In [2]:
```
# from google.colab import drive
# drive.mount('/content/drive')
```

SECTION 1 - Setup (Reproducible)

In [3]:
```
# ====== SECTION 1: Setup ======
import os, re, random, time
import numpy as np
import pandas as pd

# ตั้ง seed ให้ผลรันซ้ำได้
def set_seed(seed=42):
    random.seed(seed)
    np.random.seed(seed)
    os.environ["PYTHONHASHSEED"] = str(seed)

CONFIG = {
    "seed": 42,
    "dataset_uri": "hf://datasets/mahfoos/Patient-Doctor-Conversation/pred_status.csv",
    "label_col": "Status",
    "text_cols": ["Description", "Patient"],  # ถ้าชื่อคอลัมน์ไม่ตรง ให้แก้ตรงนี้
    "split": (0.70, 0.15, 0.15),
}

set_seed(CONFIG["seed"])
print("Seed =", CONFIG["seed"])
```

```
Seed = 42
```

SECTION 2 - Load + Prepare Data

In [4]:
```
# โหลด dataset จาก Hugging Face (แบบที่คุณให้มา)
df = pd.read_csv(CONFIG["dataset_uri"])
print("Shape:", df.shape)
print("Columns:", list(df.columns))
display(df.head())
```

```
/usr/local/lib/python3.12/dist-packages/huggingface_hub/utils/_auth.py:94: UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab
(https://huggingface.co/settings/tokens), set it as secret in your Google Colab and restart your session.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access public models or datasets.
  warnings.warn(
```

```
Shape: (3325, 4)
Columns: ['Description', 'Doctor', 'Patient', 'Status']
```

	Description	Doctor	Patient	Status
0	what does abutment of the nerve root mean	hi I have gone through your query with diligen...	hi doctor I am just wondering what is abutting...	medium severity
1	every time I eat spicy food I poop blood why	hello I have gone through your information and...	hi doctor I am a 26 year old male I am feet an...	high severity
2	will nano leo give permanent solution for erec...	hi for further doubts consult a sexologist online	hello doctor I am 48 years old I am experienci...	low severity
3	will kalarchikai cure multiple ovarian cysts i...	hello I just read your query see kalarachi kai...	hello doctor I have multiple small cysts in bo...	medium severity
4	I masturbate only by rubbing the tip of the pe...	hi for further doubts consult a sexologist online	hi doctor during masturbation I just rub the t...	low severity

In [5]:

```
# เช็คว่ามีคอลัมน์ที่ต้องใช้ไหม
need_cols = CONFIG["text_cols"] + [CONFIG["label_col"]]
missing = [c for c in need_cols if c not in df.columns]

if missing:
    print("❌ Missing columns:", missing)
    print("👉 แก้ CONFIG['text_cols'] หรือ CONFIG['label_col'] ให้ตรงกับ dataset")
else:
    print("✅ Columns OK")
```

```
✅ Columns OK
```

In [6]:

```
# รวม text: Description + Patient
def merge_text(row):
    a = str(row[CONFIG["text_cols"][0]]) if pd.notna(row[CONFIG["text_cols"][0]]) else ""
    b = str(row[CONFIG["text_cols"][1]]) if pd.notna(row[CONFIG["text_cols"][1]]) else ""
    return (a + " " + b).strip()

df["text_raw"] = df.apply(merge_text, axis=1)
df["label_str"] = df[CONFIG["label_col"]].astype(str)

# map label เป็นตัวเลข (3 classes)
label_map = {
    "low severity": 0,
    "medium severity": 1,
    "high severity": 2
}

df = df[df["label_str"].isin(label_map)].copy()
df["label"] = df["label_str"].map(label_map)

print(df["label_str"].value_counts())
display(df[["text_raw", "label_str", "label"]].head())
```

```
label_str
medium severity    1779
low severity       1068
high severity       473
Name: count, dtype: int64
```

	text_raw	label_str	label
0	what does abutment of the nerve root mean hi d...	medium severity	1
1	every time I eat spicy food I poop blood why h...	high severity	2
2	will nano leo give permanent solution for erec...	low severity	0
3	will kalarchikai cure multiple ovarian cysts i...	medium severity	1
4	I masturbate only by rubbing the tip of the pe...	low severity	0

In [7]:

```
# รวม text: Description + Patient
def merge_text(row):
    a = str(row[CONFIG["text_cols"][0]]) if pd.notna(row[CONFIG["text_cols"][0]]) else ""
    b = str(row[CONFIG["text_cols"][1]]) if pd.notna(row[CONFIG["text_cols"][1]]) else ""
    return (a + " " + b).strip()

df["text_raw"] = df.apply(merge_text, axis=1)
df["label_str"] = df[CONFIG["label_col"]].astype(str)

# map label เป็นตัวเลข (3 classes)
label_map = {
    "low severity": 0,
    "medium severity": 1,
    "high severity": 2
}

df = df[df["label_str"].isin(label_map)].copy()
df["label"] = df["label_str"].map(label_map)

print(df["label_str"].value_counts())
display(df[["text_raw", "label_str", "label"]].head())
```

```
label_str
medium severity    1779
low severity       1068
high severity       473
Name: count, dtype: int64
```

	text_raw	label_str	label
0	what does abutment of the nerve root mean hi d...	medium severity	1
1	every time I eat spicy food I poop blood why h...	high severity	2
2	will nano leo give permanent solution for erec...	low severity	0
3	will kalarchikai cure multiple ovarian cysts i...	medium severity	1
4	I masturbate only by rubbing the tip of the pe...	low severity	0

In [8]:

```
# ทำ cleaned version แบบง่ายๆ (ยังไม่ทำ stopword/lemma ใน section นี้)
def clean_text_simple(text):
    text = text.lower()
    text = re.sub(r"\s+", " ", text)  # รวมช่องว่าง
    text = text.strip()
    return text

df["text_clean"] = df["text_raw"].apply(clean_text_simple)
```

In [9]:
```
# Stratified split 70/15/15
from sklearn.model_selection import train_test_split

train_ratio, val_ratio, test_ratio = CONFIG["split"]

train_df, temp_df = train_test_split(
    df, test_size=(1-train_ratio),
    random_state=CONFIG["seed"],
    stratify=df["label"]
)

# split temp -> val/test
val_size = val_ratio / (val_ratio + test_ratio)
val_df, test_df = train_test_split(
    temp_df, test_size=(1-val_size),
    random_state=CONFIG["seed"],
    stratify=temp_df["label"]
)

print("Train:", train_df.shape, "Val:", val_df.shape, "Test:", test_df.shape)

# เช็ค distribution ว่าใกล้กันไหม
def show_dist(d, name):
    print("\n", name)
    print(d["label_str"].value_counts(normalize=True))

show_dist(train_df, "Train dist")
show_dist(val_df, "Val dist")
show_dist(test_df, "Test dist")
```

```
Train: (2323, 8) Val: (498, 8) Test: (499, 8)

 Train dist
label_str
medium severity    0.535945
low severity       0.321567
high severity      0.142488
Name: proportion, dtype: float64

 Val dist
label_str
medium severity    0.536145
low severity       0.321285
```

```
high severity      0.142570
Name: proportion, dtype: float64

 Test dist
label_str
medium severity    0.535070
low severity       0.322645
high severity      0.142285
Name: proportion, dtype: float64
```

SECTION 3 - EDA

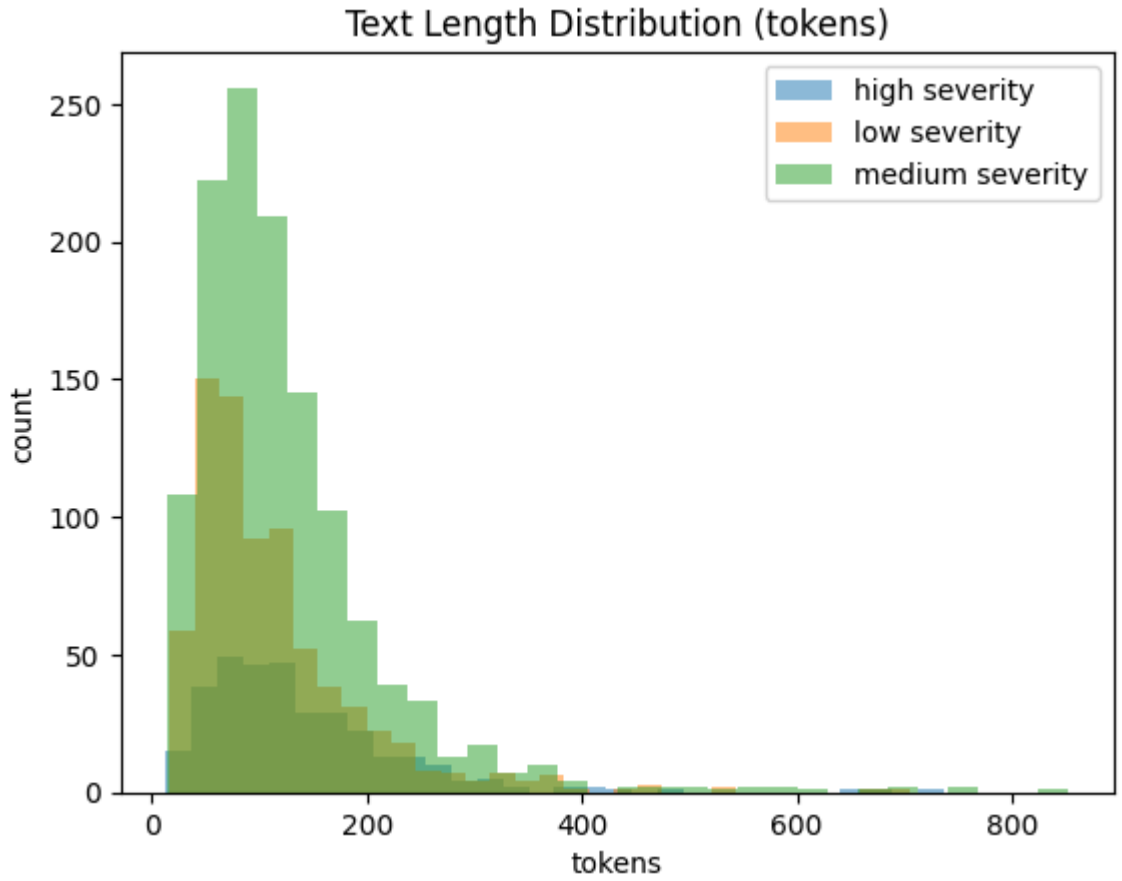
In [10]:

```
# ====== SECTION 3: EDA ======
import matplotlib.pyplot as plt
from collections import Counter

# 1) imbalance ratio
counts = train_df["label_str"].value_counts()
imbalance_ratio = counts.max() / counts.min()
print("Label counts:\n", counts)
print("Imbalance ratio (max/min) =", round(imbalance_ratio, 3))
```

```
Label counts:
 label_str
medium severity    1245
low severity        747
high severity       331
Name: count, dtype: int64
Imbalance ratio (max/min) = 3.761
```

In [11]:

```
# 2) text length per class
def plot_length_dist(df_, text_col="text_raw"):
    plt.figure()
    for cls, g in df_.groupby("label_str"):
        lens = g[text_col].str.split().apply(len)
        plt.hist(lens, bins=30, alpha=0.5, label=cls)
    plt.title("Text Length Distribution (tokens)")
    plt.xlabel("tokens")
    plt.ylabel("count")
    plt.legend()
    plt.show()

plot_length_dist(train_df, "text_raw")
```



In [12]:

```
# 3) vocab size + TTR per class
def vocab_stats(texts):
    tokens = [w for t in texts for w in t.lower().split()]
    vocab = set(tokens)
    ttr = len(vocab) / max(1, len(tokens))
    return len(vocab), ttr

rows = []
for cls, g in train_df.groupby("label_str"):
    vsize, ttr = vocab_stats(g["text_raw"])
    rows.append([cls, len(g), vsize, ttr])

eda_df = pd.DataFrame(rows, columns=["class", "num_docs", "vocab_size", "TTR"])
display(eda_df)
```

	class	num_docs	vocab_size	TTR
0	high severity	331	4852	0.105667
1	low severity	747	6143	0.072722
2	medium severity	1245	8385	0.054245

In [13]:

```
# 4) Top 20 words per class (remove stopwords เพื่อให้เห็นคำมีความหมาย)
import nltk
nltk.download("stopwords")
from nltk.corpus import stopwords
STOP = set(stopwords.words("english"))

from collections import Counter

def top_words_no_stop(texts, k=20):
    tokens = []
    for t in texts:
        # ดึงเฉพาะตัวอักษร a-z เพื่อลดคำเพี้ยน
        toks = re.findall(r"[a-z]+", str(t).lower())
        toks = [w for w in toks if w not in STOP and len(w) > 2]
        tokens.extend(toks)
    cnt = Counter(tokens)
    return cnt.most_common(k)

for cls, g in train_df.groupby("label_str"):
    print("\n===", cls, "===")
    print(top_words_no_stop(g["text_raw"], 20))
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Unzipping corpora/stopwords.zip.


=== high severity ===
[('doctor', 426), ('pain', 226), ('hello', 188), ('please', 185), ('years', 182), ('also', 160), ('like', 150), ('help',
144), ('old', 141), ('blood', 129), ('days', 125), ('get', 122), ('months', 116), ('year', 110), ('back', 109), ('two',
105), ('day', 105), ('feel', 104), ('know', 99), ('test', 97)]

=== low severity ===
[('doctor', 821), ('hello', 401), ('please', 396), ('pain', 345), ('years', 299), ('old', 290), ('also', 283), ('help',
281), ('like', 278), ('get', 264), ('days', 254), ('months', 225), ('year', 223), ('last', 207), ('two', 205), ('day',
204), ('feel', 203), ('one', 197), ('time', 194), ('back', 185)]

=== medium severity ===
[('doctor', 1521), ('pain', 978), ('please', 726), ('hello', 715), ('years', 629), ('days', 603), ('also', 537), ('help',
526), ('old', 469), ('two', 464), ('back', 462), ('like', 439), ('get', 423), ('months', 417), ('last', 402), ('one', 376),
('day', 371), ('feel', 369), ('year', 356), ('normal', 348)]
```

In [14]:

```
# 5) PMI-like word score (tokenization ดีขึ้นด้วย regex)
import math
from collections import Counter

def tokenize_simple(text):
    # เก็บเฉพาะคำ a-z และตัดคำสั้นเกินไป
    toks = re.findall(r"[a-z]+", str(text).lower())
    return [w for w in toks if len(w) > 2]

def pmi_like_clean(df_, target_cls, text_col="text_raw", min_freq=5, top_k=20):
    cls_texts = df_[df_["label_str"] == target_cls][text_col]
    rest_texts = df_[df_["label_str"] != target_cls][text_col]

    cls_tokens = [w for t in cls_texts for w in tokenize_simple(t)]
    rest_tokens = [w for t in rest_texts for w in tokenize_simple(t)]
    all_tokens = cls_tokens + rest_tokens

    c_cls = Counter(cls_tokens)
    c_all = Counter(all_tokens)

    N_cls = len(cls_tokens)
    N_all = len(all_tokens)

    scores = []
    for w, f in c_cls.items():
        if c_all[w] < min_freq:
            continue
        p_w_cls = f / N_cls
        p_w = c_all[w] / N_all
        score = math.log(p_w_cls / p_w)
        scores.append((w, score, f, c_all[w]))

    scores.sort(key=lambda x: x[1], reverse=True)
    return scores[:top_k]

for cls in sorted(train_df["label_str"].unique()):
    print("\nPMI-like words for:", cls)
    for w, s, f_cls, f_all in pmi_like_clean(train_df, cls, top_k=15):
        print(f"{w:15s} score={s:6.3f}  f_cls={f_cls:4d}  f_all={f_all:4d}")
```

```
PMI-like words for: high severity
map             score= 1.816  f_cls=   5  f_all=   5
```

```
thecar          score= 1.816  f_cls=   5  f_all=   5
torsion         score= 1.816  f_cls=   5  f_all=   5
infact          score= 1.816  f_cls=   7  f_all=   7
mercury         score= 1.816  f_cls=   7  f_all=   7
dysplasia       score= 1.816  f_cls=   5  f_all=   5
bitten          score= 1.816  f_cls=   6  f_all=   6
heroin          score= 1.816  f_cls=   5  f_all=   5
fasciculations  score= 1.816  f_cls=   7  f_all=   7
downs           score= 1.816  f_cls=   5  f_all=   5
oxidil          score= 1.816  f_cls=   5  f_all=   5
suicidal        score= 1.729  f_cls=  11  f_all=  12
platelet        score= 1.698  f_cls=   8  f_all=   9
radiculopathy   score= 1.682  f_cls=   7  f_all=   8
chickenpox      score= 1.682  f_cls=   7  f_all=   8

PMI-like words for: low severity
bikini          score= 1.225  f_cls=   5  f_all=   5
blister         score= 1.225  f_cls=   8  f_all=   8
grainy          score= 1.225  f_cls=   5  f_all=   5
tubectomy       score= 1.225  f_cls=   5  f_all=   5
wires           score= 1.225  f_cls=   5  f_all=   5
ramipril        score= 1.225  f_cls=   5  f_all=   5
contractions    score= 1.225  f_cls=   5  f_all=   5
pine            score= 1.225  f_cls=   5  f_all=   5
pigmentation    score= 1.225  f_cls=  15  f_all=  15
nap             score= 1.225  f_cls=   5  f_all=   5
tri             score= 1.225  f_cls=   5  f_all=   5
luma            score= 1.225  f_cls=   5  f_all=   5
bee             score= 1.225  f_cls=   5  f_all=   5
boiled          score= 1.225  f_cls=   5  f_all=   5
mice            score= 1.225  f_cls=  10  f_all=  10

PMI-like words for: medium severity
saliva          score= 0.609  f_cls=   5  f_all=   5
snores          score= 0.609  f_cls=   5  f_all=   5
shivering       score= 0.609  f_cls=   5  f_all=   5
choking         score= 0.609  f_cls=   5  f_all=   5
humira          score= 0.609  f_cls=   5  f_all=   5
accuracy        score= 0.609  f_cls=   5  f_all=   5
resistant       score= 0.609  f_cls=   5  f_all=   5
coronary        score= 0.609  f_cls=  10  f_all=  10
appendicitis    score= 0.609  f_cls=   5  f_all=   5
inderal         score= 0.609  f_cls=   5  f_all=   5
```

```
localized       score= 0.609  f_cls=   5  f_all=   5
returns         score= 0.609  f_cls=   5  f_all=   5
jardiance       score= 0.609  f_cls=   5  f_all=   5
chiropractic    score= 0.609  f_cls=   5  f_all=   5
pinky           score= 0.609  f_cls=   5  f_all=   5
```

SECTION 4 - Preprocessing Ablation + Macro-F1

In [15]:

```
# Optional:
# !pip install https://github.com/explosion/spacy-models/releases/download/en_core_web_sm-3.7.1/en_core_web_sm-3.7.1-py3-none-any.whl
```

In [16]:

```
# ====== SECTION 4: Full Preprocessing Ablation ======

import nltk
nltk.download("stopwords")
from nltk.corpus import stopwords
STOP = set(stopwords.words("english"))

# spaCy สำหรับ lemmatization
import spacy
nlp = spacy.load("en_core_web_sm", disable=["parser","ner"])

from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import f1_score

# ----------------------------
# Preprocess function
# ----------------------------
def preprocess_full(text, lower=False, rm_punct=False, rm_stop=False, lemma=False):
    t = str(text)

    if lower:
        t = t.lower()

    if rm_punct:
        t = re.sub(r"[^\w\s]", " ", t)

    t = re.sub(r"\s+", " ", t).strip()

    tokens = t.split()

    if rm_stop:
        tokens = [w for w in tokens if w not in STOP]

    if lemma:
        doc = nlp(" ".join(tokens))
        tokens = [tok.lemma_ for tok in doc]

    return " ".join(tokens)

# ----------------------------
# Ablation Configurations
# ----------------------------
```

```
ABLATIONS = [
    {"name": "A_raw","lower": False, "punct": False,"stop": False, "lemma": False},
    {"name": "B_clean", "lower": True,  "punct": True, "stop": False, "lemma": False},
    {"name": "C_stop", "lower": True,  "punct": True, "stop": True, "lemma": False},
    {"name": "D_stop_lemma","lower": True,"punct": True,"stop": True,"lemma": True},
]

results = []

for exp in ABLATIONS:
    print("\nRunning:", exp["name"])

    X_train = train_df["text_raw"].apply(
        lambda x: preprocess_full(
            x,
            lower=exp["lower"],
            rm_punct=exp["punct"],
            rm_stop=exp["stop"],
            lemma=exp["lemma"]
        )
    )

    X_val = val_df["text_raw"].apply(
        lambda x: preprocess_full(
            x,
            lower=exp["lower"],
            rm_punct=exp["punct"],
            rm_stop=exp["stop"],
            lemma=exp["lemma"]
        )
    )

    y_train = train_df["label"].values
    y_val   = val_df["label"].values

    # TF-IDF (ปิด lowercase เพราะคุมเองแล้ว)
    vec = TfidfVectorizer(
        lowercase=False,
        ngram_range=(1,2),
        min_df=2
    )

    Xtr = vec.fit_transform(X_train)
```

```
    Xva = vec.transform(X_val)

    # Logistic Regression baseline
    clf = LogisticRegression(max_iter=300, class_weight="balanced")
    clf.fit(Xtr, y_train)
    pred = clf.predict(Xva)

    macro_f1 = f1_score(y_val, pred, average="macro")

    vocab_size = len(vec.vocabulary_)

    results.append([
        exp["name"],
        macro_f1,
        vocab_size
    ])

# ----------------------------
# Result Table
# ----------------------------
ablation_df = pd.DataFrame(
    results,
    columns=["experiment", "macro_f1", "vocab_size"]
).sort_values("macro_f1", ascending=False)

display(ablation_df)
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!


Running: A_raw

Running: B_clean

Running: C_stop

Running: D_stop_lemma
```

	experiment	macro_f1	vocab_size
0	A_raw	0.479090	31660
1	B_clean	0.479090	31660
3	D_stop_lemma	0.468989	18699
2	C_stop	0.462282	18137

In [17]:
```
base_vocab = 31660
ablation_df["vocab_reduction_%"] = (
    (base_vocab - ablation_df["vocab_size"]) / base_vocab * 100
)
display(ablation_df)
```

	experiment	macro_f1	vocab_size	vocab_reduction_%
0	A_raw	0.479090	31660	0.000000
1	B_clean	0.479090	31660	0.000000
3	D_stop_lemma	0.468989	18699	40.938092
2	C_stop	0.462282	18137	42.713203

