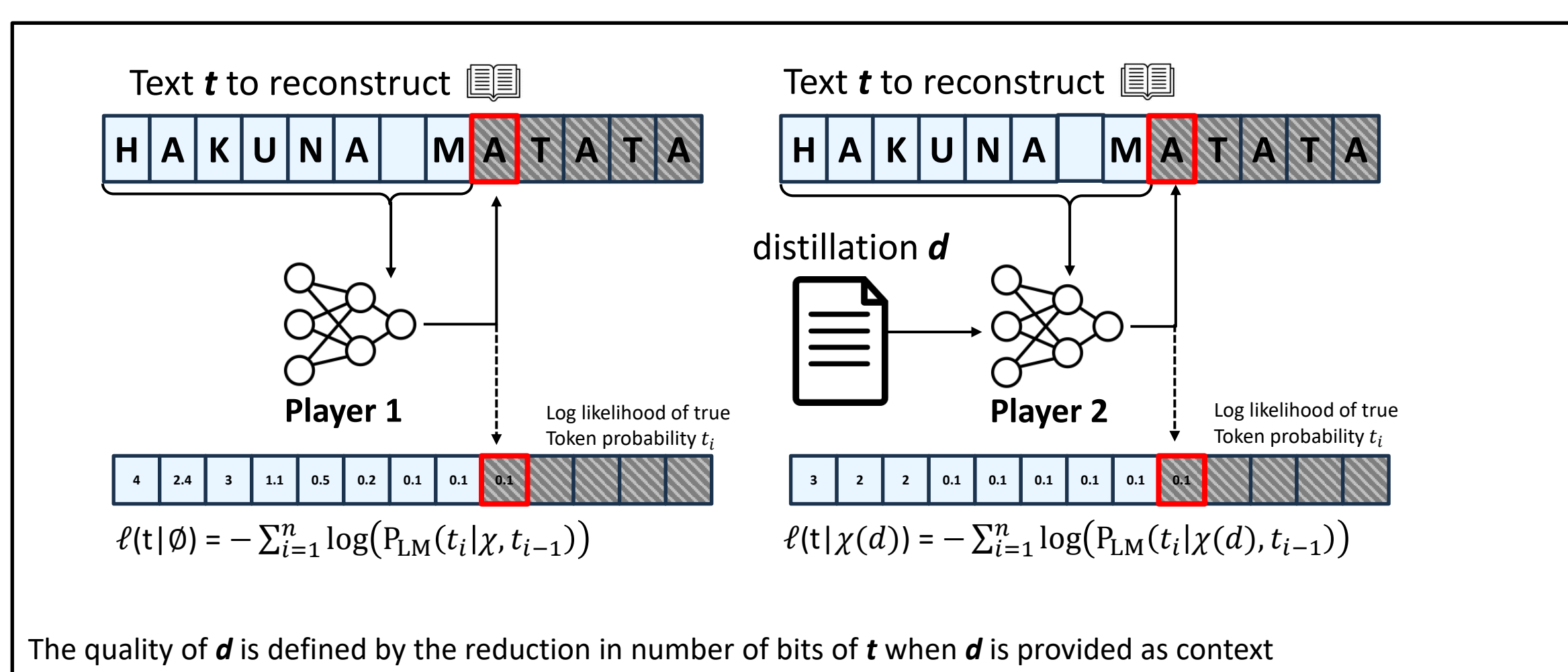
- The **Log Likelihood Gain (LLG)** is the log of the likelihood ratio of t under a language model without context to with context d :

$$LLG(t; d) := \log \left[\frac{P_{LM}(t|\chi(d))}{P_{LM}(t|\emptyset)} \right]$$

- Tenendum: LLG is a simple, natural and useful way to measure the **relevance** of the distilled content d to the source text t .