SECTION 5 - Feature Representations

5.1 TF-IDF (1–2 grams)

In [18]:

```
# ====== SECTION 5: Feature Representations ======

from sklearn.feature_extraction.text import TfidfVectorizer
import numpy as np

print("TF-IDF (1-2 grams)")

tfidf_12 = TfidfVectorizer(
    lowercase=False,   # ใช้ raw ตามที่เราวิเคราะห์ไว้
    ngram_range=(1,2),
    min_df=2
)

X_train_12 = tfidf_12.fit_transform(train_df["text_raw"])
X_val_12   = tfidf_12.transform(val_df["text_raw"])

print("Shape:", X_train_12.shape)
print("Vocab size:", len(tfidf_12.vocabulary_))
print("Sparsity:", 100 * (1 - X_train_12.count_nonzero() / (X_train_12.shape[0] * X_train_12.shape[1])), "%")
```

```
TF-IDF (1-2 grams)
Shape: (2323, 31660)
Vocab size: 31660
Sparsity: 99.55588991841589 %
```

5.2 TF-IDF (1–3 grams)

In [19]:
```
print("\nTF-IDF (1-3 grams)")

tfidf_13 = TfidfVectorizer(
    lowercase=False,
    ngram_range=(1,3),
    min_df=2
)

X_train_13 = tfidf_13.fit_transform(train_df["text_raw"])
X_val_13   = tfidf_13.transform(val_df["text_raw"])

print("Shape:", X_train_13.shape)
print("Vocab size:", len(tfidf_13.vocabulary_))
print("Sparsity:", 100 * (1 - X_train_13.count_nonzero() / (X_train_13.shape[0] * X_train_13.shape[1])), "%")
```

```
TF-IDF (1-3 grams)
Shape: (2323, 50113)
Vocab size: 50113
Sparsity: 99.65907870425494 %
```

5.3 GloVe Embeddings (Static Embedding)

In [20]:
```
!pip install gensim
```

```
Collecting gensim
  Downloading gensim-4.4.0-cp312-cp312-manylinux_2_24_x86_64.manylinux_2_28_x86_64.whl.metadata (8.4 kB)
Requirement already satisfied: numpy>=1.18.5 in /usr/local/lib/python3.12/dist-packages (from gensim) (2.0.2)
Requirement already satisfied: scipy>=1.7.0 in /usr/local/lib/python3.12/dist-packages (from gensim) (1.16.3)
Requirement already satisfied: smart_open>=1.8.1 in /usr/local/lib/python3.12/dist-packages (from gensim) (7.5.0)
Requirement already satisfied: wrapt in /usr/local/lib/python3.12/dist-packages (from smart_open>=1.8.1->gensim) (2.1.1)
Downloading gensim-4.4.0-cp312-cp312-manylinux_2_24_x86_64.manylinux_2_28_x86_64.whl (27.9 MB)
[2K   [90m━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━[0m [32m27.9/27.9 MB[0m [31m43.5 MB/s[0m eta [36m0:00:00[0m
[?25hInstalling collected packages: gensim
Successfully installed gensim-4.4.0
```

In [21]:
```
# โหลด GloVe จาก gensim downloader
import gensim.downloader as api

print("Loading GloVe...")
glove = api.load("glove-wiki-gigaword-100")  # 100-dim

def glove_vector(text):
    tokens = text.lower().split()
    vectors = [glove[w] for w in tokens if w in glove]

    if len(vectors) == 0:
        return np.zeros(100)

    return np.mean(vectors, axis=0)

print("Building GloVe features...")

X_train_glove = np.vstack(train_df["text_raw"].apply(glove_vector))
X_val_glove   = np.vstack(val_df["text_raw"].apply(glove_vector))

print("Shape:", X_train_glove.shape)
```

```
Loading GloVe...
[================================================] 100.0% 128.1/128.1MB downloaded
Building GloVe features...
Shape: (2323, 100)
```

5.4 BERT Tokenizer Representation (Contextual Input)

In [22]:
```
from transformers import AutoTokenizer, EarlyStoppingCallback
tokenizer = AutoTokenizer.from_pretrained("bert-base-uncased")

def bert_token_length(text):
    return len(tokenizer.encode(text, truncation=True, max_length=512))

train_lengths = train_df["text_raw"].apply(bert_token_length)

print("Average BERT token length:", np.mean(train_lengths))
print("Max BERT token length:", np.max(train_lengths))
```

```
Warning: You are sending unauthenticated requests to the HF Hub. Please set a HF_TOKEN to enable higher rate limits and
faster downloads.
WARNING:huggingface_hub.utils._http:Warning: You are sending unauthenticated requests to the HF Hub. Please set a
HF_TOKEN to enable higher rate limits and faster downloads.


config.json:   0%|          | 0.00/570 [00:00<?, ?B/s]


tokenizer_config.json:   0%|          | 0.00/48.0 [00:00<?, ?B/s]


vocab.txt:   0%|          | 0.00/232k [00:00<?, ?B/s]


tokenizer.json:   0%|          | 0.00/466k [00:00<?, ?B/s]

Average BERT token length: 135.39345673697804
Max BERT token length: 512
```

comparison

In [23]:
```
feature_summary = pd.DataFrame([
    ["TF-IDF (1-2)", X_train_12.shape[1], "Sparse", "High"],
    ["TF-IDF (1-3)", X_train_13.shape[1], "Very Sparse", "Very High"],
    ["GloVe (100d)", X_train_glove.shape[1], "Dense", "Low"],
    ["BERT Input", "Variable", "Dense", "Very High"],
], columns=["Representation", "Dimensionality", "Sparsity", "Memory Cost"])

display(feature_summary)
```

	Representation	Dimensionality	Sparsity	Memory Cost
0	TF-IDF (1-2)	31660	Sparse	High
1	TF-IDF (1-3)	50113	Very Sparse	Very High
2	GloVe (100d)	100	Dense	Low
3	BERT Input	Variable	Dense	Very High

SECTION 6 - Models (Minimum 5)

Helper: Evaluation Function

In [24]:
```
# ====== SECTION 6: Models ======

from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

def evaluate_model(name, y_true, y_pred):
    return {
        "Model": name,
        "Accuracy": accuracy_score(y_true, y_pred),
        "Macro_F1": f1_score(y_true, y_pred, average="macro"),
        "Macro_Precision": precision_score(y_true, y_pred, average="macro", zero_division=0),
        "Macro_Recall": recall_score(y_true, y_pred, average="macro", zero_division=0),
    }
```

6.1 Logistic Regression (TF-IDF 1-2)

In [25]:
```
from sklearn.linear_model import LogisticRegression

print("Training Logistic Regression...")

lr = LogisticRegression(max_iter=500, class_weight="balanced")
lr.fit(X_train_12, train_df["label"])

pred_lr = lr.predict(X_val_12)

res_lr = evaluate_model("Logistic Regression", val_df["label"], pred_lr)
res_lr
```

```
Training Logistic Regression...
```

Out[25]:
```
{'Model': 'Logistic Regression',
 'Accuracy': 0.5401606425702812,
 'Macro_F1': 0.47909029127748015,
 'Macro_Precision': 0.4772002515795168,
 'Macro_Recall': 0.48167519473897064}
```

6.2 Linear SVM (TF-IDF 1-2)

In [26]:
```
from sklearn.svm import LinearSVC

print("Training Linear SVM...")

svm = LinearSVC(class_weight="balanced")
svm.fit(X_train_12, train_df["label"])

pred_svm = svm.predict(X_val_12)

res_svm = evaluate_model("Linear SVM", val_df["label"], pred_svm)
res_svm
```

```
Training Linear SVM...
```

Out[26]:
```
{'Model': 'Linear SVM',
 'Accuracy': 0.5341365461847389,
 'Macro_F1': 0.40589061971089396,
 'Macro_Precision': 0.424306689651001,
 'Macro_Recall': 0.40870116140036217}
```

6.3 Multinomial Naive Bayes (TF-IDF 1-2)

In [27]:
```
from sklearn.naive_bayes import MultinomialNB

print("Training Multinomial NB...")

nb = MultinomialNB()
nb.fit(X_train_12, train_df["label"])

pred_nb = nb.predict(X_val_12)

res_nb = evaluate_model("Multinomial NB", val_df["label"], pred_nb)
res_nb
```

```
Training Multinomial NB...
```

Out[27]:
```
{'Model': 'Multinomial NB',
 'Accuracy': 0.536144578313253,
 'Macro_F1': 0.23267973856209148,
 'Macro_Precision': 0.178714859437751,
 'Macro_Recall': 0.3333333333333333}
```

6.4 FNN (GloVe mean)

In [28]:

```
# 6.4 FNN / MLP (GloVe mean)  ✅ แทน BiLSTM เดิมทั้งก้อน
from sklearn.metrics import f1_score
import numpy as np
import torch
import torch.nn as nn
from torch.utils.data import DataLoader, TensorDataset

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Device:", device)

# แปลง numpy -> torch tensor
X_train_tensor = torch.tensor(X_train_glove, dtype=torch.float32)
y_train_tensor = torch.tensor(train_df["label"].values, dtype=torch.long)

X_val_tensor = torch.tensor(X_val_glove, dtype=torch.float32)
y_val_tensor = torch.tensor(val_df["label"].values, dtype=torch.long)

train_loader = DataLoader(TensorDataset(X_train_tensor, y_train_tensor), batch_size=32, shuffle=True)
val_loader   = DataLoader(TensorDataset(X_val_tensor, y_val_tensor), batch_size=32, shuffle=False)

# โมเดล FNN แบบง่าย ๆ (2 ชั้น + dropout) => ถือเป็น Deep Learning baseline
class MLPClassifier(nn.Module):
    def __init__(self, input_dim=100, hidden_dim=128, num_classes=3, dropout=0.3):
        super().__init__()
        self.net = nn.Sequential(
            nn.Linear(input_dim, hidden_dim),
            nn.ReLU(),
            nn.Dropout(dropout),
            nn.Linear(hidden_dim, num_classes)
        )
    def forward(self, x):
        return self.net(x)

model = MLPClassifier(input_dim=100, hidden_dim=128, num_classes=3, dropout=0.3).to(device)

criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr=1e-3)

# train แบบง่าย ๆ
EPOCHS = 10
from sklearn.metrics import f1_score

def eval_fnn(model, loader):
```

```
    model.eval()
    preds_all, y_all = [], []
    with torch.no_grad():
        for xb, yb in loader:
            xb = xb.to(device)
            logits = model(xb)
            preds = torch.argmax(logits, dim=1).cpu().numpy()
            preds_all.extend(preds)
            y_all.extend(yb.numpy())
    return f1_score(y_all, preds_all, average="macro")

for epoch in range(1, EPOCHS+1):
    model.train()
    total_loss = 0.0

    for xb, yb in train_loader:
        xb, yb = xb.to(device), yb.to(device)
        optimizer.zero_grad()
        logits = model(xb)
        loss = criterion(logits, yb)
        loss.backward()
        optimizer.step()
        total_loss += loss.item()

    val_f1 = eval_fnn(model, val_loader)
    print(f"Epoch {epoch}: train_loss={total_loss/len(train_loader):.4f}  val_macro_f1={val_f1:.4f}")
# eval บน val
model.eval()
all_preds = []
with torch.no_grad():
    for xb, _ in val_loader:
        xb = xb.to(device)
        logits = model(xb)
        preds = torch.argmax(logits, dim=1)
        all_preds.extend(preds.cpu().numpy())

res_fnn = evaluate_model("FNN (GloVe mean)", val_df["label"], all_preds)
res_fnn
```

```
Device: cuda
Epoch 1: train_loss=0.9910  val_macro_f1=0.2327
Epoch 2: train_loss=0.9673  val_macro_f1=0.2327
Epoch 3: train_loss=0.9506  val_macro_f1=0.2527
```

```
Epoch 4: train_loss=0.9394  val_macro_f1=0.3512
Epoch 5: train_loss=0.9351  val_macro_f1=0.2733
Epoch 6: train_loss=0.9317  val_macro_f1=0.3943
Epoch 7: train_loss=0.9241  val_macro_f1=0.3547
Epoch 8: train_loss=0.9157  val_macro_f1=0.3604
Epoch 9: train_loss=0.9187  val_macro_f1=0.3629
Epoch 10: train_loss=0.9115  val_macro_f1=0.3370
```

Out[28]:
```
{'Model': 'FNN (GloVe mean)',
 'Accuracy': 0.5642570281124498,
 'Macro_F1': 0.3370347227646298,
 'Macro_Precision': 0.3855273103393404,
 'Macro_Recall': 0.37919787765293383}
```

6.5 BERT Fine-Tuning

In [29]:
```
!pip install transformers datasets accelerate -q
```

In [30]:
```
from transformers import AutoModelForSequenceClassification, TrainingArguments, Trainer
from datasets import Dataset

tokenizer = AutoTokenizer.from_pretrained("bert-base-uncased")

def tokenize(batch):
    return tokenizer(batch["text_raw"], truncation=True, padding=True)

train_ds = Dataset.from_pandas(train_df[["text_raw","label"]])
val_ds   = Dataset.from_pandas(val_df[["text_raw","label"]])

train_ds = train_ds.map(tokenize, batched=True)
val_ds   = val_ds.map(tokenize, batched=True)

train_ds.set_format("torch", columns=["input_ids","attention_mask","label"])
val_ds.set_format("torch", columns=["input_ids","attention_mask","label"])
```

```
Map:   0%|          | 0/2323 [00:00<?, ? examples/s]
```

```
Map:   0%|          | 0/498 [00:00<?, ? examples/s]
```

In [31]:
```
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score
import numpy as np

def compute_metrics(eval_pred):
    logits, labels = eval_pred
    preds = np.argmax(logits, axis=1)

    return {
        "accuracy": accuracy_score(labels, preds),
        "macro_f1": f1_score(labels, preds, average="macro"),
        "macro_precision": precision_score(labels, preds, average="macro", zero_division=0),
        "macro_recall": recall_score(labels, preds, average="macro", zero_division=0),
    }
```

In [32]:

```
model_bert = AutoModelForSequenceClassification.from_pretrained(
    "bert-base-uncased",
    num_labels=3
)

training_args = TrainingArguments(
    output_dir="/content/drive/MyDrive/Colab_Notebooks/pj_nlp/bert_results65",
    num_train_epochs=10,
    per_device_train_batch_size=16,
    per_device_eval_batch_size=16,
    eval_strategy="epoch",
    save_strategy="epoch",
    load_best_model_at_end=True,
    metric_for_best_model="macro_f1",
    greater_is_better=True,
    logging_steps=100,
    report_to="none",
    learning_rate=3e-5
)

trainer = Trainer(
    model=model_bert,
    args=training_args,
    train_dataset=train_ds,
    eval_dataset=val_ds,
    compute_metrics=compute_metrics,
    callbacks=[EarlyStoppingCallback(early_stopping_patience=2)]
)

trainer.train()

predictions = trainer.predict(val_ds)
preds_bert = np.argmax(predictions.predictions, axis=1)

res_bert = evaluate_model("BERT", val_df["label"], preds_bert)
res_bert
```

```
model.safetensors:   0%|          | 0.00/440M [00:00<?, ?B/s]
```

```
Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]
```

```
BertForSequenceClassification LOAD REPORT from: bert-base-uncased
Key                                          | Status     |
---------------------------------------------+------------+-
cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
cls.predictions.bias                         | UNEXPECTED |
cls.seq_relationship.bias                    | UNEXPECTED |
cls.predictions.transform.dense.bias         | UNEXPECTED |
cls.seq_relationship.weight                  | UNEXPECTED |
cls.predictions.transform.LayerNorm.bias     | UNEXPECTED |
cls.predictions.transform.dense.weight       | UNEXPECTED |
classifier.bias                              | MISSING    |
classifier.weight                            | MISSING    |

Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```

[1022/1460 35:26 < 15:13, 0.48 it/s, Epoch 7/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.975340	0.943602	0.536145	0.232680	0.178715	0.333333
2	0.949892	0.871589	0.608434	0.418427	0.402697	0.446738
3	0.818527	0.857538	0.586345	0.403512	0.384053	0.432171
4	0.672729	0.951379	0.566265	0.484269	0.526513	0.479858
5	0.484540	1.090267	0.578313	0.505512	0.528295	0.494542
6	0.320616	1.290881	0.598394	0.482344	0.539543	0.475067
7	0.189999	1.752618	0.600402	0.486153	0.549712	0.476422

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
```

```
 'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
 'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
 'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
 'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
 'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
 'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
 'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
 'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
 'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
 'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
 'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
 'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
 'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
 'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
 'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
 'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
 'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
 'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
 'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
 'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
 'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
 'bert.encoder.layer.11.output.LayerNorm.gamma'].
```



```
{'Model': 'BERT',
 'Accuracy': 0.5783132530120482,
 'Macro_F1': 0.5055117807439539,
 'Macro_Precision': 0.5282949095903681,
 'Macro_Recall': 0.49454192382760986}
```

In [33]:
```
results_df = pd.DataFrame([
    res_lr,
    res_svm,
    res_nb,
    res_fnn,
    res_bert
])
results_df.sort_values("Macro_F1", ascending=False)
```

Out[33]:

	Model	Accuracy	Macro_F1	Macro_Precision	Macro_Recall
4	BERT	0.578313	0.505512	0.528295	0.494542
0	Logistic Regression	0.540161	0.479090	0.477200	0.481675
1	Linear SVM	0.534137	0.405891	0.424307	0.408701
3	FNN (GloVe mean)	0.564257	0.337035	0.385527	0.379198
2	Multinomial NB	0.536145	0.232680	0.178715	0.333333

SECTION 7 - Hyperparameter Tuning

7.1 เตรียม scorer + helper

In [34]:
```
# ====== SECTION 7: Hyperparameter Tuning ======

from sklearn.model_selection import GridSearchCV
from sklearn.pipeline import Pipeline
from sklearn.metrics import make_scorer, f1_score
import pandas as pd

macro_f1_scorer = make_scorer(f1_score, average="macro")

X_train_text = train_df["text_raw"]
y_train = train_df["label"]

X_val_text = val_df["text_raw"]
y_val = val_df["label"]

print("Train size:", len(X_train_text), "Val size:", len(X_val_text))
```

```
Train size: 2323 Val size: 498
```

7.2 ML Grid Search (Logistic Regression + Linear SVM + NB)

* 7.2.1 Logistic Regression (TF-IDF + LR)

In [35]:
```
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression

pipe_lr = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", LogisticRegression(max_iter=800, class_weight="balanced"))
])

param_grid_lr = {
    "tfidf__ngram_range": [(1,2), (1,3)],
    "tfidf__min_df": [1, 2],
    "clf__C": [0.1, 1, 10],
}

gs_lr = GridSearchCV(
    pipe_lr,
    param_grid_lr,
    scoring=macro_f1_scorer,
    cv=3,
    n_jobs=-1,
    verbose=1
)

gs_lr.fit(X_train_text, y_train)

print("Best LR params:", gs_lr.best_params_)
print("Best CV Macro-F1:", gs_lr.best_score_)

best_lr = gs_lr.best_estimator_
pred_lr_val = best_lr.predict(X_val_text)
res_lr_tuned = evaluate_model("LR (tuned)", y_val, pred_lr_val)
res_lr_tuned
```

```
Fitting 3 folds for each of 12 candidates, totalling 36 fits
Best LR params: {'clf__C': 0.1, 'tfidf__min_df': 1, 'tfidf__ngram_range': (1, 3)}
Best CV Macro-F1: 0.4523897105046994
```

Out[35]:
```
{'Model': 'LR (tuned)',
 'Accuracy': 0.5220883534136547,
 'Macro_F1': 0.4766869535001151,
 'Macro_Precision': 0.47726133192289,
 'Macro_Recall': 0.48788486223206906}
```

* 7.2.2 Linear SVM (TF-IDF + LinearSVC)

In [36]:
```
from sklearn.svm import LinearSVC

pipe_svm = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", LinearSVC(class_weight="balanced"))
])

param_grid_svm = {
    "tfidf__ngram_range": [(1,2), (1,3)],
    "tfidf__min_df": [1, 2],
    "clf__C": [0.1, 1, 10],
}

gs_svm = GridSearchCV(
    pipe_svm,
    param_grid_svm,
    scoring=macro_f1_scorer,
    cv=3,
    n_jobs=-1,
    verbose=1
)

gs_svm.fit(X_train_text, y_train)

print("Best SVM params:", gs_svm.best_params_)
print("Best CV Macro-F1:", gs_svm.best_score_)

best_svm = gs_svm.best_estimator_
pred_svm_val = best_svm.predict(X_val_text)
res_svm_tuned = evaluate_model("Linear SVM (tuned)", y_val, pred_svm_val)
res_svm_tuned
```

```
Fitting 3 folds for each of 12 candidates, totalling 36 fits
Best SVM params: {'clf__C': 0.1, 'tfidf__min_df': 2, 'tfidf__ngram_range': (1, 2)}
Best CV Macro-F1: 0.4093107688771879
```

Out[36]:
```
{'Model': 'Linear SVM (tuned)',
 'Accuracy': 0.572289156626506,
 'Macro_F1': 0.4365891140726505,
 'Macro_Precision': 0.49706058955776183,
 'Macro_Recall': 0.43513983401030404}
```

* 7.2.3 Multinomial Naive Bayes (TF-IDF + NB)

In [37]:
```
from sklearn.naive_bayes import MultinomialNB

pipe_nb = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", MultinomialNB())
])

param_grid_nb = {
    "tfidf__ngram_range": [(1,1), (1,2)],
    "tfidf__min_df": [1, 2],
    "clf__alpha": [0.1, 0.5, 1.0],
}

gs_nb = GridSearchCV(
    pipe_nb,
    param_grid_nb,
    scoring=macro_f1_scorer,
    cv=3,
    n_jobs=-1,
    verbose=1
)

gs_nb.fit(X_train_text, y_train)

print("Best NB params:", gs_nb.best_params_)
print("Best CV Macro-F1:", gs_nb.best_score_)

best_nb = gs_nb.best_estimator_
pred_nb_val = best_nb.predict(X_val_text)
res_nb_tuned = evaluate_model("Multinomial NB (tuned)", y_val, pred_nb_val)
res_nb_tuned
```

```
Fitting 3 folds for each of 12 candidates, totalling 36 fits
Best NB params: {'clf__alpha': 0.1, 'tfidf__min_df': 2, 'tfidf__ngram_range': (1, 1)}
Best CV Macro-F1: 0.3581382472574624
```

Out[37]:
```
{'Model': 'Multinomial NB (tuned)',
 'Accuracy': 0.6004016064257028,
 'Macro_F1': 0.41614044351264085,
 'Macro_Precision': 0.5759535655058042,
 'Macro_Recall': 0.43121153575636084}
```

7.3 สรุปผล ML tuning เป็นตารางเดียว

In [38]:
```
tuned_ml_df = pd.DataFrame([res_lr_tuned, res_svm_tuned, res_nb_tuned])
tuned_ml_df.sort_values("Macro_F1", ascending=False)
```

Out[38]:

	Model	Accuracy	Macro_F1	Macro_Precision	Macro_Recall
0	LR (tuned)	0.522088	0.476687	0.477261	0.487885
1	Linear SVM (tuned)	0.572289	0.436589	0.497061	0.435140
2	Multinomial NB (tuned)	0.600402	0.416140	0.575954	0.431212

7.4 FNN Hyperarmeter Tuning

* 7.4.1 Reusable Function

In [39]:

```
def train_eval_fnn_once(
    hidden_dim=128,
    dropout=0.3,
    lr=1e-3,
    batch_size=32,
    epochs=10
):
    device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

    train_loader = DataLoader(
        TensorDataset(X_train_tensor, y_train_tensor),
        batch_size=batch_size, shuffle=True
    )
    val_loader = DataLoader(
        TensorDataset(X_val_tensor, y_val_tensor),
        batch_size=batch_size, shuffle=False
    )

    model = MLPClassifier(
        input_dim=X_train_tensor.shape[1],
        hidden_dim=hidden_dim,
        num_classes=3,
        dropout=dropout
    ).to(device)

    criterion = nn.CrossEntropyLoss()
    optimizer = torch.optim.Adam(model.parameters(), lr=lr)

    best_f1 = -1.0

    for epoch in range(1, epochs + 1):
        model.train()

        for xb, yb in train_loader:
            xb, yb = xb.to(device), yb.to(device)
            optimizer.zero_grad()
            logits = model(xb)
            loss = criterion(logits, yb)
            loss.backward()
            optimizer.step()

        # validation
        model.eval()
```

```
        preds_all, y_all = [], []
        with torch.no_grad():
            for xb, yb in val_loader:
                xb = xb.to(device)
                logits = model(xb)
                preds = torch.argmax(logits, dim=1).cpu().numpy()
                preds_all.extend(preds)
                y_all.extend(yb.numpy())

        val_f1 = f1_score(y_all, preds_all, average="macro")

        if val_f1 > best_f1:
            best_f1 = val_f1

    return float(best_f1)
```

* 7.4.2 FNN Hyperparameter Tuning

In [40]:

```
import itertools
import pandas as pd

fnn_grid = {
    "hidden_dim": [64, 128, 256],
    "dropout": [0.2, 0.3, 0.5],
    "lr": [1e-3, 5e-4],
    "batch_size": [32, 64],
}

fnn_results = []

for hidden_dim, dropout, lr, batch_size in itertools.product(
    fnn_grid["hidden_dim"],
    fnn_grid["dropout"],
    fnn_grid["lr"],
    fnn_grid["batch_size"],
):
    print(f"[FNN GRID] hidden={hidden_dim}, dropout={dropout}, lr={lr}, bs={batch_size}")

    best_f1 = train_eval_fnn_once(
        hidden_dim=hidden_dim,
        dropout=dropout,
        lr=lr,
        batch_size=batch_size,
        epochs=10
    )

    fnn_results.append({
        "hidden_dim": hidden_dim,
        "dropout": dropout,
        "lr": lr,
        "batch_size": batch_size,
        "val_macro_f1": best_f1
    })

fnn_tune_df = pd.DataFrame(fnn_results).sort_values("val_macro_f1", ascending=False)

display(fnn_tune_df.head(10))

BEST_FNN_CONFIG = fnn_tune_df.iloc[0].to_dict()
print("BEST_FNN_CONFIG:", BEST_FNN_CONFIG)
```

```
[FNN GRID] hidden=64, dropout=0.2, lr=0.001, bs=32
[FNN GRID] hidden=64, dropout=0.2, lr=0.001, bs=64
[FNN GRID] hidden=64, dropout=0.2, lr=0.0005, bs=32
[FNN GRID] hidden=64, dropout=0.2, lr=0.0005, bs=64
[FNN GRID] hidden=64, dropout=0.3, lr=0.001, bs=32
[FNN GRID] hidden=64, dropout=0.3, lr=0.001, bs=64
[FNN GRID] hidden=64, dropout=0.3, lr=0.0005, bs=32
[FNN GRID] hidden=64, dropout=0.3, lr=0.0005, bs=64
[FNN GRID] hidden=64, dropout=0.5, lr=0.001, bs=32
[FNN GRID] hidden=64, dropout=0.5, lr=0.001, bs=64
[FNN GRID] hidden=64, dropout=0.5, lr=0.0005, bs=32
[FNN GRID] hidden=64, dropout=0.5, lr=0.0005, bs=64
[FNN GRID] hidden=128, dropout=0.2, lr=0.001, bs=32
[FNN GRID] hidden=128, dropout=0.2, lr=0.001, bs=64
[FNN GRID] hidden=128, dropout=0.2, lr=0.0005, bs=32
[FNN GRID] hidden=128, dropout=0.2, lr=0.0005, bs=64
[FNN GRID] hidden=128, dropout=0.3, lr=0.001, bs=32
[FNN GRID] hidden=128, dropout=0.3, lr=0.001, bs=64
[FNN GRID] hidden=128, dropout=0.3, lr=0.0005, bs=32
[FNN GRID] hidden=128, dropout=0.3, lr=0.0005, bs=64
[FNN GRID] hidden=128, dropout=0.5, lr=0.001, bs=32
[FNN GRID] hidden=128, dropout=0.5, lr=0.001, bs=64
[FNN GRID] hidden=128, dropout=0.5, lr=0.0005, bs=32
[FNN GRID] hidden=128, dropout=0.5, lr=0.0005, bs=64
[FNN GRID] hidden=256, dropout=0.2, lr=0.001, bs=32
[FNN GRID] hidden=256, dropout=0.2, lr=0.001, bs=64
[FNN GRID] hidden=256, dropout=0.2, lr=0.0005, bs=32
[FNN GRID] hidden=256, dropout=0.2, lr=0.0005, bs=64
[FNN GRID] hidden=256, dropout=0.3, lr=0.001, bs=32
[FNN GRID] hidden=256, dropout=0.3, lr=0.001, bs=64
[FNN GRID] hidden=256, dropout=0.3, lr=0.0005, bs=32
[FNN GRID] hidden=256, dropout=0.3, lr=0.0005, bs=64
[FNN GRID] hidden=256, dropout=0.5, lr=0.001, bs=32
[FNN GRID] hidden=256, dropout=0.5, lr=0.001, bs=64
[FNN GRID] hidden=256, dropout=0.5, lr=0.0005, bs=32
[FNN GRID] hidden=256, dropout=0.5, lr=0.0005, bs=64
```

	hidden_dim	dropout	lr	batch_size	val_macro_f1
24	256	0.2	0.0010	32	0.410495
26	256	0.2	0.0005	32	0.394257

	hidden_dim	dropout	lr	batch_size	val_macro_f1
0	64	0.2	0.0010	32	0.393754
16	128	0.3	0.0010	32	0.391036
12	128	0.2	0.0010	32	0.390740
28	256	0.3	0.0010	32	0.389589
25	256	0.2	0.0010	64	0.388741
33	256	0.5	0.0010	64	0.385022
32	256	0.5	0.0010	32	0.382029
17	128	0.3	0.0010	64	0.380435

```
BEST_FNN_CONFIG: {'hidden_dim': 256.0, 'dropout': 0.2, 'lr': 0.001, 'batch_size': 32.0, 'val_macro_f1':
0.41049527279035475}
```

7.5 BERT Hyperparameter Tuning

* 7.5.1 **ฟังก์ชันรัน** BERT 1 **ชุดค่า**

In [41]:

```
from transformers import (
    AutoModelForSequenceClassification,
    TrainingArguments,
    Trainer,
    EarlyStoppingCallback
)

def run_bert_once(lr, batch_size, epochs, seed=42, patience=2):
    """
    epochs = max_epochs (เพดาน) -> EarlyStopping จะหยุดเองถ้าไม่ดีขึ้น
    patience = จำนวนครั้งที่ metric ไม่ดีขึ้นก่อนหยุด
    """

    model = AutoModelForSequenceClassification.from_pretrained(
        "bert-base-uncased",
        num_labels=3
    )

    args = TrainingArguments(
        output_dir=f"./bert_tune/lr{lr}_bs{batch_size}_ep{epochs}_seed{seed}",

        num_train_epochs=epochs,
        learning_rate=lr,
        per_device_train_batch_size=batch_size,
        per_device_eval_batch_size=batch_size,

        eval_strategy="epoch",
        save_strategy="epoch",

        load_best_model_at_end=True,
        metric_for_best_model="macro_f1",
        greater_is_better=True,

        logging_steps=50,
        seed=seed,
        report_to="none",
        fp16=True,

        save_total_limit=2
    )

    trainer = Trainer(
        model=model,
```

```
        args=args,
        train_dataset=train_ds,
        eval_dataset=val_ds,
        compute_metrics=compute_metrics,
        callbacks=[EarlyStoppingCallback(early_stopping_patience=patience)]
    )

    trainer.train()
    eval_metrics = trainer.evaluate(val_ds)
    return eval_metrics
```

* 7.5.2 ลูปทดลองครบ grid และสรุปตาราง

In [42]:

```
bert_grid = []
for lr in [2e-5, 3e-5]:
    for bs in [8, 16]:
        for ep in [10]:
            print("\nRunning BERT:", "lr", lr, "bs", bs, "ep", ep)
            metrics = run_bert_once(lr, bs, ep, seed=CONFIG["seed"])
            bert_grid.append({
                "lr": lr,
                "batch_size": bs,
                "epochs": ep,
                "val_macro_f1": metrics.get("eval_macro_f1"),
                "val_accuracy": metrics.get("eval_accuracy"),
                "val_loss": metrics.get("eval_loss"),
            })

bert_tune_df = pd.DataFrame(bert_grid).sort_values("val_macro_f1", ascending=False)
bert_tune_df
```

```
Running BERT: lr 2e-05 bs 8 ep 10

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]


 BertForSequenceClassification LOAD REPORT from: bert-base-uncased
 Key                                          | Status     |
 ---------------------------------------------+------------+-
 cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
 cls.predictions.bias                       | UNEXPECTED |
 cls.seq_relationship.bias                  | UNEXPECTED |
 cls.predictions.transform.dense.bias       | UNEXPECTED |
 cls.seq_relationship.weight                | UNEXPECTED |
 cls.predictions.transform.LayerNorm.bias   | UNEXPECTED |
 cls.predictions.transform.dense.weight     | UNEXPECTED |
 classifier.bias                            | MISSING    |
 classifier.weight                          | MISSING    |

 Notes:
 - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
 - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
 downstream task.
```

[1455/2910 07:57 < 07:58, 3.04 it/s, Epoch 5/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	1.004000	0.959792	0.554217	0.302166	0.374781	0.361267
2	0.898016	0.830689	0.610442	0.425825	0.400683	0.457171
3	0.743381	0.879521	0.616466	0.510970	0.558066	0.513854
4	0.503918	1.093303	0.590361	0.510106	0.528081	0.500877
5	0.283625	1.692486	0.620482	0.475531	0.563187	0.485654

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
```

'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

 [63/63 00:03]

Running BERT: lr 2e-05 bs 16 ep 10

```
Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]
```

```
BertForSequenceClassification LOAD REPORT from: bert-base-uncased
Key                                          | Status     |
---------------------------------------------+------------+-
cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
cls.predictions.bias                         | UNEXPECTED |
cls.seq_relationship.bias                    | UNEXPECTED |
cls.predictions.transform.dense.bias         | UNEXPECTED |
cls.seq_relationship.weight                  | UNEXPECTED |
cls.predictions.transform.LayerNorm.bias     | UNEXPECTED |
cls.predictions.transform.dense.weight       | UNEXPECTED |
classifier.bias                              | MISSING    |
classifier.weight                            | MISSING    |

Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```


[876/1460 09:36 < 06:25, 1.52 it/s, Epoch 6/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.950570	0.896735	0.600402	0.381568	0.425207	0.414193
2	0.826759	0.850904	0.614458	0.494920	0.631226	0.492355
3	0.695368	0.870613	0.608434	0.483146	0.569589	0.478591
4	0.471599	1.075481	0.592369	0.500130	0.546967	0.487204
5	0.304670	1.183955	0.608434	0.470377	0.537112	0.470863
6	0.186156	1.458685	0.604418	0.451727	0.517266	0.457299

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
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'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
```

```
 'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
 'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
 'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
 'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
 'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
 'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
 'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
 'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
 'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
 'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
 'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
 'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
 'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
 'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
 'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
 'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
 'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
 'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
 'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
 'bert.encoder.layer.11.output.LayerNorm.gamma'].
```

 [32/32 00:03]

```
Running BERT: lr 3e-05 bs 8 ep 10

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

 BertForSequenceClassification LOAD REPORT from: bert-base-uncased
 Key                                        | Status     |
 -------------------------------------------+------------+-
 cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
 cls.predictions.bias                       | UNEXPECTED |
 cls.seq_relationship.bias                  | UNEXPECTED |
 cls.predictions.transform.dense.bias       | UNEXPECTED |
 cls.seq_relationship.weight                | UNEXPECTED |
 cls.predictions.transform.LayerNorm.bias   | UNEXPECTED |
 cls.predictions.transform.dense.weight     | UNEXPECTED |
 classifier.bias                            | MISSING    |
 classifier.weight                          | MISSING    |
```

```
Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```

[1455/2910 08:50 < 08:51, 2.74 it/s, Epoch 5/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.995159	0.935302	0.580321	0.345883	0.420602	0.389185
2	0.927814	0.891149	0.574297	0.357528	0.391573	0.392954
3	0.758825	0.893713	0.604418	0.472621	0.596225	0.482453
4	0.656774	1.149013	0.526104	0.471091	0.512183	0.486013
5	0.468271	1.464940	0.576305	0.442389	0.602561	0.467266

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
```

'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

[63/63 00:03]

```
Running BERT: lr 3e-05 bs 16 ep 10

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

  BertForSequenceClassification LOAD REPORT from: bert-base-uncased
  Key                                          | Status     |
  ---------------------------------------------+------------+-
  cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
  cls.predictions.bias                       | UNEXPECTED |
  cls.seq_relationship.bias                  | UNEXPECTED |
  cls.predictions.transform.dense.bias       | UNEXPECTED |
  cls.seq_relationship.weight                | UNEXPECTED |
  cls.predictions.transform.LayerNorm.bias   | UNEXPECTED |
  cls.predictions.transform.dense.weight     | UNEXPECTED |
  classifier.bias                            | MISSING    |
  classifier.weight                          | MISSING    |

  Notes:
  - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
  - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
  downstream task.
```

[1022/1460 11:35 < 04:58, 1.47 it/s, Epoch 7/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.941371	0.898496	0.604418	0.420420	0.396736	0.450921
2	0.834128	0.849442	0.592369	0.500898	0.522468	0.491893
3	0.674655	0.913372	0.620482	0.479218	0.550070	0.494838
4	0.372556	1.130385	0.622490	0.513764	0.564153	0.501329
5	0.190082	1.484329	0.582329	0.519818	0.531653	0.525318
6	0.085835	1.905367	0.600402	0.512037	0.533280	0.505236
7	0.047988	2.244231	0.612450	0.516151	0.564766	0.502087

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
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'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
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'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
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'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
```

```
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].
```

 [32/32 00:03]

	lr	batch_size	epochs	val_macro_f1	val_accuracy	val_loss
3	0.00003	16	10	0.518154	0.580321	1.484953
0	0.00002	8	10	0.506041	0.616466	0.880834
1	0.00002	16	10	0.498468	0.590361	1.075962
2	0.00003	8	10	0.472621	0.604418	0.894638

* 7.5.3 เลือก best config + สรุป

In [43]:
```
best_bert_row = bert_tune_df.iloc[0]
print("Best BERT config:", best_bert_row.to_dict())
```

```
Best BERT config: {'lr': 3e-05, 'batch_size': 16.0, 'epochs': 10.0, 'val_macro_f1': 0.5181535676088059, 'val_accuracy':
0.5803212851405622, 'val_loss': 1.4849528074264526}
```

SECTION 8 - Statistical Robustness

8.1 Seeds

In [44]:
```
import time
import numpy as np
import pandas as pd
from scipy.stats import ttest_rel
from sklearn.metrics import f1_score

from sklearn.pipeline import Pipeline
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.svm import LinearSVC
from sklearn.naive_bayes import MultinomialNB

SEEDS = [42, 123, 2026, 4539, 832]
print("Seeds:", SEEDS)

def set_all_seeds(seed: int):
    random.seed(seed)
    np.random.seed(seed)
    os.environ["PYTHONHASHSEED"] = str(seed)
```

```
Seeds: [42, 123, 2026, 4539, 832]
```

8.2 Helper: make stratified 70/15/15 split per seed

In [45]:
```
def make_split(df_all: pd.DataFrame, seed: int, label_col="label", split=(0.70, 0.15, 0.15)):
    train_ratio, val_ratio, test_ratio = split
    train_df, temp_df = train_test_split(
        df_all,
        test_size=(1 - train_ratio),
        random_state=seed,
        stratify=df_all[label_col]
    )
    val_size = val_ratio / (val_ratio + test_ratio)
    val_df, test_df = train_test_split(
        temp_df,
        test_size=(1 - val_size),
        random_state=seed,
        stratify=temp_df[label_col]
    )
    return train_df.reset_index(drop=True), val_df.reset_index(drop=True), test_df.reset_index(drop=True)
```

8.3 Set Best Params (Dynamic Params)

In [46]:

```
# ===== SECTION 8.3 (UPDATED): Dynamic best params from Section 7 =====
import numpy as np

def _as_int(x, default=None):
    try:
        return int(x)
    except Exception:
        return default

def _as_float(x, default=None):
    try:
        return float(x)
    except Exception:
        return default

def get_best_params_from_gs(gs_obj, fallback: dict, name: str):
    """
    ดึง gs.best_params_ ถ้ามี / ถ้าไม่มีใช้ fallback
    """
    if gs_obj is None:
        print(f"[WARN] {name}: gs_obj not found -> using fallback")
        return fallback

    best_params = getattr(gs_obj, "best_params_", None)
    if not isinstance(best_params, dict) or len(best_params) == 0:
        print(f"[WARN] {name}: gs_obj has no best_params_ -> using fallback")
        return fallback

    return dict(best_params)

# ---- Fallback (กรณีไม่ได้รัน Section 7 หรือรันไม่ครบ) ----
FALLBACK_LR = {"tfidf__ngram_range": (1, 3), "tfidf__min_df": 1, "clf__C": 0.1}
FALLBACK_SVM = {"tfidf__ngram_range": (1, 2), "tfidf__min_df": 2, "clf__C": 0.1}
FALLBACK_NB = {"tfidf__ngram_range": (1, 1), "tfidf__min_df": 2, "clf__alpha": 0.1}

# ---- ดึงจากผล Section 7 (ถ้ามี) ----
BEST_LR_PARAMS  = get_best_params_from_gs(globals().get("gs_lr"),  FALLBACK_LR,  "LR")
BEST_SVM_PARAMS = get_best_params_from_gs(globals().get("gs_svm"), FALLBACK_SVM, "SVM")
BEST_NB_PARAMS  = get_best_params_from_gs(globals().get("gs_nb"),  FALLBACK_NB,  "NB")

# ---- FNN: ดึงจาก BEST_FNN_CONFIG (ที่คุณสร้างใน Section 7) ----
# ในโน้ตบุ๊กคุณ BEST_FNN_CONFIG มี key: hidden_dim, dropout, lr, batch_size, val_macro_f1 :contentReference[oaicite:1]{index=1}
FNN_DEFAULT = {
```

```
    "hidden_dim": 128,
    "dropout": 0.3,
    "lr": 1e-3,
    "batch_size": 32,
    "epochs": 10,
    "patience": 2
}

BEST_FNN_CONFIG = globals().get("BEST_FNN_CONFIG", None)

FNN_CONFIG = dict(FNN_DEFAULT)
if isinstance(BEST_FNN_CONFIG, dict) and len(BEST_FNN_CONFIG) > 0:
    # override เฉพาะค่าที่ tune มา
    if "hidden_dim" in BEST_FNN_CONFIG:
        FNN_CONFIG["hidden_dim"] = _as_int(BEST_FNN_CONFIG["hidden_dim"], FNN_CONFIG["hidden_dim"])
    if "dropout" in BEST_FNN_CONFIG:
        FNN_CONFIG["dropout"] = _as_float(BEST_FNN_CONFIG["dropout"], FNN_CONFIG["dropout"])
    if "lr" in BEST_FNN_CONFIG:
        FNN_CONFIG["lr"] = _as_float(BEST_FNN_CONFIG["lr"], FNN_CONFIG["lr"])
    if "batch_size" in BEST_FNN_CONFIG:
        FNN_CONFIG["batch_size"] = _as_int(BEST_FNN_CONFIG["batch_size"], FNN_CONFIG["batch_size"])

    # epochs/patience: ถ้าคุณมีตัวแปรพวกนี้ใน Section 7 ก็ให้ดึงด้วย (optional)
    if "epochs" in BEST_FNN_CONFIG:
        FNN_CONFIG["epochs"] = _as_int(BEST_FNN_CONFIG["epochs"], FNN_CONFIG["epochs"])
    if "patience" in BEST_FNN_CONFIG:
        FNN_CONFIG["patience"] = _as_int(BEST_FNN_CONFIG["patience"], FNN_CONFIG["patience"])
else:
    print("[WARN] FNN: BEST_FNN_CONFIG not found -> using default FNN_CONFIG")

# ===== Print show ก่อนเข้า 8.4 =====
print("\n===== CHECK BEST PARAMS (Auto pulled) =====")
print("BEST_LR_PARAMS :", BEST_LR_PARAMS)
print("BEST_SVM_PARAMS:", BEST_SVM_PARAMS)
print("BEST_NB_PARAMS :", BEST_NB_PARAMS)
print("FNN_CONFIG     :", FNN_CONFIG)
print("========================================\n")
```

```
===== CHECK BEST PARAMS (Auto pulled) =====
BEST_LR_PARAMS : {'clf__C': 0.1, 'tfidf__min_df': 1, 'tfidf__ngram_range': (1, 3)}
BEST_SVM_PARAMS: {'clf__C': 0.1, 'tfidf__min_df': 2, 'tfidf__ngram_range': (1, 2)}
BEST_NB_PARAMS : {'clf__alpha': 0.1, 'tfidf__min_df': 2, 'tfidf__ngram_range': (1, 1)}
```

```
FNN_CONFIG     : {'hidden_dim': 256, 'dropout': 0.2, 'lr': 0.001, 'batch_size': 32, 'epochs': 10, 'patience': 2}
========================================
```