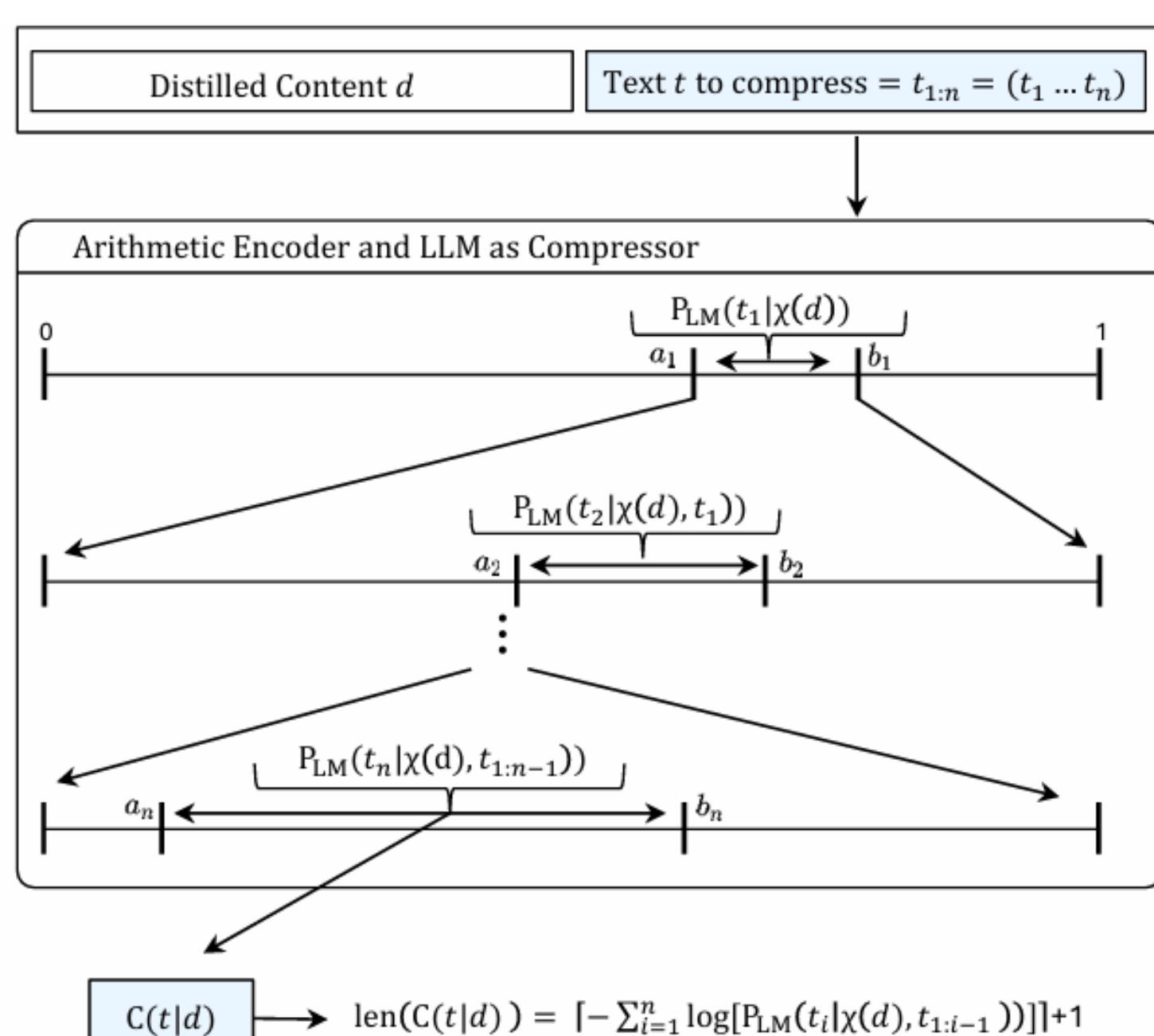
2. Motivation: LLG as a Guessing Game 🎮

- LLG** is inspired by a variation of the Shannon Guessing game (1951) where a text's information is measured by how well a **human** player predicts it. (Shannon 1951, Hovy et.al. 1998)
- LLG** plays the **Guessing Game** with LMs as players.



3. Lossless Compression

- Result 1: LLG** is the **reduction in binary codelength** when compressing text t using a **state-of-the-art lossless compression** procedure and distillation d as side information



$$|\text{Len}(C(t|\emptyset)) - \text{Len}(C(t|\chi(d))) - LLG(t; d)| \leq 1$$

(Izacard 2019), (Bellard 2019), (Goyal et. al. 2021), (Mao et. al. 2022), (Deletang et. al. 2023)

4. LLG as Normalized Compression Distance

- NCD (Vitányi 2008) is a universal compression based similarity measure between two objects from any domain:

$$NCD_Z(x, y) = \frac{Z(xy) - \min\{Z(x), Z(y)\}}{\max\{Z(x), Z(y)\}}$$

(Cebrián .et.al 2007), (Cilibras, Vitányi 2004), (Pinho .et.al 2016), (Jiang Z .etl.al 2023)

Result 2:

$\frac{LLG(t; d)}{\log[1/P_{LM}(t|\emptyset)]}$ is an NCD (under LM + arithmetic encoder compression)

5. Empirical Analysis

- Result 3:** LLG is empirically competitive with other evaluation methods in the domains of summary and paraphrase evaluation.

Measure	summEval	Newsroom	SFF	CNN	EAPoe	HPotter	CNN-para	HPotter-para
LLG	0.18 (0.017)	0.54 (0.026)	0.26 (0.011)	0.61 (0.01)	0.55 (0.02)	0.6 (0.02)	0.4 (0.03)	0.32 (0.067)
LLG	0.15 (0.018)	0.45 (0.027)	0.25 (0.011)	0.55 (0.012)	0.55 (0.019)	0.61 (0.02)	0.68 (0.008)	0.34 (0.074)
NCD_gzip	0.18 (0.017)	0.44 (0.027)	0.26 (0.011)	0.45 (0.013)	0.48 (0.023)	0.56 (0.024)	0.37 (0.032)	-0.45 (0.065)
BLANC	0.13 (0.018)	0.48 (0.026)	0.26 (0.011)	0.39 (0.014)	0.3 (0.027)	0.36 (0.031)	0.2 (0.037)	-0.31 (0.073)
BARTScore	0.27 (0.016)	0.5 (0.028)	0.15 (0.012)	0.43 (0.014)	0.06 (0.031)	0.06 (0.035)	-0.71 (0.001)	-0.71 (0.005)
ROUGUEL	0.13 (0.017)	0.49 (0.027)	0.27 (0.011)	0.48 (0.012)	0.46 (0.022)	0.6 (0.02)	0.71 (0.002)	0.42 (0.065)
BERTScore	0.31 (0.016)	0.48 (0.03)	0.2 (0.011)	0.63 (0.01)	0.56 (0.019)	0.61 (0.021)	-0.71 (0.001)	-0.71 (0.005)