In [47]:

```
# ===== Dynamic BEST_BERT (pulled from Section 7 if available) =====
import pandas as pd

def _as_int(x, default=None):
    try:
        return int(x)
    except Exception:
        return default

def _as_float(x, default=None):
    try:
        return float(x)
    except Exception:
        return default

BEST_BERT_FALLBACK = {"lr": 3e-5, "batch_size": 8, "epochs": 10}

def get_best_bert_config():
    """
    Priority:
    1) ถ้ามี bert_tune_df -> เลือกแถวที่ val_macro_f1 สูงสุด
    2) ถ้ามี BEST_BERT เดิม (ที่ user ตั้งไว้) -> ใช้เป็น fallback
    3) ไม่งั้นใช้ BEST_BERT_FALLBACK
    """
    # (2) เริ่มจาก BEST_BERT เดิมที่มีอยู่ (ถ้ามี) เป็น fallback
    cur_best = globals().get("BEST_BERT", None)
    best = dict(BEST_BERT_FALLBACK)
    source = "fallback_default"

    if isinstance(cur_best, dict) and len(cur_best) > 0:
        # ถือเป็น fallback ชั้นที่ 2 (manual)
        best.update(cur_best)
        source = "manual(BEST_BERT)"

    # (1) ถ้ามีผล tuning จริง (bert_tune_df) ให้ override เป็นตัวที่ดีที่สุด
    tune_df = globals().get("bert_tune_df", None)
    if isinstance(tune_df, pd.DataFrame) and len(tune_df) > 0:
        # ต้องมีคอลัมน์วัดผล เช่น val_macro_f1 (ถ้าชื่อไม่ตรง เปลี่ยนตรงนี้ได้)
        metric_col = "val_macro_f1" if "val_macro_f1" in tune_df.columns else None
        if metric_col is not None:
            best_row = tune_df.sort_values(metric_col, ascending=False).iloc[0].to_dict()
            # override เฉพาะ key ที่ต้องใช้
            if "lr" in best_row:         best["lr"] = _as_float(best_row["lr"], best["lr"])
```

```
            if "batch_size" in best_row: best["batch_size"] = _as_int(best_row["batch_size"], best["batch_size"])
            if "epochs" in best_row:     best["epochs"] = _as_int(best_row["epochs"], best["epochs"])
            source = "bert_tune_df(best val_macro_f1)"
        else:
            print("[WARN] bert_tune_df found but no 'val_macro_f1' column -> keep fallback/manual")
    else:
        # บางคนตั้งชื่อเป็น bert_results_df อะไรพวกนี้ (ถ้ามีคุณค่อยเพิ่มเองได้)
        pass

    return best, source

# สร้าง BEST_BERT แบบ dynamic
BEST_BERT, BEST_BERT_SOURCE = get_best_bert_config()

# ===== Print show ก่อนเริ่ม Section 8.4/robustness =====
print("\n===== CHECK BEST PARAMS (Auto pulled) =====")
print("BEST_BERT_SOURCE:", BEST_BERT_SOURCE)
print("BEST_BERT       :", BEST_BERT)
print("==========================================\n")
```

```
===== CHECK BEST PARAMS (Auto pulled) =====
BEST_BERT_SOURCE: bert_tune_df(best val_macro_f1)
BEST_BERT       : {'lr': 3e-05, 'batch_size': 16, 'epochs': 10}
==========================================
```

8.4 Train/Eval functions for 5 models

In [56]:

```
# ===== SECTION 8.4 (UPDATED): Train/Eval functions for 5 models =====
import numpy as np
import time
import torch
import torch.nn as nn
from torch.utils.data import DataLoader, TensorDataset
from sklearn.pipeline import Pipeline
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.svm import LinearSVC
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import f1_score
from transformers import TrainingArguments, Trainer, EarlyStoppingCallback, AutoModelForSequenceClassification

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Device:", device)

# ----------------------------
# 1) ML models (TF-IDF)
# ----------------------------
def train_eval_lr(train_df, val_df, text_col="text_raw", label_col="label"):
    pipe = Pipeline([
        ("tfidf", TfidfVectorizer(lowercase=False)),
        ("clf", LogisticRegression(max_iter=800, class_weight="balanced"))
    ])
    pipe.set_params(**BEST_LR_PARAMS)
    pipe.fit(train_df[text_col], train_df[label_col])
    pred = pipe.predict(val_df[text_col])
    return float(f1_score(val_df[label_col], pred, average="macro"))

def train_eval_svm(train_df, val_df, text_col="text_raw", label_col="label"):
    pipe = Pipeline([
        ("tfidf", TfidfVectorizer(lowercase=False)),
        ("clf", LinearSVC(class_weight="balanced"))
    ])
    pipe.set_params(**BEST_SVM_PARAMS)
    pipe.fit(train_df[text_col], train_df[label_col])
    pred = pipe.predict(val_df[text_col])
    return float(f1_score(val_df[label_col], pred, average="macro"))

def train_eval_nb(train_df, val_df, text_col="text_raw", label_col="label"):
    pipe = Pipeline([
        ("tfidf", TfidfVectorizer(lowercase=False)),
```

```
        ("clf", MultinomialNB())
    ])
    pipe.set_params(**BEST_NB_PARAMS)
    pipe.fit(train_df[text_col], train_df[label_col])
    pred = pipe.predict(val_df[text_col])
    return float(f1_score(val_df[label_col], pred, average="macro"))

# ----------------------------
# 2) FNN (GloVe mean) — ใช้ FNN_CONFIG ที่ดึงจาก Section 7
# ----------------------------
# ถ้ายังไม่มี glove_vector / MLPClassifier (กรณีรันไม่ครบ) ให้สร้าง fallback แบบง่าย
if "glove_vector" not in globals():
    def glove_vector(text):
        tokens = str(text).lower().split()
        vecs = [glove[w] for w in tokens if w in glove]
        if len(vecs) == 0:
            return np.zeros(100, dtype=np.float32)
        return np.mean(vecs, axis=0).astype(np.float32)

if "MLPClassifier" not in globals():
    class MLPClassifier(nn.Module):
        def __init__(self, input_dim=100, hidden_dim=128, num_classes=3, dropout=0.3):
            super().__init__()
            self.net = nn.Sequential(
                nn.Linear(input_dim, hidden_dim),
                nn.ReLU(),
                nn.Dropout(dropout),
                nn.Linear(hidden_dim, num_classes)
            )
        def forward(self, x):
            return self.net(x)

def _set_torch_seed(seed: int):
    torch.manual_seed(seed)
    torch.cuda.manual_seed_all(seed)

def train_eval_fnn(train_df, val_df, seed: int, text_col="text_raw", label_col="label"):
    set_all_seeds(seed)
    _set_torch_seed(seed)

    Xtr = np.vstack(train_df[text_col].astype(str).apply(glove_vector).values)
    Xva = np.vstack(val_df[text_col].astype(str).apply(glove_vector).values)
    ytr = train_df[label_col].astype(int).values
```

```
yva = val_df[label_col].astype(int).values

train_loader = DataLoader(
    TensorDataset(torch.tensor(Xtr, dtype=torch.float32), torch.tensor(ytr, dtype=torch.long)),
    batch_size=int(FNN_CONFIG["batch_size"]), shuffle=True
)
val_loader = DataLoader(
    TensorDataset(torch.tensor(Xva, dtype=torch.float32), torch.tensor(yva, dtype=torch.long)),
    batch_size=int(FNN_CONFIG["batch_size"]), shuffle=False
)

model = MLPClassifier(
    input_dim=Xtr.shape[1],
    hidden_dim=int(FNN_CONFIG["hidden_dim"]),
    num_classes=3,
    dropout=float(FNN_CONFIG["dropout"])
).to(device)

opt = torch.optim.Adam(model.parameters(), lr=float(FNN_CONFIG["lr"]))
loss_fn = nn.CrossEntropyLoss()

def eval_macro_f1():
    model.eval()
    preds_all, y_all = [], []
    with torch.no_grad():
        for xb, yb in val_loader:
            xb = xb.to(device)
            logits = model(xb)
            preds = torch.argmax(logits, dim=1).cpu().numpy()
            preds_all.extend(preds)
            y_all.extend(yb.numpy())
    return float(f1_score(y_all, preds_all, average="macro"))

best_f1 = -1.0
best_state = None
patience_left = int(FNN_CONFIG.get("patience", 2))

for _ in range(int(FNN_CONFIG.get("epochs", 10))):
    model.train()
    for xb, yb in train_loader:
        xb, yb = xb.to(device), yb.to(device)
        opt.zero_grad()
        logits = model(xb)
```

```
            loss = loss_fn(logits, yb)
            loss.backward()
            opt.step()

        val_f1 = eval_macro_f1()
        if val_f1 > best_f1 + 1e-6:
            best_f1 = val_f1
            best_state = {k: v.detach().cpu().clone() for k, v in model.state_dict().items()}
            patience_left = int(FNN_CONFIG.get("patience", 2))
        else:
            patience_left -= 1
            if patience_left <= 0:
                break

    if best_state is not None:
        model.load_state_dict({k: v.to(device) for k, v in best_state.items()})

    return eval_macro_f1()

# ----------------------------
# 3) BERT — ใช้ BEST_BERT (Dynamic) ที่คุณดึงจาก bert_tune_df แล้ว
# ----------------------------
import os, shutil, inspect
import torch
from transformers import TrainingArguments, Trainer, EarlyStoppingCallback, AutoModelForSequenceClassification

def _reset_dir(path: str):
    # แทน overwrite_output_dir
    if os.path.isdir(path):
        shutil.rmtree(path)
    os.makedirs(path, exist_ok=True)

def _make_bert_args(seed: int):
    out_dir = f"/content/drive/MyDrive/Colab_Notebooks/pj_nlp/bert_robust/seed{seed}"
    _reset_dir(out_dir)

    # ค่าหลักที่อยากใช้
    desired = dict(
        output_dir=out_dir,
        num_train_epochs=int(BEST_BERT["epochs"]),
        learning_rate=float(BEST_BERT["lr"]),
        per_device_train_batch_size=int(BEST_BERT["batch_size"]),
        per_device_eval_batch_size=int(BEST_BERT["batch_size"]),
```

```
        save_strategy="epoch",
        load_best_model_at_end=True,
        metric_for_best_model="macro_f1",
        greater_is_better=True,

        save_total_limit=1,
        logging_steps=100,
        seed=seed,
        report_to="none",
        fp16=torch.cuda.is_available(),
    )

    # -------- compat layer: ส่งเฉพาะ args ที่ TrainingArguments รองรับจริง --------
    sig = inspect.signature(TrainingArguments.__init__)
    allowed = set(sig.parameters.keys())
    allowed.discard("self")

    # ชื่อพารามิเตอร์ eval strategy อาจต่างกัน
    if "eval_strategy" in allowed:
        desired["eval_strategy"] = "epoch"
    elif "evaluation_strategy" in allowed:
        desired["evaluation_strategy"] = "epoch"
    # ถ้าไม่มีทั้งคู่ ก็ไม่ใส่ (trainer จะไม่ eval เป็นรอบ ๆ)

    filtered = {k: v for k, v in desired.items() if k in allowed}
    return TrainingArguments(**filtered)

def train_eval_bert(train_df, val_df, seed: int, patience: int = 2):
    set_all_seeds(seed)

    train_ds = make_hf_ds(train_df)
    val_ds   = make_hf_ds(val_df)

    model = AutoModelForSequenceClassification.from_pretrained(
        "bert-base-uncased",
        num_labels=3
    )

    args = _make_bert_args(seed)

    trainer = Trainer(
        model=model,
```

```
        args=args,
        train_dataset=train_ds,
        eval_dataset=val_ds,
        compute_metrics=compute_metrics,
        data_collator=data_collator,
        callbacks=[EarlyStoppingCallback(early_stopping_patience=patience)]
    )

    trainer.train()
    metrics = trainer.evaluate(val_ds)
    return float(metrics["eval_macro_f1"])
```

```
Device: cuda
```

In [57]:

```
import numpy as np
from datasets import Dataset
from transformers import AutoTokenizer, DataCollatorWithPadding
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

if "tokenizer" not in globals():
    tokenizer = AutoTokenizer.from_pretrained("bert-base-uncased")

if "data_collator" not in globals():
    data_collator = DataCollatorWithPadding(tokenizer=tokenizer)

# metrics
if "compute_metrics" not in globals():
    def compute_metrics(eval_pred):
        logits, labels = eval_pred
        preds = np.argmax(logits, axis=1)
        return {
            "accuracy": accuracy_score(labels, preds),
            "macro_f1": f1_score(labels, preds, average="macro"),
            "macro_precision": precision_score(labels, preds, average="macro", zero_division=0),
            "macro_recall": recall_score(labels, preds, average="macro", zero_division=0),
        }

# make_hf_ds (ตัวที่คุณใช้ใน train_eval_bert)
if "make_hf_ds" not in globals():
    def make_hf_ds(df_, text_col="text_raw", label_col="label"):
        ds = Dataset.from_pandas(df_[[text_col, label_col]].copy())

        def tok(batch):
            return tokenizer(batch[text_col], truncation=True, max_length=512)

        # แนะนำ: remove_columns เพื่อไม่ให้มีคอลัมน์อื่นปน (กันบางเคส Trainer งอแง)
        ds = ds.map(tok, batched=True, remove_columns=[text_col])
        ds = ds.rename_column(label_col, "labels")
        ds.set_format(type="torch", columns=["input_ids", "attention_mask", "labels"])
        return ds

print("✅ BERT prerequisites ready:",
      "tokenizer" in globals(),
      "data_collator" in globals(),
      "compute_metrics" in globals(),
      "make_hf_ds" in globals())
```

```
✅ BERT prerequisites ready: True True True True
```

8.5 Run robustness loop

In [58]:

```
# ===== SECTION 8.5 (UPDATED): Robustness loop for 5 models =====
import pandas as pd
from scipy.stats import ttest_rel

FULL_DF = df.copy()

scores = {"LR": [], "SVM": [], "NB": [], "FNN": [], "BERT": []}
rows = []

for seed in SEEDS:
    print(f"\n===== Seed {seed} =====")
    t0 = time.perf_counter()

    tr_df, va_df, te_df = make_split(FULL_DF, seed=seed, label_col="label", split=CONFIG["split"])

    lr_f1  = train_eval_lr(tr_df, va_df)
    svm_f1 = train_eval_svm(tr_df, va_df)
    nb_f1  = train_eval_nb(tr_df, va_df)
    fnn_f1 = train_eval_fnn(tr_df, va_df, seed=seed)
    bert_f1 = train_eval_bert(tr_df, va_df, seed=seed)

    scores["LR"].append(lr_f1)
    scores["SVM"].append(svm_f1)
    scores["NB"].append(nb_f1)
    scores["FNN"].append(fnn_f1)
    scores["BERT"].append(bert_f1)

    print("LR  :", lr_f1)
    print("SVM :", svm_f1)
    print("NB  :", nb_f1)
    print("FNN :", fnn_f1)
    print("BERT:", bert_f1)

    rows.append({
        "seed": seed,
        "lr_macro_f1": lr_f1,
        "svm_macro_f1": svm_f1,
        "nb_macro_f1": nb_f1,
        "fnn_macro_f1": fnn_f1,
        "bert_macro_f1": bert_f1,
        "time_sec": float(time.perf_counter() - t0)
    })
```

```
robust_df = pd.DataFrame(rows)
display(robust_df)

summary_rows = []
for m in ["LR", "SVM", "NB", "FNN", "BERT"]:
    mean = float(np.mean(scores[m]))
    std  = float(np.std(scores[m], ddof=1))
    summary_rows.append({"model": m, "mean_macro_f1": mean, "std_macro_f1": std})

robust_summary = pd.DataFrame(summary_rows).sort_values("mean_macro_f1", ascending=False)
display(robust_summary)
```

```
===== Seed 42 =====

Map:   0%|          | 0/2323 [00:00<?, ? examples/s]

Map:   0%|          | 0/498 [00:00<?, ? examples/s]

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

BertForSequenceClassification LOAD REPORT from: bert-base-uncased
Key                                         | Status     |
--------------------------------------------+------------+-
cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
cls.predictions.bias                        | UNEXPECTED |
cls.seq_relationship.bias                   | UNEXPECTED |
cls.predictions.transform.dense.bias        | UNEXPECTED |
cls.seq_relationship.weight                 | UNEXPECTED |
cls.predictions.transform.LayerNorm.bias    | UNEXPECTED |
cls.predictions.transform.dense.weight      | UNEXPECTED |
classifier.bias                             | MISSING    |
classifier.weight                           | MISSING    |

Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```


[730/1460 05:01 < 05:02, 2.41 it/s, Epoch 5/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.982359	0.926941	0.594378	0.389819	0.401379	0.418797
2	0.904837	0.888798	0.602410	0.478977	0.536257	0.470885
3	0.682042	0.910576	0.624498	0.490323	0.579758	0.505791
4	0.507305	1.392966	0.522088	0.475520	0.505932	0.497195
5	0.254464	1.543288	0.584337	0.482752	0.512493	0.474269

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
```

'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

 [32/32 00:02]

LR : 0.4766869535001151
SVM : 0.4365891140726505
NB : 0.41614044351264085
FNN : 0.37176485383815855

```
BERT: 0.4886542792078563

===== Seed 123 =====

Map:   0%|          | 0/2323 [00:00<?, ? examples/s]

Map:   0%|          | 0/498 [00:00<?, ? examples/s]

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

  BertForSequenceClassification LOAD REPORT from: bert-base-uncased
  Key                                         | Status     |
  --------------------------------------------+------------+-
  cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
  cls.predictions.bias                        | UNEXPECTED |
  cls.seq_relationship.bias                   | UNEXPECTED |
  cls.predictions.transform.dense.bias        | UNEXPECTED |
  cls.seq_relationship.weight                 | UNEXPECTED |
  cls.predictions.transform.LayerNorm.bias    | UNEXPECTED |
  cls.predictions.transform.dense.weight      | UNEXPECTED |
  classifier.bias                             | MISSING    |
  classifier.weight                           | MISSING    |

  Notes:
  - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
  - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
  downstream task.
```

[1168/1460 08:47 < 02:11, 2.21 it/s, Epoch 8/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.982454	0.909633	0.580321	0.371982	0.403358	0.402544
2	0.915321	0.876528	0.608434	0.418129	0.410845	0.444234
3	0.745396	0.909680	0.604418	0.478041	0.544290	0.476822
4	0.568912	1.022895	0.622490	0.522203	0.591360	0.514474
5	0.307882	1.209944	0.586345	0.513967	0.530848	0.509234

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
6	0.201870	1.631920	0.586345	0.526047	0.536087	0.519059
7	0.066805	1.913327	0.614458	0.525550	0.562250	0.520547
8	0.049187	2.172580	0.608434	0.522750	0.556665	0.509608

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
```

'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

 [32/32 00:02]

```
LR  : 0.46594808998901066
SVM : 0.401364502146718
NB  : 0.3786567927271565
FNN : 0.39042887656898745
BERT: 0.5260470958220155

===== Seed 2026 =====

Map:   0%|          | 0/2323 [00:00<?, ? examples/s]

Map:   0%|          | 0/498 [00:00<?, ? examples/s]

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

  BertForSequenceClassification LOAD REPORT from: bert-base-uncased
  Key                                         | Status     |
  --------------------------------------------+------------+-
  cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
  cls.predictions.bias                        | UNEXPECTED |
  cls.seq_relationship.bias                   | UNEXPECTED |
  cls.predictions.transform.dense.bias        | UNEXPECTED |
  cls.seq_relationship.weight                 | UNEXPECTED |
  cls.predictions.transform.LayerNorm.bias    | UNEXPECTED |
  cls.predictions.transform.dense.weight      | UNEXPECTED |
  classifier.bias                             | MISSING    |
  classifier.weight                           | MISSING    |

  Notes:
  - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
  - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
  downstream task.
```


[1168/1460 08:22 < 02:05, 2.32 it/s, Epoch 8/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.980121	0.981626	0.481928	0.345083	0.342699	0.409831
2	0.929424	0.935716	0.568273	0.390008	0.372214	0.417595
3	0.795584	0.908087	0.586345	0.414344	0.384752	0.448869

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
4	0.726614	0.949302	0.600402	0.422898	0.398527	0.452598
5	0.510114	1.055323	0.562249	0.515087	0.522810	0.522678
6	0.436456	1.150227	0.610442	0.533363	0.569701	0.518585
7	0.287682	1.420736	0.602410	0.518131	0.564171	0.504087
8	0.223752	1.649249	0.592369	0.510389	0.551551	0.495553

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
```

'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

[32/32 00:02]

```
LR  : 0.4807311576247338
SVM : 0.4151215118276395
NB  : 0.34668824844976615
FNN : 0.3599957684464727
BERT: 0.530487123797704

===== Seed 4539 =====

Map:   0%|          | 0/2323 [00:00<?, ? examples/s]

Map:   0%|          | 0/498 [00:00<?, ? examples/s]

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

  BertForSequenceClassification LOAD REPORT from: bert-base-uncased
  Key                                         | Status     |
  --------------------------------------------+------------+-
  cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
  cls.predictions.bias                        | UNEXPECTED |
  cls.seq_relationship.bias                   | UNEXPECTED |
  cls.predictions.transform.dense.bias        | UNEXPECTED |
  cls.seq_relationship.weight                 | UNEXPECTED |
  cls.predictions.transform.LayerNorm.bias    | UNEXPECTED |
  cls.predictions.transform.dense.weight      | UNEXPECTED |
  classifier.bias                             | MISSING    |
  classifier.weight                           | MISSING    |

  Notes:
  - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
  - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
  downstream task.
```

[1022/1460 07:30 < 03:13, 2.27 it/s, Epoch 7/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.961771	0.895195	0.606426	0.500862	0.602178	0.490206

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
2	0.837650	0.786331	0.654618	0.550356	0.659804	0.530488
3	0.575408	0.866923	0.626506	0.558369	0.585015	0.552784
4	0.401200	1.257878	0.586345	0.535429	0.566510	0.535048
5	0.180644	1.376218	0.630522	0.572186	0.597596	0.564785
6	0.106690	1.660122	0.646586	0.570474	0.610672	0.555250
7	0.049816	1.945445	0.652610	0.560728	0.641384	0.544375

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
```

'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

[32/32 00:02]

```
LR  : 0.5180680579449525
SVM : 0.4310951875442321
NB  : 0.3703655245930229
FNN : 0.38123575639291
BERT: 0.5736390511212055

===== Seed 832 =====

Map:   0%|          | 0/2323 [00:00<?, ? examples/s]

Map:   0%|          | 0/498 [00:00<?, ? examples/s]

Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]

  BertForSequenceClassification LOAD REPORT from: bert-base-uncased
  Key                                        | Status     |
  -------------------------------------------+------------+-
  cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
  cls.predictions.bias                       | UNEXPECTED |
  cls.seq_relationship.bias                  | UNEXPECTED |
  cls.predictions.transform.dense.bias       | UNEXPECTED |
  cls.seq_relationship.weight                | UNEXPECTED |
  cls.predictions.transform.LayerNorm.bias   | UNEXPECTED |
  cls.predictions.transform.dense.weight     | UNEXPECTED |
  classifier.bias                            | MISSING    |
  classifier.weight                          | MISSING    |

  Notes:
  - UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
  - MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
  downstream task.
```

[1022/1460 07:47 < 03:20, 2.18 it/s, Epoch 7/10]

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
1	0.961370	0.910145	0.564257	0.391965	0.367470	0.421777

Epoch	Training Loss	Validation Loss	Accuracy	Macro F1	Macro Precision	Macro Recall
2	0.877775	0.907858	0.572289	0.427251	0.604657	0.468730
3	0.653525	0.947794	0.606426	0.481026	0.567295	0.487982
4	0.499338	1.113312	0.598394	0.522053	0.555427	0.509745
5	0.222904	1.410167	0.610442	0.527838	0.563498	0.514517
6	0.120729	2.007586	0.558233	0.492659	0.529194	0.491047
7	0.052586	2.159408	0.582329	0.503272	0.529404	0.491816

```
Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
There were missing keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.weight',
'bert.embeddings.LayerNorm.bias', 'bert.encoder.layer.0.attention.output.LayerNorm.weight',
'bert.encoder.layer.0.attention.output.LayerNorm.bias', 'bert.encoder.layer.0.output.LayerNorm.weight',
'bert.encoder.layer.0.output.LayerNorm.bias', 'bert.encoder.layer.1.attention.output.LayerNorm.weight',
'bert.encoder.layer.1.attention.output.LayerNorm.bias', 'bert.encoder.layer.1.output.LayerNorm.weight',
'bert.encoder.layer.1.output.LayerNorm.bias', 'bert.encoder.layer.2.attention.output.LayerNorm.weight',
'bert.encoder.layer.2.attention.output.LayerNorm.bias', 'bert.encoder.layer.2.output.LayerNorm.weight',
'bert.encoder.layer.2.output.LayerNorm.bias', 'bert.encoder.layer.3.attention.output.LayerNorm.weight',
'bert.encoder.layer.3.attention.output.LayerNorm.bias', 'bert.encoder.layer.3.output.LayerNorm.weight',
'bert.encoder.layer.3.output.LayerNorm.bias', 'bert.encoder.layer.4.attention.output.LayerNorm.weight',
'bert.encoder.layer.4.attention.output.LayerNorm.bias', 'bert.encoder.layer.4.output.LayerNorm.weight',
```

'bert.encoder.layer.4.output.LayerNorm.bias', 'bert.encoder.layer.5.attention.output.LayerNorm.weight',
'bert.encoder.layer.5.attention.output.LayerNorm.bias', 'bert.encoder.layer.5.output.LayerNorm.weight',
'bert.encoder.layer.5.output.LayerNorm.bias', 'bert.encoder.layer.6.attention.output.LayerNorm.weight',
'bert.encoder.layer.6.attention.output.LayerNorm.bias', 'bert.encoder.layer.6.output.LayerNorm.weight',
'bert.encoder.layer.6.output.LayerNorm.bias', 'bert.encoder.layer.7.attention.output.LayerNorm.weight',
'bert.encoder.layer.7.attention.output.LayerNorm.bias', 'bert.encoder.layer.7.output.LayerNorm.weight',
'bert.encoder.layer.7.output.LayerNorm.bias', 'bert.encoder.layer.8.attention.output.LayerNorm.weight',
'bert.encoder.layer.8.attention.output.LayerNorm.bias', 'bert.encoder.layer.8.output.LayerNorm.weight',
'bert.encoder.layer.8.output.LayerNorm.bias', 'bert.encoder.layer.9.attention.output.LayerNorm.weight',
'bert.encoder.layer.9.attention.output.LayerNorm.bias', 'bert.encoder.layer.9.output.LayerNorm.weight',
'bert.encoder.layer.9.output.LayerNorm.bias', 'bert.encoder.layer.10.attention.output.LayerNorm.weight',
'bert.encoder.layer.10.attention.output.LayerNorm.bias', 'bert.encoder.layer.10.output.LayerNorm.weight',
'bert.encoder.layer.10.output.LayerNorm.bias', 'bert.encoder.layer.11.attention.output.LayerNorm.weight',
'bert.encoder.layer.11.attention.output.LayerNorm.bias', 'bert.encoder.layer.11.output.LayerNorm.weight',
'bert.encoder.layer.11.output.LayerNorm.bias'].
There were unexpected keys in the checkpoint model loaded: ['bert.embeddings.LayerNorm.beta',
'bert.embeddings.LayerNorm.gamma', 'bert.encoder.layer.0.attention.output.LayerNorm.beta',
'bert.encoder.layer.0.attention.output.LayerNorm.gamma', 'bert.encoder.layer.0.output.LayerNorm.beta',
'bert.encoder.layer.0.output.LayerNorm.gamma', 'bert.encoder.layer.1.attention.output.LayerNorm.beta',
'bert.encoder.layer.1.attention.output.LayerNorm.gamma', 'bert.encoder.layer.1.output.LayerNorm.beta',
'bert.encoder.layer.1.output.LayerNorm.gamma', 'bert.encoder.layer.2.attention.output.LayerNorm.beta',
'bert.encoder.layer.2.attention.output.LayerNorm.gamma', 'bert.encoder.layer.2.output.LayerNorm.beta',
'bert.encoder.layer.2.output.LayerNorm.gamma', 'bert.encoder.layer.3.attention.output.LayerNorm.beta',
'bert.encoder.layer.3.attention.output.LayerNorm.gamma', 'bert.encoder.layer.3.output.LayerNorm.beta',
'bert.encoder.layer.3.output.LayerNorm.gamma', 'bert.encoder.layer.4.attention.output.LayerNorm.beta',
'bert.encoder.layer.4.attention.output.LayerNorm.gamma', 'bert.encoder.layer.4.output.LayerNorm.beta',
'bert.encoder.layer.4.output.LayerNorm.gamma', 'bert.encoder.layer.5.attention.output.LayerNorm.beta',
'bert.encoder.layer.5.attention.output.LayerNorm.gamma', 'bert.encoder.layer.5.output.LayerNorm.beta',
'bert.encoder.layer.5.output.LayerNorm.gamma', 'bert.encoder.layer.6.attention.output.LayerNorm.beta',
'bert.encoder.layer.6.attention.output.LayerNorm.gamma', 'bert.encoder.layer.6.output.LayerNorm.beta',
'bert.encoder.layer.6.output.LayerNorm.gamma', 'bert.encoder.layer.7.attention.output.LayerNorm.beta',
'bert.encoder.layer.7.attention.output.LayerNorm.gamma', 'bert.encoder.layer.7.output.LayerNorm.beta',
'bert.encoder.layer.7.output.LayerNorm.gamma', 'bert.encoder.layer.8.attention.output.LayerNorm.beta',
'bert.encoder.layer.8.attention.output.LayerNorm.gamma', 'bert.encoder.layer.8.output.LayerNorm.beta',
'bert.encoder.layer.8.output.LayerNorm.gamma', 'bert.encoder.layer.9.attention.output.LayerNorm.beta',
'bert.encoder.layer.9.attention.output.LayerNorm.gamma', 'bert.encoder.layer.9.output.LayerNorm.beta',
'bert.encoder.layer.9.output.LayerNorm.gamma', 'bert.encoder.layer.10.attention.output.LayerNorm.beta',
'bert.encoder.layer.10.attention.output.LayerNorm.gamma', 'bert.encoder.layer.10.output.LayerNorm.beta',
'bert.encoder.layer.10.output.LayerNorm.gamma', 'bert.encoder.layer.11.attention.output.LayerNorm.beta',
'bert.encoder.layer.11.attention.output.LayerNorm.gamma', 'bert.encoder.layer.11.output.LayerNorm.beta',
'bert.encoder.layer.11.output.LayerNorm.gamma'].

 [32/32 00:02]

```
LR  : 0.4533262278665197
SVM : 0.4257578918092059
NB  : 0.39201383503809556
FNN : 0.36971297410527254
BERT: 0.5294804967967465
```

	seed	lr_macro_f1	svm_macro_f1	nb_macro_f1	fnn_macro_f1	bert_macro_f1	time_sec
0	42	0.476687	0.436589	0.416140	0.371765	0.488654	313.210228
1	123	0.465948	0.401365	0.378657	0.390429	0.526047	543.406638
2	2026	0.480731	0.415122	0.346688	0.359996	0.530487	524.680698
3	4539	0.518068	0.431095	0.370366	0.381236	0.573639	464.520404
4	832	0.453326	0.425758	0.392014	0.369713	0.529480	483.534821

	model	mean_macro_f1	std_macro_f1
4	BERT	0.529662	0.030122
0	LR	0.478952	0.024311
1	SVM	0.421986	0.013989
2	NB	0.380773	0.025748
3	FNN	0.374628	0.011617

8.6 Paired t-test on per-seed scores

In [59]:
```
# ===== SECTION 8.6 (UPDATED): Paired t-tests =====
tests = []
for m in ["LR", "SVM", "NB", "FNN"]:
    t_stat, p_val = ttest_rel(scores["BERT"], scores[m])
    tests.append({
        "compare": f"BERT vs {m}",
        "t_stat": float(t_stat),
        "p_value": float(p_val)
    })

ttest_df = pd.DataFrame(tests).sort_values("p_value")
display(ttest_df)

print("\nInterpretation note:")
print("- ถ้า p < 0.05: ความต่าง BERT vs baseline มีนัยสำคัญ (ตาม seeds ที่ใช้)")
print("- ถ้า p >= 0.05: ยังสรุปไม่ได้ชัด (อาจต้องเพิ่มจำนวน seeds เพื่อ power ที่สูงขึ้น)")
```

	compare	t_stat	p_value
3	BERT vs FNN	11.736612	0.000301
1	BERT vs SVM	7.044784	0.002140
2	BERT vs NB	6.611641	0.002713
0	BERT vs LR	4.769191	0.008845

```
Interpretation note:
- ถ้า p < 0.05: ความต่าง BERT vs baseline มีนัยสำคัญ (ตาม seeds ที่ใช้)
- ถ้า p >= 0.05: ยังสรุปไม่ได้ชัด (อาจต้องเพิ่มจำนวน seeds เพื่อ power ที่สูงขึ้น)
```

SECTION 9 - Error Taxonomy

9.0 Config และ Label Names

In [64]:
```
LABEL_NAMES = {0: "low", 1: "medium", 2: "high"}
TEXT_COL = "text_raw"
LABEL_COL = "label"

def decode_label(y):
    return LABEL_NAMES.get(int(y), str(y))
```

9.1 Train+Predict on TEST for LR/SVM/NB

In [65]:

```
# ===== SECTION 9.1 (UPDATED): Train+Predict on TEST for LR/SVM/NB =====
import time
import numpy as np
import pandas as pd

from sklearn.pipeline import Pipeline
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.svm import LinearSVC
from sklearn.naive_bayes import MultinomialNB

# ----------------------------
# (0) trainval = train + val
# ----------------------------
trainval_df = pd.concat([train_df, val_df], ignore_index=True)

# ----------------------------
# (1) fallback ถ้าดันไม่ได้รัน Section 8.3 มาก่อน
# ----------------------------
if "BEST_LR_PARAMS" not in globals():
    BEST_LR_PARAMS = {"tfidf__ngram_range": (1, 3), "tfidf__min_df": 1, "clf__C": 0.1}
if "BEST_SVM_PARAMS" not in globals():
    BEST_SVM_PARAMS = {"tfidf__ngram_range": (1, 2), "tfidf__min_df": 2, "clf__C": 0.1}
if "BEST_NB_PARAMS" not in globals():
    BEST_NB_PARAMS = {"tfidf__ngram_range": (1, 1), "tfidf__min_df": 2, "clf__alpha": 0.1}

# ----------------------------
# (2) helper: softmax สำหรับ SVM pseudo-confidence
# ----------------------------
def softmax_np(scores_2d):
    z = scores_2d - np.max(scores_2d, axis=1, keepdims=True)
    e = np.exp(z)
    return e / np.sum(e, axis=1, keepdims=True)

# ----------------------------
# (3) LR
# ----------------------------
lr_pipe = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", LogisticRegression(max_iter=800, class_weight="balanced"))
])
lr_pipe.set_params(**BEST_LR_PARAMS)
```

```
t0 = time.perf_counter()
lr_pipe.fit(trainval_df[TEXT_COL], trainval_df[LABEL_COL])
lr_train_time_sec = time.perf_counter() - t0
print("LR train time (s):", round(lr_train_time_sec, 3))

lr_test_pred = lr_pipe.predict(test_df[TEXT_COL])

# LR confidence
if hasattr(lr_pipe, "predict_proba"):
    lr_test_proba = lr_pipe.predict_proba(test_df[TEXT_COL])
    lr_test_conf = lr_test_proba.max(axis=1)
else:
    lr_test_proba = None
    lr_test_conf = np.full(len(test_df), np.nan)

# ----------------------------
# (4) Linear SVM
# ----------------------------
svm_pipe = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", LinearSVC(class_weight="balanced"))
])
svm_pipe.set_params(**BEST_SVM_PARAMS)

t0 = time.perf_counter()
svm_pipe.fit(trainval_df[TEXT_COL], trainval_df[LABEL_COL])
svm_train_time_sec = time.perf_counter() - t0
print("SVM train time (s):", round(svm_train_time_sec, 3))

svm_test_pred = svm_pipe.predict(test_df[TEXT_COL])

# SVM pseudo-confidence (จาก decision_function -> softmax)
if hasattr(svm_pipe, "decision_function"):
    svm_scores = svm_pipe.decision_function(test_df[TEXT_COL])  # (n,3) ปกติ
    if svm_scores.ndim == 1:
        # เผื่อเคส binary (แต่โปรเจคนี้ 3 class ปกติจะไม่เข้า)
        svm_scores = np.vstack([-svm_scores, svm_scores]).T
    svm_test_proba = softmax_np(svm_scores)
    svm_test_conf = svm_test_proba.max(axis=1)
else:
    svm_test_proba = None
    svm_test_conf = np.full(len(test_df), np.nan)
```

```
# ----------------------------
# (5) Multinomial NB
# ----------------------------
nb_pipe = Pipeline([
    ("tfidf", TfidfVectorizer(lowercase=False)),
    ("clf", MultinomialNB())
])
nb_pipe.set_params(**BEST_NB_PARAMS)

t0 = time.perf_counter()
nb_pipe.fit(trainval_df[TEXT_COL], trainval_df[LABEL_COL])
nb_train_time_sec = time.perf_counter() - t0
print("NB train time (s):", round(nb_train_time_sec, 3))

nb_test_pred = nb_pipe.predict(test_df[TEXT_COL])

# NB confidence
if hasattr(nb_pipe, "predict_proba"):
    nb_test_proba = nb_pipe.predict_proba(test_df[TEXT_COL])
    nb_test_conf = nb_test_proba.max(axis=1)
else:
    nb_test_proba = None
    nb_test_conf = np.full(len(test_df), np.nan)
```

```
LR train time (s): 4.463
SVM train time (s): 1.009
NB train time (s): 0.328
```

9.2 Train+Predict on TEST for FNN

In [66]:

```
# ===== SECTION 9.2 (UPDATED): Train+Predict on TEST for FNN =====
import torch
import torch.nn as nn
from torch.utils.data import DataLoader, TensorDataset

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

# fallback ถ้ายังไม่มี FNN_CONFIG
if "FNN_CONFIG" not in globals():
    FNN_CONFIG = {"hidden_dim": 256, "dropout": 0.2, "lr": 1e-3, "batch_size": 32, "epochs": 10}

# fallback ถ้ายังไม่มี glove_vector / MLPClassifier
if "glove_vector" not in globals():
    def glove_vector(text):
        tokens = str(text).lower().split()
        vecs = [glove[w] for w in tokens if w in glove]
        if len(vecs) == 0:
            return np.zeros(100, dtype=np.float32)
        return np.mean(vecs, axis=0).astype(np.float32)

if "MLPClassifier" not in globals():
    class MLPClassifier(nn.Module):
        def __init__(self, input_dim=100, hidden_dim=128, num_classes=3, dropout=0.3):
            super().__init__()
            self.net = nn.Sequential(
                nn.Linear(input_dim, hidden_dim),
                nn.ReLU(),
                nn.Dropout(dropout),
                nn.Linear(hidden_dim, num_classes)
            )
        def forward(self, x):
            return self.net(x)

def softmax_torch(logits):
    return torch.softmax(logits, dim=1)

# build features
X_trainval = np.vstack(trainval_df[TEXT_COL].astype(str).apply(glove_vector).values)
y_trainval = trainval_df[LABEL_COL].astype(int).values
X_test_g   = np.vstack(test_df[TEXT_COL].astype(str).apply(glove_vector).values)

train_loader = DataLoader(
    TensorDataset(torch.tensor(X_trainval, dtype=torch.float32),
```

```
                torch.tensor(y_trainval, dtype=torch.long)),
    batch_size=int(FNN_CONFIG["batch_size"]),
    shuffle=True
)

fnn_model = MLPClassifier(
    input_dim=X_trainval.shape[1],
    hidden_dim=int(FNN_CONFIG["hidden_dim"]),
    num_classes=3,
    dropout=float(FNN_CONFIG["dropout"])
).to(device)

opt = torch.optim.Adam(fnn_model.parameters(), lr=float(FNN_CONFIG["lr"]))
loss_fn = nn.CrossEntropyLoss()

# train (ไม่มี val -> train fixed epochs)
t0 = time.perf_counter()
for epoch in range(1, int(FNN_CONFIG["epochs"]) + 1):
    fnn_model.train()
    total_loss = 0.0
    for xb, yb in train_loader:
        xb, yb = xb.to(device), yb.to(device)
        opt.zero_grad()
        logits = fnn_model(xb)
        loss = loss_fn(logits, yb)
        loss.backward()
        opt.step()
        total_loss += loss.item()
    print(f"Epoch {epoch}: train_loss={total_loss/len(train_loader):.4f}")

fnn_train_time_sec = time.perf_counter() - t0
print("FNN train time (s):", round(fnn_train_time_sec, 3))

# predict test + confidence
fnn_model.eval()
with torch.no_grad():
    Xt = torch.tensor(X_test_g, dtype=torch.float32).to(device)
    logits = fnn_model(Xt)
    probs = softmax_torch(logits).detach().cpu().numpy()

fnn_test_pred = probs.argmax(axis=1)
fnn_test_conf = probs.max(axis=1)
```

```
Epoch 1: train_loss=0.9794
Epoch 2: train_loss=0.9563
Epoch 3: train_loss=0.9356
Epoch 4: train_loss=0.9227
Epoch 5: train_loss=0.9200
Epoch 6: train_loss=0.9125
Epoch 7: train_loss=0.9107
Epoch 8: train_loss=0.9094
Epoch 9: train_loss=0.9114
Epoch 10: train_loss=0.8971
FNN train time (s): 1.529
```

9.3 Retrain BERT on TRAIN+VAL, then TEST (compat)

In [67]:

```
# ===== SECTION 9.3 (UPDATED): Retrain BERT on TRAIN+VAL, then TEST (compat) =====
import os, shutil, inspect
import numpy as np
import time
import torch
from transformers import AutoModelForSequenceClassification, TrainingArguments, Trainer

# fallback ถ้ายังไม่มี BEST_BERT (แต่คุณมี dynamic แล้วใน Section 8.3)
if "BEST_BERT" not in globals():
    BEST_BERT = {"lr": 3e-5, "batch_size": 16, "epochs": 10}

def _reset_dir(path: str):
    if os.path.isdir(path):
        shutil.rmtree(path)
    os.makedirs(path, exist_ok=True)

def make_args_compat(desired: dict):
    sig = inspect.signature(TrainingArguments.__init__)
    allowed = set(sig.parameters.keys())
    allowed.discard("self")
    filtered = {k: v for k, v in desired.items() if k in allowed}
    return TrainingArguments(**filtered)

bert_train_ds = make_hf_ds(trainval_df)
bert_test_ds  = make_hf_ds(test_df)

bert_model = AutoModelForSequenceClassification.from_pretrained(
    "bert-base-uncased",
    num_labels=3
)

out_dir = "/content/drive/MyDrive/Colab_Notebooks/pj_nlp/bert_final_trainval"
_reset_dir(out_dir)

desired = dict(
    output_dir=out_dir,
    num_train_epochs=int(BEST_BERT["epochs"]),
    learning_rate=float(BEST_BERT["lr"]),
    per_device_train_batch_size=int(BEST_BERT["batch_size"]),
    per_device_eval_batch_size=int(BEST_BERT["batch_size"]),
    save_strategy="no",          # ถ้ารองรับจะไม่ save
    report_to="none",
    logging_steps=100,
```

```
    seed=42,
    fp16=torch.cuda.is_available(),
)