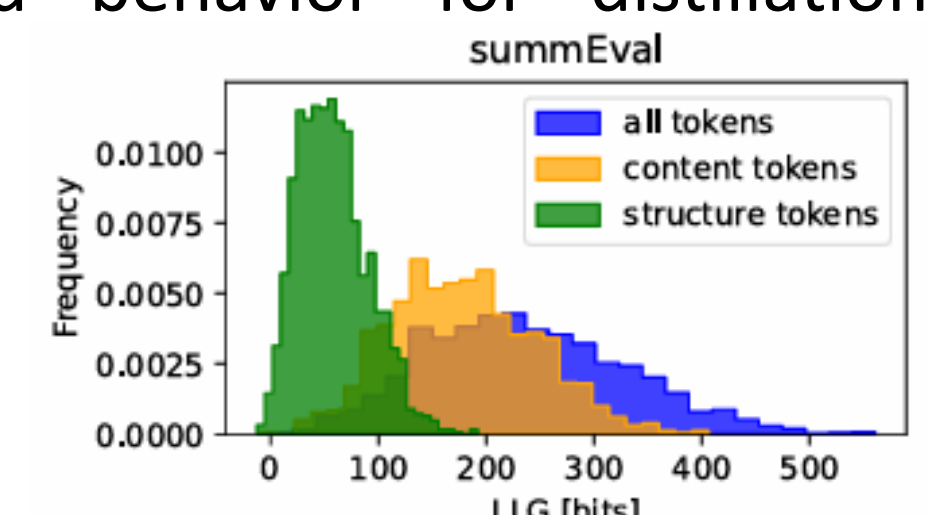
(T Zhang .et.al 2019), (CY Lin 2004), (W Yuan .et.al 2021), (O Vasilyev .etl.al 2020)

6. Structure/Content Word Analysis

- Result 4:** LLG is overwhelmingly affected by the text's content words than its structure – desired behavior for distillation evaluation.

Measure	summEval	Newsroom	SFF	CNN
LLG	0.18 (0.018)	0.54 (0.026)	0.26 (0.011)	0.61 (0.01)
LLG _{cont}	0.17 (0.017)	0.54 (0.026)	0.27 (0.01)	0.6 (0.011)
LLG _{stru}	0.15 (0.017)	0.47 (0.03)	0.15 (0.011)	0.34 (0.015)

Kendall tau correlation with reference scores



7. Content Distillation with LLG

- Can we use LLG as an objective for content distillation?

$$d^*(t) = \underset{d \in D}{\operatorname{argmax}} LLG(d; t)$$

- To find $d^*(t)$, we measure LLG for each potential distillation $d \in D$

Slogan: d. Q: What is the product? A: Organic skin-care line.

Slogan: d. Q: What are the brand values? A: Sustainability, purity, self care.

Slogan: d. Q: Who is the target audience? A: Environmentally conscious individuals seeking natural beauty solutions.

Slogan: d. Q: What is the brand tone? A: Gentle and nurturing.

For $D = \{\text{all word bigram}\}$, $d^*(t) = \text{Naturally Blossom}$

- $d^*(t)$ is **objectively** the optimal distillation from the LM perspective.

Challenge	Content				LLG-optimized distilled content
Tagline	Ever noticed how plane seats appear to be getting smaller and smaller? With increasing numbers of people taking to the skies, some experts are questioning if having such packed out planes is putting passengers at risk.				Overcrowd Aircraft
Tagline	A drunk teenage boy had to be rescued by security after jumping into a lions' enclosure at a zoo in western India.				Drunk Tiger
Slogan	What is the product?	What are the brand values?	Who is the target audience?	What is the brand tone?	
Slogan	Organic skin-care line	Sustainability, purity, self care	Environmentally conscious individuals seeking natural beauty solutions	Gentle and nurturing	Naturally Blossom
Slogan	Luxury watch	Craftsmanship, tradition, prestige	High income individuals who value timeless elegance	Classic and refined	timeless elegance
Slogan	Energy drink.	Performance, vitality, boldness	Active individuals and fitness enthusiasts.	Energetic and high spirited	Energetic high
Slogan	Running shoes.	Performance, durability, innovation	Runners and athletes who aim to push their limits	Motivational and energetic	Nike mph
Slogan	Streaming service	Convenience, entertainment, variety	People seeking on-demand video content	Engaging and inclusive	Hulu on-demand
Slogan	Electric car	Sustainability, innovation, luxury	Environmentally conscious drivers who value performance.	Sophisticated and forward thinking	Tesla S