# ปิด eval ถ้า supported
sig = inspect.signature(TrainingArguments.__init__)
allowed = set(sig.parameters.keys())
if "eval_strategy" in allowed:
    desired["eval_strategy"] = "no"
elif "evaluation_strategy" in allowed:
    desired["evaluation_strategy"] = "no"

args = make_args_compat(desired)

bert_trainer = Trainer(
    model=bert_model,
    args=args,
    train_dataset=bert_train_ds,
    data_collator=data_collator,
)

t0 = time.perf_counter()
bert_trainer.train()
BERT_TRAIN_TIME_SEC = time.perf_counter() - t0
print("BERT_TRAIN_TIME_SEC:", round(BERT_TRAIN_TIME_SEC, 3))

# predict on TEST
bert_out = bert_trainer.predict(bert_test_ds)
bert_logits = bert_out.predictions
bert_test_pred = np.argmax(bert_logits, axis=1)

# softmax confidence
z = bert_logits - bert_logits.max(axis=1, keepdims=True)
probs = np.exp(z) / np.exp(z).sum(axis=1, keepdims=True)
bert_test_conf = probs.max(axis=1)

# เผื่อ Section 10 ต้องใช้โมเดลที่ train แล้ว
bert_model_final = bert_model
```

```
Map:   0%|          | 0/2821 [00:00<?, ? examples/s]
```

```
Map:   0%|          | 0/499 [00:00<?, ? examples/s]
```

```
Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]
```

```
BertForSequenceClassification LOAD REPORT from: bert-base-uncased
Key                                          | Status     |
---------------------------------------------+------------+-
cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
cls.predictions.bias                         | UNEXPECTED |
cls.seq_relationship.bias                    | UNEXPECTED |
cls.predictions.transform.dense.bias         | UNEXPECTED |
cls.seq_relationship.weight                  | UNEXPECTED |
cls.predictions.transform.LayerNorm.bias     | UNEXPECTED |
cls.predictions.transform.dense.weight       | UNEXPECTED |
classifier.bias                              | MISSING    |
classifier.weight                            | MISSING    |

Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```

 [1770/1770 08:10, Epoch 10/10]

Step	Training Loss
100	1.016421
200	0.931440
300	0.892505
400	0.804257
500	0.685777
600	0.542071
700	0.514956
800	0.351196
900	0.283366
1000	0.175728

Step	Training Loss
1100	0.148864
1200	0.074145
1300	0.078473
1400	0.039182
1500	0.023865
1600	0.019382
1700	0.014760

```
BERT_TRAIN_TIME_SEC: 490.796
```

9.4 Build error dataframe for 5 models

In [73]:

```
# ===== SECTION 9.4 (UPDATED): Build error dataframe for 5 models =====
def build_error_df(model_name, df_, y_pred, y_conf):
    out = df_[[TEXT_COL, LABEL_COL]].copy()
    out["true"] = out[LABEL_COL].astype(int)
    out["pred"] = pd.Series(y_pred).astype(int).values
    out["conf"] = y_conf
    out["is_error"] = out["true"] != out["pred"]
    out["true_name"] = out["true"].map(decode_label)
    out["pred_name"] = out["pred"].map(decode_label)
    out["text_len"] = out[TEXT_COL].astype(str).str.split().apply(len)
    out["model"] = model_name
    return out[out["is_error"]].reset_index(drop=True)

err_lr   = build_error_df("LR",   test_df, lr_test_pred,   lr_test_conf)
err_svm  = build_error_df("SVM",  test_df, svm_test_pred,  svm_test_conf)
err_nb   = build_error_df("NB",   test_df, nb_test_pred,   nb_test_conf)
err_fnn  = build_error_df("FNN",  test_df, fnn_test_pred,  fnn_test_conf)
err_bert = build_error_df("BERT", test_df, bert_test_pred, bert_test_conf)

errors_all = pd.concat([err_lr, err_svm, err_nb, err_fnn, err_bert], ignore_index=True)

print("Errors (LR):", len(err_lr))
print("Errors (SVM):", len(err_svm))
print("Errors (NB):", len(err_nb))
print("Errors (FNN):", len(err_fnn))
print("Errors (BERT):", len(err_bert))
# display(errors_all.head(20))

errors_sampled = (
    errors_all
    .groupby("model", group_keys=False)
    .head(10)
    .reset_index(drop=True)
)

# print(errors_sampled["model"].value_counts())
display(errors_sampled)
```

```
Errors (LR): 214
Errors (SVM): 203
Errors (NB): 205
```

```
Errors (FNN): 205
Errors (BERT): 184
```

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model
0	other than baclofen which medicine can be used...	1	1	2	0.372260	True	medium	high	345	LR
1	why am I having swelling and pain in penis aft...	2	2	1	0.374376	True	high	medium	208	LR
2	is it advisable to take xyzal for seasonal all...	0	0	1	0.339638	True	low	medium	117	LR
3	my wife has small itchy pimples in between her...	0	0	1	0.352385	True	low	medium	78	LR
4	please explain the presentation of dot hi doct...	0	0	1	0.346175	True	low	medium	146	LR
5	please let me know the findings of my blood re...	0	0	1	0.335861	True	low	medium	62	LR
6	even after surgery and chemo some swelling in ...	2	2	1	0.351477	True	high	medium	100	LR
7	I have a bump in my scrotum after safe sex wil...	1	1	0	0.351968	True	medium	low	125	LR
8	to confirm depression how long should the symp...	0	0	1	0.350040	True	low	medium	195	LR
9	my irregular bleeding is disturbing my cycle t...	1	1	0	0.348775	True	medium	low	138	LR
10	what does my psi value of 79 mom indicate hi d...	0	0	1	0.346556	True	low	medium	30	SVM
11	why am I having swelling and pain in penis aft...	2	2	1	0.510871	True	high	medium	208	SVM
12	is it advisable to take xyzal for seasonal all...	0	0	1	0.369380	True	low	medium	117	SVM

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model
13	my wife has small itchy pimples in between her...	0	0	1	0.432802	True	low	medium	78	SVM
14	please explain the presentation of dot hi doct...	0	0	1	0.387811	True	low	medium	146	SVM
15	please let me know the findings of my blood re...	0	0	1	0.378866	True	low	medium	62	SVM
16	does my egg report show any issue with periphe...	2	2	1	0.365499	True	high	medium	86	SVM
17	even after surgery and chemo some swelling in ...	2	2	1	0.467706	True	high	medium	100	SVM
18	I have a bump in my scrotum after safe sex wil...	1	1	0	0.388090	True	medium	low	125	SVM
19	my hemoglobin is and iron is with saturation d...	2	2	1	0.426362	True	high	medium	84	SVM
20	why do I have little red dots all over my leg ...	0	0	1	0.488266	True	low	medium	64	NB
21	what does my psi value of 79 mom indicate hi d...	0	0	1	0.607593	True	low	medium	30	NB
22	why am I having swelling and pain in penis aft...	2	2	1	0.621113	True	high	medium	208	NB
23	please explain the presentation of dot hi doct...	0	0	1	0.547031	True	low	medium	146	NB
24	please let me know the findings of my blood re...	0	0	1	0.749042	True	low	medium	62	NB
25	does my egg report show any issue with periphe...	2	2	1	0.642631	True	high	medium	86	NB
26	even after surgery and chemo some swelling in ...	2	2	1	0.738832	True	high	medium	100	NB

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model
27	my hemoglobin is and iron is with saturation d...	2	2	1	0.581340	True	high	medium	84	NB
28	to confirm depression how long should the symp...	0	0	1	0.701254	True	low	medium	195	NB
29	my irregular bleeding is disturbing my cycle t...	1	1	0	0.520221	True	medium	low	138	NB
30	why am I having swelling and pain in penis aft...	2	2	1	0.631989	True	high	medium	208	FNN
31	what does my put report suggest hello doctor I...	1	1	0	0.628137	True	medium	low	161	FNN
32	please let me know the findings of my blood re...	0	0	1	0.527910	True	low	medium	62	FNN
33	does my egg report show any issue with periphe...	2	2	1	0.507690	True	high	medium	86	FNN
34	even after surgery and chemo some swelling in ...	2	2	1	0.640043	True	high	medium	100	FNN
35	I have a bump in my scrotum after safe sex wil...	1	1	0	0.559263	True	medium	low	125	FNN
36	my hemoglobin is and iron is with saturation d...	2	2	1	0.545934	True	high	medium	84	FNN
37	to confirm depression how long should the symp...	0	0	1	0.519109	True	low	medium	195	FNN
38	my brother is on tagrisso and has persistent v...	1	1	0	0.535756	True	medium	low	89	FNN
39	my irregular bleeding is disturbing my cycle t...	1	1	0	0.450689	True	medium	low	138	FNN
40	why am I having swelling and pain in penis aft...	2	2	1	0.992847	True	high	medium	208	BERT

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model
41	please explain the presentation of dot hi doct...	0	0	1	0.734658	True	low	medium	146	BERT
42	what does my put report suggest hello doctor l...	1	1	0	0.999270	True	medium	low	161	BERT
43	please let me know the findings of my blood re...	0	0	1	0.994477	True	low	medium	62	BERT
44	does my egg report show any issue with periphe...	2	2	1	0.999042	True	high	medium	86	BERT
45	even after surgery and chemo some swelling in ...	2	2	1	0.993574	True	high	medium	100	BERT
46	my hemoglobin is and iron is with saturation d...	2	2	1	0.999091	True	high	medium	84	BERT
47	to confirm depression how long should the symp...	0	0	2	0.969744	True	low	high	195	BERT
48	my brother is on tagrisso and has persistent v...	1	1	2	0.996040	True	medium	high	89	BERT
49	how to improve my serum iron level hi doctor l...	0	0	1	0.999186	True	low	medium	156	BERT

In [84]:
```
# Optional for save to .csv
# errors_all.to_csv("all_errors_all_models.csv", index=False)
# print("Saved: all_errors_all_models.csv")
# from google.colab import files
# files.download("/content/all_errors_all_models.csv")
```

```
Saved: all_errors_all_models.csv
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.Javascript object>
```

9.5 **นิยาม** Taxonomy Categories (Rule-based, **อธิบายได้**)

หมวดตาม requirement:
1. Class overlap
2. Short input ambiguity
3. Rare vocabulary
4. Symptom severity confusion
5. Linguistic ambiguity

* 9.5.1 **สร้างสัญญาณประกอบ** (rare words / negation / uncertainty)

In [69]:

```
import re

# --- Rare vocabulary (ใช้ train TF-IDF vocab frequency แบบง่าย) ---
# สร้าง token frequency จาก train_df
from collections import Counter

token_pat = re.compile(r"[A-Za-z']+")
train_tokens = Counter()

for txt in train_df[TEXT_COL].astype(str).tolist():
    toks = token_pat.findall(txt.lower())
    train_tokens.update(toks)

RARE_THRESHOLD = 2  # token เจอใน train <= 2 ถือว่าหายาก (ปรับได้)

def rare_ratio(text):
    toks = token_pat.findall(str(text).lower())
    if not toks:
        return 0.0
    rare = sum(1 for t in toks if train_tokens.get(t, 0) <= RARE_THRESHOLD)
    return rare / len(toks)

# --- Linguistic ambiguity: negation/uncertainty cues ---
NEGATION = {"no", "not", "never", "without", "deny", "denies", "denied"}
UNCERTAIN = {"maybe", "possibly", "seems", "seem", "unclear", "unsure", "might", "could", "probably", "think"}

def has_negation(text):
    toks = set(token_pat.findall(str(text).lower()))
    return int(len(toks & NEGATION) > 0)

def has_uncertainty(text):
    toks = set(token_pat.findall(str(text).lower()))
    return int(len(toks & UNCERTAIN) > 0)

# --- Symptom severity confusion cues (keyword-based แบบง่าย) ---
SEVERE_CUES = {"severe", "intense", "unbearable", "emergency", "faint", "chest", "bleeding", "vomiting"}
MILD_CUES   = {"mild", "slight", "little", "minor", "occasionally"}

def severity_cue(text):
    toks = set(token_pat.findall(str(text).lower()))
    severe = len(toks & SEVERE_CUES)
    mild = len(toks & MILD_CUES)
    if severe > mild and severe > 0:
```

```
        return "severe_cue"
    if mild > severe and mild > 0:
        return "mild_cue"
    return "no_clear_cue"
```

* 9.5.2 **ฟังก์ชันจัดหมวด** Error Taxonomy

In [75]:

```
def categorize_error(row):
    """
    ส่งกลับ list ของ category (1 ตัวอย่างอาจมีหลายสาเหตุ)
    """
    cats = []
    true_y = int(row["true"])
    pred_y = int(row["pred"])
    text = row[TEXT_COL]
    L = int(row["text_len"])

    # 1) Class overlap: ทำนายคลาสข้างเคียง (adjacent) เช่น low<->medium, medium<->high
    if abs(true_y - pred_y) == 1:
        cats.append("class_overlap")

    # 2) Short input ambiguity
    if L <= 12:  # ปรับได้ตาม distribution ของคุณ
        cats.append("short_input_ambiguity")

    # 3) Rare vocabulary
    rr = rare_ratio(text)
    if rr >= 0.25:  # 25% ของคำเป็น rare (ปรับได้)
        cats.append("rare_vocabulary")

    # 4) Symptom severity confusion (cue ขัดกับ label ที่ทำนาย)
    cue = severity_cue(text)
    if cue == "severe_cue" and pred_y == 0:
        cats.append("symptom_severity_confusion")
    elif cue == "mild_cue" and pred_y == 2:
        cats.append("symptom_severity_confusion")

    # 5) Linguistic ambiguity
    if has_negation(text) or has_uncertainty(text):
        cats.append("linguistic_ambiguity")

    # fallback
    if not cats:
        cats.append("other/uncategorized")
    return cats

errors_all["categories"] = errors_all.apply(categorize_error, axis=1)
errors_all["primary_category"] = errors_all["categories"].apply(lambda xs: xs[0])
errors_all.head(10)
```

Out[75]:

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model	categories
0	other than baclofen which medicine can be used...	1	1	2	0.372260	True	medium	high	345	LR	[class_overlap, symptom_severity_confusion, li...
1	why am I having swelling and pain in penis aft...	2	2	1	0.374376	True	high	medium	208	LR	[class_overlap, linguistic_ambiguity]
2	is it advisable to take xyzal for seasonal all...	0	0	1	0.339638	True	low	medium	117	LR	[class_overlap, linguistic_ambiguity]
3	my wife has small itchy pimples in between her...	0	0	1	0.352385	True	low	medium	78	LR	[class_overlap]
4	please explain the presentation of dot hi doct...	0	0	1	0.346175	True	low	medium	146	LR	[class_overlap, linguistic_ambiguity]
5	please let me know the findings of my blood re...	0	0	1	0.335861	True	low	medium	62	LR	[class_overlap]
6	even after surgery and chemo	2	2	1	0.351477	True	high	medium	100	LR	[class_overlap]

	text_raw	label	true	pred	conf	is_error	true_name	pred_name	text_len	model	categories
	some swelling in ...										
7	I have a bump in my scrotum after safe sex wil...	1	1	0	0.351968	True	medium	low	125	LR	[class_overlap, linguistic_ambiguity]
8	to confirm depression how long should the symp...	0	0	1	0.350040	True	low	medium	195	LR	[class_overlap, linguistic_ambiguity]
9	my irregular bleeding is disturbing my cycle t...	1	1	0	0.348775	True	medium	low	138	LR	[class_overlap, symptom_severity_confusion, li...

9.6 **สร้าง** “Structured Analysis Table” **ตามหมวด** (**นับจำนวน** + **สัดส่วน** + **ค่าเฉลี่ย** length/conf)

In [85]:
```
# explode เพื่อให้นับ multi-label ได้
exploded = errors_all.explode("categories")

summary = (exploded
           .groupby(["model", "categories"])
           .agg(
               n_errors=("categories", "count"),
               avg_len=("text_len", "mean"),
               avg_conf=("conf", "mean"),
           )
           .reset_index()
          )

# เพิ่มสัดส่วนต่อจำนวน error ทั้งหมดของแต่ละ model
total_by_model = exploded.groupby("model")["categories"].count().rename("total").reset_index()
summary = summary.merge(total_by_model, on="model", how="left")
summary["pct_of_errors"] = (summary["n_errors"] / summary["total"] * 100).round(2)

summary = summary.sort_values(["model", "n_errors"], ascending=[True, False])
summary
```

Out[85]:

	model	categories	n_errors	avg_len	avg_conf	total	pct_of_errors
0	BERT	class_overlap	174	121.810345	0.958776	309	56.31
1	BERT	linguistic_ambiguity	125	141.520000	0.953529	309	40.45
3	BERT	symptom_severity_confusion	6	139.333333	0.923291	309	1.94
2	BERT	other/uncategorized	4	47.500000	0.954722	309	1.29
4	FNN	class_overlap	188	138.202128	0.539520	345	54.49
5	FNN	linguistic_ambiguity	141	162.574468	0.536977	345	40.87
7	FNN	symptom_severity_confusion	11	169.090909	0.512008	345	3.19
6	FNN	other/uncategorized	5	63.600000	0.569319	345	1.45
8	LR	class_overlap	185	139.016216	0.355451	349	53.01
9	LR	linguistic_ambiguity	144	161.847222	0.356246	349	41.26
10	LR	other/uncategorized	10	89.400000	0.361678	349	2.87

	model	categories	n_errors	avg_len	avg_conf	total	pct_of_errors
11	LR	symptom_severity_confusion	10	165.200000	0.358002	349	2.87
12	NB	class_overlap	200	122.670000	0.628232	350	57.14
13	NB	linguistic_ambiguity	140	141.707143	0.618109	350	40.00
15	NB	symptom_severity_confusion	8	154.125000	0.589697	350	2.29
14	NB	other/uncategorized	2	69.500000	0.531488	350	0.57
16	SVM	class_overlap	192	125.854167	0.410514	337	56.97
17	SVM	linguistic_ambiguity	138	146.652174	0.409591	337	40.95
19	SVM	symptom_severity_confusion	4	156.750000	0.407062	337	1.19
18	SVM	other/uncategorized	3	117.666667	0.395503	337	0.89

In [87]:
```
# Optional for save to .csv
# summary.to_csv("summary961.csv", index=False)
# print("summary961.csv")
# files.download("/content/summary961.csv")
```

```
summary96.csv

<IPython.core.display.Javascript object>

<IPython.core.display.Javascript object>
```

In [89]:
```
ALL_CATS = [
    "class_overlap",
    "short_input_ambiguity",
    "rare_vocabulary",
    "symptom_severity_confusion",
    "linguistic_ambiguity",
    "other/uncategorized"
]

# ทำตาราง cross product (model x category) แล้วเติม missing เป็น 0
models = summary["model"].unique().tolist()
full_index = pd.MultiIndex.from_product([models, ALL_CATS], names=["model", "categories"])
summary = summary.set_index(["model", "categories"]).reindex(full_index).reset_index()

# เติมค่า missing
summary["n_errors"] = summary["n_errors"].fillna(0).astype(int)
summary["avg_len"] = summary["avg_len"].fillna(0.0)
summary["avg_conf"] = summary["avg_conf"].fillna(0.0)
summary["total"] = summary.groupby("model")["n_errors"].transform("sum")
summary["pct_of_errors"] = (summary["n_errors"] / summary["total"].replace(0, np.nan) * 100).fillna(0).round(2)

summary = summary.sort_values(["model", "n_errors"], ascending=[True, False])
display(summary)
```

	model	categories	n_errors	avg_len	avg_conf	total	pct_of_errors
0	BERT	class_overlap	174	121.810345	0.958776	309	56.31
4	BERT	linguistic_ambiguity	125	141.520000	0.953529	309	40.45
3	BERT	symptom_severity_confusion	6	139.333333	0.923291	309	1.94
5	BERT	other/uncategorized	4	47.500000	0.954722	309	1.29
1	BERT	short_input_ambiguity	0	0.000000	0.000000	309	0.00
2	BERT	rare_vocabulary	0	0.000000	0.000000	309	0.00
6	FNN	class_overlap	188	138.202128	0.539520	345	54.49
10	FNN	linguistic_ambiguity	141	162.574468	0.536977	345	40.87
9	FNN	symptom_severity_confusion	11	169.090909	0.512008	345	3.19

	model	categories	n_errors	avg_len	avg_conf	total	pct_of_errors
11	FNN	other/uncategorized	5	63.600000	0.569319	345	1.45
7	FNN	short_input_ambiguity	0	0.000000	0.000000	345	0.00
8	FNN	rare_vocabulary	0	0.000000	0.000000	345	0.00
12	LR	class_overlap	185	139.016216	0.355451	349	53.01
16	LR	linguistic_ambiguity	144	161.847222	0.356246	349	41.26
15	LR	symptom_severity_confusion	10	165.200000	0.358002	349	2.87
17	LR	other/uncategorized	10	89.400000	0.361678	349	2.87
13	LR	short_input_ambiguity	0	0.000000	0.000000	349	0.00
14	LR	rare_vocabulary	0	0.000000	0.000000	349	0.00
18	NB	class_overlap	200	122.670000	0.628232	350	57.14
22	NB	linguistic_ambiguity	140	141.707143	0.618109	350	40.00
21	NB	symptom_severity_confusion	8	154.125000	0.589697	350	2.29
23	NB	other/uncategorized	2	69.500000	0.531488	350	0.57
19	NB	short_input_ambiguity	0	0.000000	0.000000	350	0.00
20	NB	rare_vocabulary	0	0.000000	0.000000	350	0.00
24	SVM	class_overlap	192	125.854167	0.410514	337	56.97
28	SVM	linguistic_ambiguity	138	146.652174	0.409591	337	40.95
27	SVM	symptom_severity_confusion	4	156.750000	0.407062	337	1.19
29	SVM	other/uncategorized	3	117.666667	0.395503	337	0.89
25	SVM	short_input_ambiguity	0	0.000000	0.000000	337	0.00
26	SVM	rare_vocabulary	0	0.000000	0.000000	337	0.00

In [90]:
```
# Optional for save to .csv
# summary.to_csv("summary962.csv", index=False)
# print("summary962.csv")
# files.download("/content/summary962.csv")
```

```
summary962.csv
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.Javascript object>
```

9.7 Examples for 5 models

In [93]:

```
# ===== SECTION 9.7 (UPDATED): Examples for 5 models =====
def show_examples(df, model_name, category, k=3):
    sub = df[(df["model"] == model_name) &
             (df["categories"].apply(lambda xs: category in xs))].copy()
    sub = sub.sort_values("conf", ascending=False).head(k)
    cols = ["model", "true_name", "pred_name", "conf", "text_len", TEXT_COL, "categories"]
    return sub[cols]

CATS = ["class_overlap", "short_input_ambiguity", "rare_vocabulary",
        "symptom_severity_confusion", "linguistic_ambiguity", "other/uncategorized"]

MODEL_LIST = ["LR", "SVM", "NB", "FNN", "BERT"]

for m in MODEL_LIST:
    print("\n====================", m, "====================")
    for c in CATS:
        ex = show_examples(errors_all, m, c, k=3)
        if len(ex) > 0:
            print(f"\n--- Category: {c} (top confident wrong) ---")
            display(ex)
```

```
==================== LR ====================

--- Category: class_overlap (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
67	LR	medium	high	0.418729	1003	what is the reason for my daughter constipatio...	[class_overlap, linguistic_ambiguity]
82	LR	medium	high	0.398737	160	what is the outcome of the tests taken for bre...	[class_overlap]
155	LR	medium	high	0.398295	255	please give a second opinion on the diagnosis ...	[class_overlap, linguistic_ambiguity]

```
--- Category: symptom_severity_confusion (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
136	LR	medium	low	0.387172	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
0	LR	medium	high	0.372260	345	other than baclofen which medicine can be used...	[class_overlap, symptom_severity_confusion, li...
107	LR	medium	high	0.358952	114	is my grandfather having parkinson s hi doctor...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: linguistic_ambiguity (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
67	LR	medium	high	0.418729	1003	what is the reason for my daughter constipatio...	[class_overlap, linguistic_ambiguity]
155	LR	medium	high	0.398295	255	please give a second opinion on the diagnosis ...	[class_overlap, linguistic_ambiguity]
136	LR	medium	low	0.387172	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: other/uncategorized (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
205	LR	low	high	0.396287	214	my brother with ocd is scared and homesick how...	[other/uncategorized]
25	LR	low	high	0.394049	212	would you recommend pranayama for a 90 year ol...	[other/uncategorized]
181	LR	low	high	0.379717	80	my dad feet are so puffy why hi doctor my dad ...	[other/uncategorized]

```
==================== SVM ====================

--- Category: class_overlap (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
279	SVM	high	medium	0.536139	222	will preeclampsia during pregnancy lead to pot...	[class_overlap, linguistic_ambiguity]
352	SVM	medium	low	0.531624	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
353	SVM	high	medium	0.519004	51	seminal leak associated with tests pain with j...	[class_overlap, linguistic_ambiguity]

```
--- Category: symptom_severity_confusion (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
352	SVM	medium	low	0.531624	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
344	SVM	medium	high	0.388225	224	I used cannabis in my teenage am I at a risk o...	[class_overlap, symptom_severity_confusion, li...
321	SVM	medium	high	0.354561	114	is my grandfather having parkinson s hi doctor...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: linguistic_ambiguity (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
279	SVM	high	medium	0.536139	222	will preeclampsia during pregnancy lead to pot...	[class_overlap, linguistic_ambiguity]
352	SVM	medium	low	0.531624	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
353	SVM	high	medium	0.519004	51	seminal leak associated with tests pain with j...	[class_overlap, linguistic_ambiguity]

```
--- Category: other/uncategorized (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
239	SVM	low	high	0.429272	212	would you recommend pranayama for a 90 year ol...	[other/uncategorized]
376	SVM	high	low	0.378974	61	I am 80 keg will it affect the outcome of all ...	[other/uncategorized]
388	SVM	low	high	0.378263	80	my dad feet are so puffy why hi doctor my dad ...	[other/uncategorized]

```
=================== NB ====================
```

```
--- Category: class_overlap (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
498	NB	medium	low	0.922286	67	is there any medical procedure to heal acne pi...	[class_overlap, linguistic_ambiguity]
564	NB	low	medium	0.895491	21	I have vocal nodules please suggest home remed...	[class_overlap]
549	NB	medium	low	0.883043	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: symptom_severity_confusion (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
549	NB	medium	low	0.883043	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
463	NB	medium	high	0.638366	172	what does an mri finding of mild cerebral atro...	[class_overlap, symptom_severity_confusion, li...
464	NB	medium	low	0.577942	260	I do not have occlusion in one side of my crow...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: linguistic_ambiguity (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
498	NB	medium	low	0.922286	67	is there any medical procedure to heal acne pi...	[class_overlap, linguistic_ambiguity]
549	NB	medium	low	0.883043	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
535	NB	medium	low	0.843350	104	what are these bumps I have in my nose upper l...	[class_overlap, linguistic_ambiguity]

```
--- Category: other/uncategorized (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
471	NB	low	high	0.554095	76	what is the chance of passing the structural b...	[other/uncategorized]
468	NB	high	low	0.508882	63	I cannot sustain erection and my blood pressur...	[other/uncategorized]

```
=================== FNN ====================

--- Category: class_overlap (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
747	FNN	medium	low	0.798921	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
731	FNN	medium	low	0.786482	66	I have painful pea like lump on labia will it ...	[class_overlap, linguistic_ambiguity]
728	FNN	medium	low	0.770703	24	why do I have to strain too much to pass stool...	[class_overlap, linguistic_ambiguity]

```
--- Category: symptom_severity_confusion (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
747	FNN	medium	low	0.798921	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
699	FNN	medium	low	0.538085	210	is it possible for tension headache to be pers...	[class_overlap, symptom_severity_confusion, li...
630	FNN	medium	low	0.535756	89	my brother is on tagrisso and has persistent v...	[class_overlap, symptom_severity_confusion]

```
--- Category: linguistic_ambiguity (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
747	FNN	medium	low	0.798921	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...
731	FNN	medium	low	0.786482	66	I have painful pea like lump on labia will it ...	[class_overlap, linguistic_ambiguity]
728	FNN	medium	low	0.770703	24	why do I have to strain too much to pass stool...	[class_overlap, linguistic_ambiguity]

```
--- Category: other/uncategorized (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
671	FNN	high	low	0.653557	63	I cannot sustain erection and my blood pressur...	[other/uncategorized]
743	FNN	high	low	0.612404	68	cyst in my testicles are getting bigger while ...	[other/uncategorized]
637	FNN	high	low	0.556101	82	I am trying to conceive with irregular periods...	[other/uncategorized]

```
==================== BERT ====================

--- Category: class_overlap (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
852	BERT	low	medium	0.999423	110	on taking medications my postnatal drip has be...	[class_overlap, linguistic_ambiguity]
851	BERT	high	medium	0.999421	94	I have headache and increased heart rate with ...	[class_overlap]
860	BERT	high	medium	0.999383	55	I have pain on left side of chest and tip of m...	[class_overlap]

```
--- Category: symptom_severity_confusion (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
916	BERT	medium	high	0.999123	114	is my grandfather having parkinson s hi doctor...	[class_overlap, symptom_severity_confusion, li...
1008	BERT	high	low	0.997466	196	loose motion is not controlled with antibiotic...	[symptom_severity_confusion, linguistic_ambigu...
947	BERT	medium	low	0.991644	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...

```
--- Category: linguistic_ambiguity (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
852	BERT	low	medium	0.999423	110	on taking medications my postnatal drip has be...	[class_overlap, linguistic_ambiguity]
903	BERT	low	medium	0.999330	140	I have constant cold problem with phlegm passi...	[class_overlap, linguistic_ambiguity]
886	BERT	medium	low	0.999321	155	I have tooth and gum pain below the right jaw ...	[class_overlap, linguistic_ambiguity]

```
--- Category: other/uncategorized (top confident wrong) ---
```

	model	true_name	pred_name	conf	text_len	text_raw	categories
1001	BERT	low	high	0.997580	35	will tetanus vaccine act against coronavirus h...	[other/uncategorized]
869	BERT	low	high	0.992347	61	there is chest pain with high be is it due to ...	[other/uncategorized]
926	BERT	high	low	0.969356	46	how to avoid coma while getting anesthesia hi ...	[other/uncategorized]

	model	true_name	pred_name	conf	text_len	text_raw	categories	category
0	LR	medium	high	0.418729	1003	what is the reason for my daughter constipatio...	[class_overlap, linguistic_ambiguity]	class_overlap
1	LR	medium	high	0.398737	160	what is the outcome of the tests taken for bre...	[class_overlap]	class_overlap
2	LR	medium	high	0.398295	255	please give a second opinion on the diagnosis ...	[class_overlap, linguistic_ambiguity]	class_overlap
3	LR	medium	low	0.387172	101	I have a circular black patch on the back with...	[class_overlap, symptom_severity_confusion, li...	symptom_severity_confusion
4	LR	medium	high	0.372260	345	other than baclofen which medicine can be used...	[class_overlap, symptom_severity_confusion, li...	symptom_severity_confusion

```
Saved: section97_examples_top3.csv
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.Javascript object>
```

In [ ]:
```
# Optional for save to .csv
# all_examples = []

# for m in MODEL_LIST:
#     for c in CATS:
#         ex = show_examples(errors_all, m, c, k=3)
#         if len(ex) > 0:
#             ex = ex.copy()
#             ex["category"] = c   # ระบุ category ชัด ๆ
#             all_examples.append(ex)

# # รวมทั้งหมด
# examples_df = pd.concat(all_examples, ignore_index=True)

# display(examples_df.head())

# # ===== Save CSV =====
# examples_df.to_csv("section97_examples_top3.csv", index=False)
# print("Saved: section97_examples_top3.csv")
# files.download("/content/section97_examples_top3.csv")
```

9.8 Insights table

In [91]:

```
# ===== SECTION 9.8 (UPDATED): Insights for 5 models =====
def model_error_insights(summary_df, model_name):
    top = (summary_df[summary_df["model"] == model_name]
           .sort_values("n_errors", ascending=False)
           .head(5))
    return top[["categories", "n_errors", "pct_of_errors", "avg_len", "avg_conf"]]

for m in ["LR", "SVM", "NB", "FNN", "BERT"]:
    display(model_error_insights(summary, m))
```

	categories	n_errors	pct_of_errors	avg_len	avg_conf
12	class_overlap	185	53.01	139.016216	0.355451
16	linguistic_ambiguity	144	41.26	161.847222	0.356246
15	symptom_severity_confusion	10	2.87	165.200000	0.358002
17	other/uncategorized	10	2.87	89.400000	0.361678
13	short_input_ambiguity	0	0.00	0.000000	0.000000

	categories	n_errors	pct_of_errors	avg_len	avg_conf
24	class_overlap	192	56.97	125.854167	0.410514
28	linguistic_ambiguity	138	40.95	146.652174	0.409591
27	symptom_severity_confusion	4	1.19	156.750000	0.407062
29	other/uncategorized	3	0.89	117.666667	0.395503
25	short_input_ambiguity	0	0.00	0.000000	0.000000

	categories	n_errors	pct_of_errors	avg_len	avg_conf
18	class_overlap	200	57.14	122.670000	0.628232
22	linguistic_ambiguity	140	40.00	141.707143	0.618109
21	symptom_severity_confusion	8	2.29	154.125000	0.589697
23	other/uncategorized	2	0.57	69.500000	0.531488

	categories	n_errors	pct_of_errors	avg_len	avg_conf
19	short_input_ambiguity	0	0.00	0.000000	0.000000

	categories	n_errors	pct_of_errors	avg_len	avg_conf
6	class_overlap	188	54.49	138.202128	0.539520
10	linguistic_ambiguity	141	40.87	162.574468	0.536977
9	symptom_severity_confusion	11	3.19	169.090909	0.512008
11	other/uncategorized	5	1.45	63.600000	0.569319
7	short_input_ambiguity	0	0.00	0.000000	0.000000

	categories	n_errors	pct_of_errors	avg_len	avg_conf
0	class_overlap	174	56.31	121.810345	0.958776
4	linguistic_ambiguity	125	40.45	141.520000	0.953529
3	symptom_severity_confusion	6	1.94	139.333333	0.923291
5	other/uncategorized	4	1.29	47.500000	0.954722
1	short_input_ambiguity	0	0.00	0.000000	0.000000

In [95]:
```
# Optional for save to .csv
# MODEL_LIST = ["LR", "SVM", "NB", "FNN", "BERT"]

# insights_all = []

# for m in MODEL_LIST:
#     df_m = (
#         summary[summary["model"] == m]
#         .sort_values("n_errors", ascending=False)
#         .copy()
#     )
#     insights_all.append(df_m)

# insights_df = pd.concat(insights_all, ignore_index=True)

# # display(insights_df)

# # ===== Save CSV =====
# insights_df.to_csv("section98_insights_all_categories.csv", index=False)
# print("Saved: section98_insights_all_categories.csv")
# files.download("section98_insights_all_categories.csv")
```

```
Saved: section98_insights_all_categories.csv
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.Javascript object>
```

SECTION 10 - INTERPRETABILITY

10.1 Linear models: Top features (LR + SVM)

In [101]:

```
import numpy as np
import pandas as pd
import re
import matplotlib.pyplot as plt

# Sanity check

need_vars = [
    "lr_pipe", "svm_pipe", "nb_pipe",
    "fnn_model",
    "tokenizer",
    "test_df", "TEXT_COL", "LABEL_COL"
]
missing = [v for v in need_vars if v not in globals()]
print("Missing vars:", missing)

# LABEL_NAMES: รองรับทั้ง list ["low","medium","high"] หรือ dict {0:"low",...}
def _label_name(i):
    if "LABEL_NAMES" in globals():
        if isinstance(LABEL_NAMES, dict):
            return LABEL_NAMES.get(i, str(i))
        if isinstance(LABEL_NAMES, (list, tuple)) and i < len(LABEL_NAMES):
            return LABEL_NAMES[i]
    return str(i)
```

```
Missing vars: []
```

In [102]:

```
def show_top_features_linear(pipe, model_name, top_k=20):
    """
    ใช้ได้กับ:
    - LogisticRegression (coef_ = [C, V])
    - LinearSVC (coef_ = [C, V])  (multi-class one-vs-rest)
    """
    vec = pipe.named_steps["tfidf"]
    clf = pipe.named_steps["clf"]
    feat = np.array(vec.get_feature_names_out())
    coef = clf.coef_
    if coef.ndim == 1:
        coef = coef.reshape(1, -1)

    print(f"\n===== {model_name}: Top TF-IDF Features =====")
    for c in range(coef.shape[0]):
        w = coef[c]
        top_pos = np.argsort(w)[-top_k:][::-1]
        top_neg = np.argsort(w)[:top_k]
        df_show = pd.DataFrame({
            "top_positive": feat[top_pos],
            "weight_pos": w[top_pos],
            "top_negative": feat[top_neg],
            "weight_neg": w[top_neg],
        })
        print(f"\n--- Class {c}: {_label_name(c)} ---")
        display(df_show)

show_top_features_linear(lr_pipe, "LR", top_k=20)
show_top_features_linear(svm_pipe, "SVM", top_k=20)
```

```
===== LR: Top TF-IDF Features =====

--- Class 0: low ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	skin	0.212065	and	-0.300796
1	teeth	0.202638	she	-0.282242
2	on my	0.168582	pain	-0.277007

	top_positive	weight_pos	top_negative	weight_neg
3	hair	0.167087	he	-0.254044
4	acne	0.139998	cancer	-0.204978
5	eyes	0.132612	with	-0.196118
6	itching	0.128749	blood	-0.187409
7	eye	0.125722	chest	-0.157903
8	on	0.124301	her	-0.145747
9	spots	0.117959	pregnant	-0.143120
10	it	0.117118	severe	-0.142862
11	can	0.115510	treatment	-0.142388
12	face	0.107826	was	-0.138215
13	itchy	0.099277	scan	-0.133692
14	take	0.096730	heart	-0.133269
15	black	0.096577	hiv	-0.128256
16	doctor have	0.095240	had	-0.127485
17	my	0.095063	mri	-0.126706
18	how	0.092705	of	-0.124209
19	dark	0.092700	weeks	-0.120657

```
--- Class 1: medium ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	pain	0.230196	he	-0.097957
1	days	0.131026	hiv	-0.087918
2	and	0.124875	his	-0.082849

	top_positive	weight_pos	top_negative	weight_neg
3	back	0.104554	to	-0.078820
4	pain in	0.102648	face	-0.076594
5	cough	0.097720	you	-0.076549
6	swollen	0.092707	eyes	-0.075413
7	knee	0.089284	teeth	-0.072857
8	two	0.087590	cancer	-0.072689
9	ear	0.086502	safe	-0.068524
10	lump	0.084077	cold	-0.066515
11	headache	0.083030	we	-0.066507
12	discharge	0.080503	did	-0.064279
13	please help	0.072839	this	-0.063574
14	swelling	0.072054	does	-0.061909
15	in	0.071944	breath	-0.060610
16	sore	0.071855	spots	-0.060565
17	painful	0.071613	egg	-0.059036
18	sore throat	0.068569	do	-0.058123
19	normal	0.066597	can	-0.057174

```
--- Class 2: high ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	he	0.352001	it	-0.159897
1	she	0.334975	skin	-0.159559
2	cancer	0.277667	hair	-0.136529

	top_positive	weight_pos	top_negative	weight_neg
3	hiv	0.216174	on my	-0.133375
4	chest	0.203379	teeth	-0.129781
5	her	0.195797	doctor have	-0.121190
6	and	0.175921	days	-0.115445
7	scan	0.173773	ear	-0.110119
8	pregnant	0.166883	periods	-0.107772
9	report	0.164234	why	-0.107555
10	of	0.159091	eye	-0.104398
11	blood	0.157471	period	-0.100297
12	his	0.156164	take	-0.099989
13	was	0.153040	and it	-0.094891
14	with	0.151724	itchy	-0.093842
15	severe	0.151627	acne	-0.088829
16	heart	0.143930	hello doctor have	-0.088106
17	we	0.138515	please suggest	-0.084770
18	treatment	0.137237	but it	-0.084281
19	he is	0.132813	it is	-0.084100

```
===== SVM: Top TF-IDF Features =====

--- Class 0: low ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	teeth	0.574391	and	-0.742736

	top_positive	weight_pos	top_negative	weight_neg
1	itching	0.539945	pain	-0.686037
2	skin	0.517075	blood	-0.511069
3	eyes	0.495081	pregnant	-0.504408
4	hair	0.476323	with	-0.486450
5	it normal	0.440548	cancer	-0.484832
6	spots	0.423827	treatment	-0.482778
7	acne	0.414594	surgery	-0.447630
8	on my	0.412664	help hello	-0.431505
9	can	0.405038	severe	-0.414555
10	to	0.402721	had	-0.390724
11	on	0.375951	he	-0.385547
12	face	0.342102	she	-0.360400
13	but it	0.339505	please help	-0.356439
14	eye	0.330668	heart	-0.342330
15	patches	0.329408	bleeding	-0.333161
16	safe	0.326204	mri	-0.331636
17	increase	0.324511	anxiety	-0.331251
18	to increase	0.322203	again	-0.330048
19	contact	0.318582	hearing	-0.325521

```
--- Class 1: medium ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	pain	0.561854	eyes	-0.360940

	top_positive	weight_pos	top_negative	weight_neg
1	and	0.453514	teeth	-0.338687
2	cough	0.346452	itching	-0.332080
3	days	0.346341	face	-0.317677
4	lump	0.340917	safe	-0.312578
5	knee	0.335761	to	-0.306097
6	back	0.331954	spots	-0.294969
7	discharge	0.326686	this	-0.290975
8	headache	0.324480	can	-0.281171
9	pain in	0.322764	cold	-0.277526
10	swollen	0.306471	it normal	-0.268343
11	two	0.305821	does	-0.260562
12	had	0.298999	does my	-0.251542
13	painful	0.271076	black	-0.250236
14	please help	0.268224	you	-0.249686
15	help hello	0.265457	skin	-0.248457
16	pregnancy	0.260361	on	-0.246137
17	anxiety	0.257242	foods	-0.243512
18	urination	0.255020	did	-0.239882
19	hearing	0.253525	time	-0.236352

```
--- Class 2: high ---
```

	top_positive	weight_pos	top_negative	weight_neg
0	cancer	0.939343	days	-0.421473

	top_positive	weight_pos	top_negative	weight_neg
1	hiv	0.732558	cough	-0.410714
2	pregnant	0.693769	normal	-0.410370
3	chest	0.637198	why	-0.408457
4	he	0.632917	it	-0.392169
5	severe	0.607899	and it	-0.382347
6	scan	0.551165	hair	-0.381634
7	she	0.523779	skin	-0.377459
8	abnormal	0.518799	doctor have	-0.364506
9	treatment	0.511808	some	-0.346084
10	report	0.500023	take	-0.344101
11	now	0.473275	or	-0.334632
12	shortness of	0.472646	period	-0.320715
13	shortness	0.465320	food	-0.309364
14	of	0.464992	on my	-0.303896
15	says	0.461977	any	-0.297397
16	breathing	0.440026	periods	-0.296806
17	egg	0.435532	since	-0.294607
18	rabies	0.427334	are	-0.294385
19	blood	0.418980	make	-0.293130

10.2 Naive Bayes: Top indicative features

In [103]:

```
def show_top_features_nb(pipe, top_k=20):
    """
    MultinomialNB interpretability แบบง่าย:
    - ดู feature_log_prob_ (log P(w|class))
    - ใช้ score = logP(w|c) - mean(logP(w|all classes)) เพื่อหา token ที่ "เด่น" ในคลาสนั้น
    """
    vec = pipe.named_steps["tfidf"]
    nb = pipe.named_steps["clf"]
    feat = np.array(vec.get_feature_names_out())

    logp = nb.feature_log_prob_  # shape: (C, V)
    mean_logp = logp.mean(axis=0, keepdims=True)

    print("\n===== NB: Top indicative features =====")
    for c in range(logp.shape[0]):
        score = logp[c] - mean_logp[0]
        idx = np.argsort(score)[-top_k:][::-1]
        df_show = pd.DataFrame({
            "token": feat[idx],
            "score": score[idx],
            "logP(w|class)": logp[c][idx],
        })
        print(f"\n--- Class {c}: {_label_name(c)} ---")
        display(df_show)

show_top_features_nb(nb_pipe, top_k=20)
```

```
===== NB: Top indicative features =====

--- Class 0: low ---
```

	token	score	logP(w|class)
0	pores	1.952676	-8.111007
1	blister	1.897315	-8.194048
2	retainer	1.832348	-8.291500
3	glue	1.679250	-8.521146
4	peroxide	1.657667	-8.553521

	token	score	logP(w|class)
5	neosporin	1.645100	-8.572371
6	pigmentation	1.643328	-8.575029
7	product	1.633272	-8.152936
8	lens	1.587294	-8.153469
9	retainers	1.582823	-8.665787
10	cleaner	1.578433	-8.672371
11	braces	1.550412	-7.661795
12	wire	1.542146	-8.726802
13	oily	1.500170	-7.928394
14	lice	1.460910	-8.848656
15	patches	1.456347	-7.366653
16	benefits	1.444273	-8.591720
17	melasma	1.412881	-8.920700
18	gaps	1.403680	-8.934501
19	beard	1.398032	-8.942973

```
--- Class 1: medium ---
```

	token	score	logP(w|class)
0	625	1.388864	-8.697145
1	swings	1.374713	-8.456591
2	vocal	1.305359	-8.822402
3	shivering	1.261688	-8.887908
4	lymphocytes	1.256755	-8.535291

	token	score	logP(w|class)
5	uses	1.249508	-8.906178
6	esophagus	1.239686	-8.920911
7	pilonidal	1.195049	-8.987866
8	herniated	1.176854	-8.855338
9	penile	1.162430	-8.187794
10	palms	1.158801	-8.738101
11	lightheadedness	1.156231	-9.046093
12	treatable	1.141877	-9.067625
13	coronary	1.133247	-9.080570
14	groin	1.131061	-8.188957
15	endometrium	1.130243	-9.085075
16	stabbing	1.122298	-9.096994
17	septoplasty	1.116314	-9.105970
18	spleen	1.095025	-9.137903
19	inguinal	1.093775	-9.139777

```
--- Class 2: high ---
```

	token	score	logP(w|class)
0	suicidal	2.226186	-7.786474
1	infact	2.182648	-8.075467
2	detachment	2.166681	-8.099417
3	violent	2.009188	-8.335656
4	meningioma	1.959202	-8.410636

	token	score	logP(w|class)
5	coagulant	1.940901	-8.438087
6	sclerosis	1.890829	-8.061829
7	anaphylaxis	1.849165	-8.011782
8	fasciculations	1.848907	-8.576079
9	torsion	1.803084	-8.644813
10	chickenpox	1.784745	-8.062511
11	ve	1.782395	-8.675846
12	chef	1.775082	-8.686815
13	bitten	1.755033	-8.366858
14	kenacort	1.740026	-8.739399
15	chemo	1.716354	-8.080303
16	typhoid	1.708275	-8.529474
17	marker	1.704524	-8.197864
18	drawn	1.701393	-8.797349
19	mnd	1.700781	-8.798267

10.3 Model-agnostic local explanation (Token Occlusion)

In [104]:

```
def softmax_np(scores_2d):
    z = scores_2d - np.max(scores_2d, axis=1, keepdims=True)
    e = np.exp(z)
    return e / np.sum(e, axis=1, keepdims=True)

# ---- proba-like wrappers ----
def proba_lr(texts):
    return lr_pipe.predict_proba(texts)

def proba_nb(texts):
    return nb_pipe.predict_proba(texts)

def proba_svm(texts):
    # LinearSVC ไม่มี predict_proba -> ใช้ decision_function แล้ว softmax เป็น pseudo-proba
    scores = svm_pipe.decision_function(texts)  # (n, C)
    if scores.ndim == 1:
        scores = np.vstack([-scores, scores]).T
    return softmax_np(scores)

# FNN wrapper (ต้องมี glove_vector + torch)
import torch
import torch.nn.functional as F

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
fnn_model = fnn_model.to(device)

def _glove_vector_safe(text):
    # ใช้ของเดิมถ้ามี
    if "glove_vector" in globals():
        return glove_vector(text)
    # fallback กันพัง (แต่ควรมี glove_vector อยู่แล้วในโปรเจคคุณ)
    tokens = str(text).lower().split()
    return np.zeros(100, dtype=np.float32)

def proba_fnn(texts):
    X = np.vstack([_glove_vector_safe(t) for t in texts]).astype(np.float32)
    Xt = torch.tensor(X, dtype=torch.float32).to(device)
    fnn_model.eval()
    with torch.no_grad():
        logits = fnn_model(Xt)
        probs = F.softmax(logits, dim=1).detach().cpu().numpy()
    return probs
```

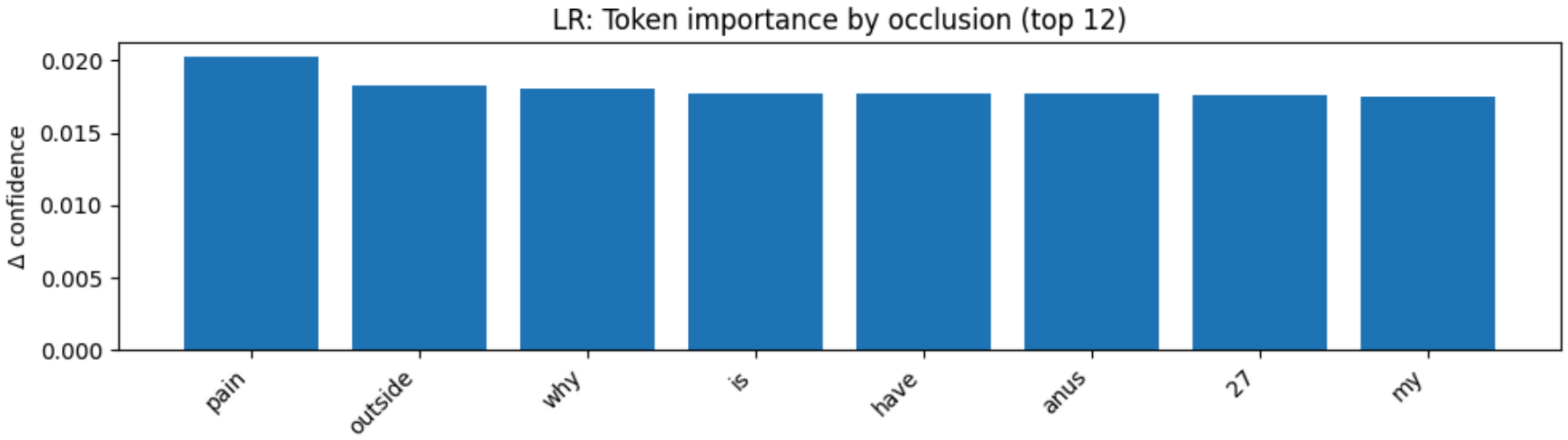
```
# BERT wrapper (ใช้ bert_model_final ถ้ามี ไม่งั้นใช้ bert_model)
bert_src = globals().get("bert_model_final", globals().get("bert_model", None))
if bert_src is None:
    print("[WARN] No bert_model_final/bert_model found for Section 10.3")

def proba_bert(texts, max_len=128):
    bert_src.eval()
    all_probs = []
    with torch.no_grad():
        for t in texts:
            inputs = tokenizer(
                str(t),
                return_tensors="pt",
                truncation=True,
                max_length=max_len
            )
            inputs = {k: v.to(device) for k, v in inputs.items()}
            logits = bert_src(**inputs).logits
            probs = F.softmax(logits, dim=1).detach().cpu().numpy()
            all_probs.append(probs[0])
    return np.vstack(all_probs)

PROBA_FN = {
    "LR": proba_lr,
    "SVM": proba_svm,
    "NB": proba_nb,
    "FNN": proba_fnn,
    "BERT": lambda texts: proba_bert(texts, max_len=128) if bert_src is not None else None
}

def simple_tokens(text, max_tokens=25):
    # tokenization แบบง่าย (นักศึกษา)
    toks = re.findall(r"[A-Za-z']+|\d+", str(text).lower())
    return toks[:max_tokens]

def occlusion_explain(model_key, text, max_tokens=25, top_show=15):
    proba_fn = PROBA_FN[model_key]
    if proba_fn is None:
        print(f"[Skip] {model_key}: proba_fn is None")
        return

    toks = simple_tokens(text, max_tokens=max_tokens)
    if len(toks) < 2:
```

```
        print(f"[Skip] {model_key}: too few tokens")
        return

    base_probs = proba_fn([text])[0]
    pred = int(np.argmax(base_probs))
    base_conf = float(base_probs[pred])

    drops = []
    for i in range(len(toks)):
        pert = " ".join([t for j, t in enumerate(toks) if j != i])
        p = proba_fn([pert])[0]
        conf_pert = float(p[pred])
        drops.append({
            "token": toks[i],
            "delta_conf": base_conf - conf_pert  # บวกมาก = คำนี้ “สำคัญ” ต่อคลาสที่ทำนาย
        })

    df_imp = pd.DataFrame(drops).sort_values("delta_conf", ascending=False)
    print(f"\n===== {model_key} Occlusion Explanation =====")
    print("Pred class:", pred, _label_name(pred), "| base_conf:", round(base_conf, 4))
    display(df_imp.head(top_show))

    # plot (ไม่ระบุสี)
    plt.figure(figsize=(10, 3))
    plt.bar(df_imp.head(top_show)["token"], df_imp.head(top_show)["delta_conf"])
    plt.xticks(rotation=45, ha="right")
    plt.title(f"{model_key}: Token importance by occlusion (top {top_show})")
    plt.ylabel("Δ confidence")
    plt.tight_layout()
    plt.show()

# เลือกข้อความตัวอย่าง: เอาจาก test_df แถวแรก (ปรับเองได้)
sample_text = str(test_df.iloc[0][TEXT_COL])
print("\nSample text:", sample_text[:200], "...")

for m in ["LR", "SVM", "NB", "FNN", "BERT"]:
    occlusion_explain(m, sample_text, max_tokens=25, top_show=12)
```

```
Sample text: why do I have pain inside my anus hi doctor I am 27 years old I have pain inside my anus my anus outside is
normal with no pain and injury along the same line of my anus right inside I feel the pain n ...
```

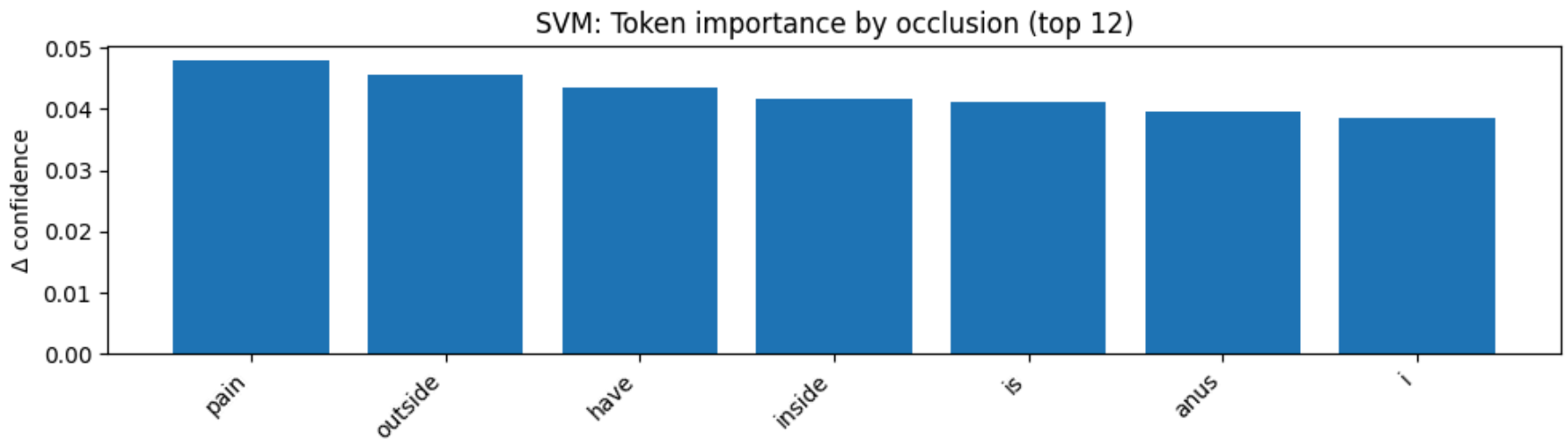
```
===== LR Occlusion Explanation =====
Pred class: 1 medium | base_conf: 0.3688
```

	token	delta_conf
17	pain	0.020211
4	pain	0.019980
23	outside	0.018228
0	why	0.018007
24	is	0.017761
16	have	0.017705
22	anus	0.017677
12	27	0.017663
20	anus	0.017645
6	my	0.017539
19	my	0.017539
21	my	0.017414



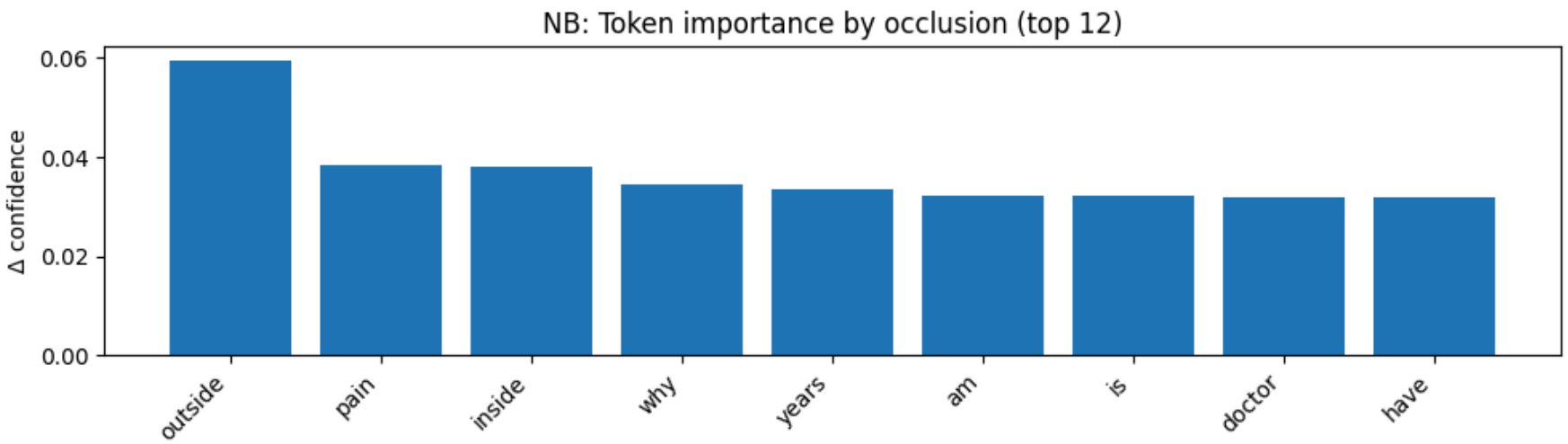
```
===== SVM Occlusion Explanation =====
Pred class: 1 medium | base_conf: 0.4812
```

	token	delta_conf
4	pain	0.047846
17	pain	0.047846
23	outside	0.045558
16	have	0.043647
5	inside	0.041582
18	inside	0.041582
24	is	0.041268
22	anus	0.039613
7	anus	0.039613
20	anus	0.038689
2	i	0.038546
15	i	0.038546



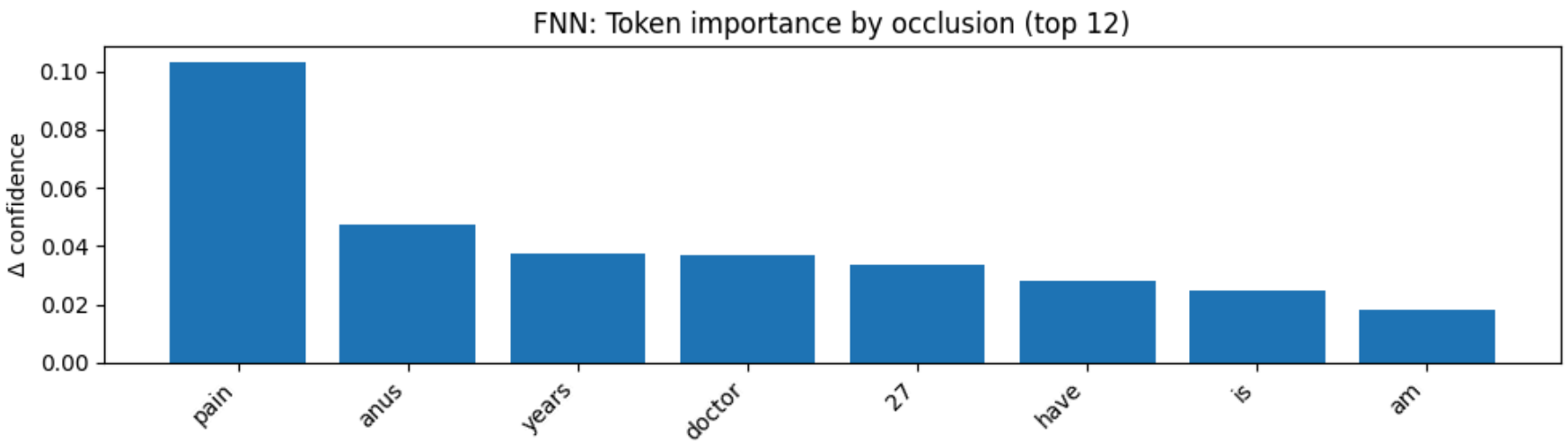
```
===== NB Occlusion Explanation =====
Pred class: 1 medium | base_conf: 0.7711
```

	token	delta_conf
23	outside	0.059336
17	pain	0.038380
4	pain	0.038380
5	inside	0.038018
18	inside	0.038018
0	why	0.034468
13	years	0.033413
11	am	0.032336
24	is	0.032233
9	doctor	0.031911
3	have	0.031873
16	have	0.031873



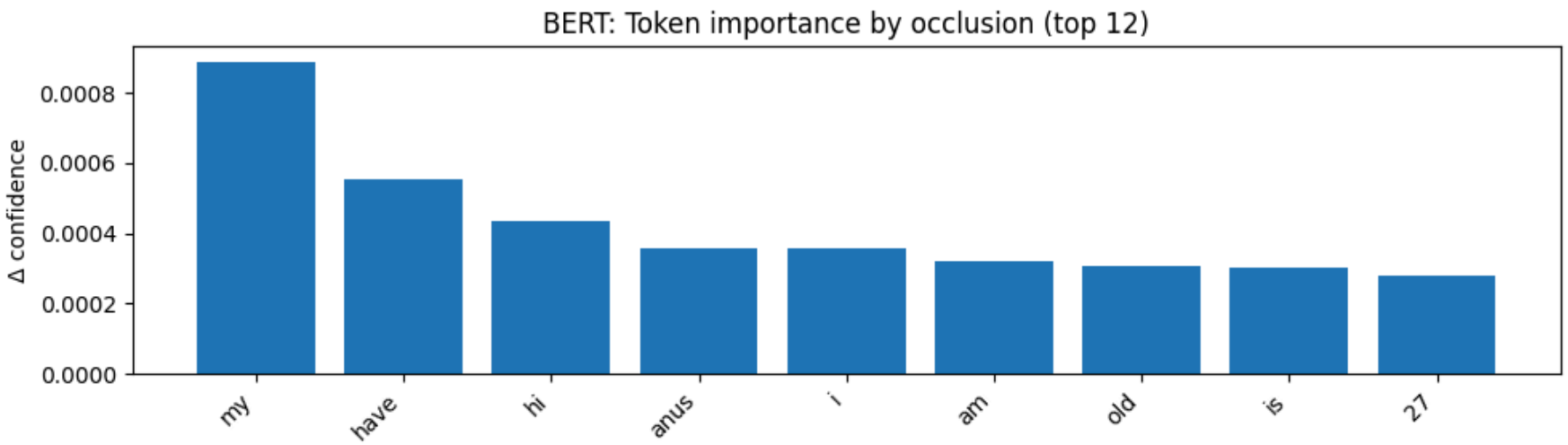
```
===== FNN Occlusion Explanation =====
Pred class: 1 medium | base_conf: 0.5091
```

	token	delta_conf
17	pain	0.103272
4	pain	0.103272
7	anus	0.047104
20	anus	0.047104
22	anus	0.047104
13	years	0.037672
9	doctor	0.036932
12	27	0.033512
3	have	0.028254
16	have	0.028254
24	is	0.024530
11	am	0.018205



```
===== BERT Occlusion Explanation =====
Pred class: 1 medium | base_conf: 0.9993
```

	token	delta_conf
6	my	0.000888
16	have	0.000553
8	hi	0.000437
22	anus	0.000359
2	i	0.000357
11	am	0.000319
14	old	0.000308
15	i	0.000307
24	is	0.000303
10	i	0.000298
19	my	0.000283
12	27	0.000280



10.4 BERT attention visualization (**ของเดิม** + **ทำให้** robust **ขึ้น**)

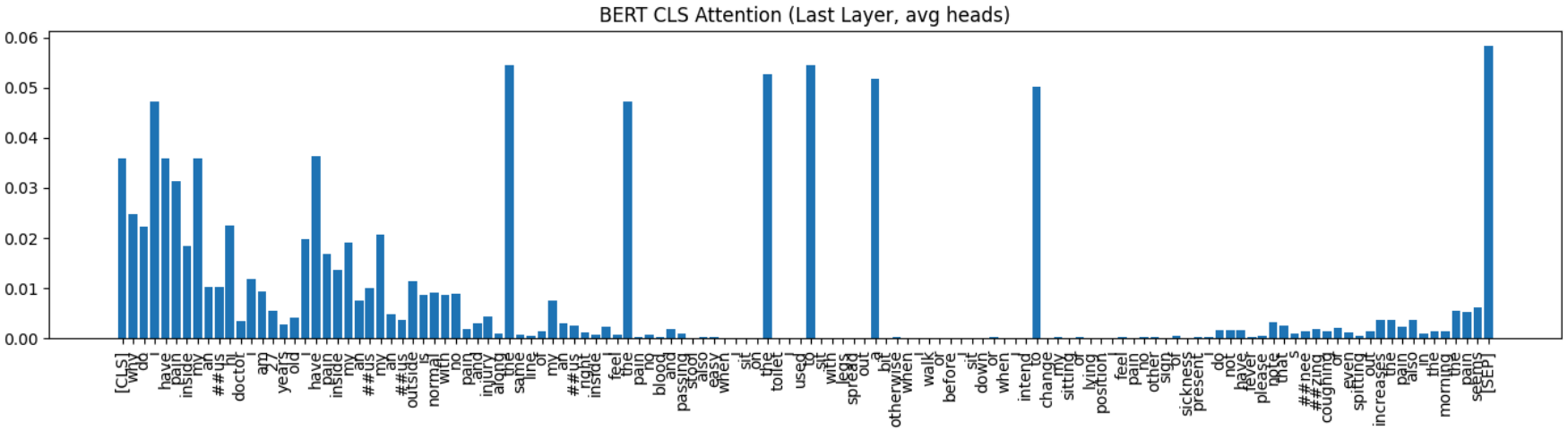
In [105]:

```
from transformers import AutoModelForSequenceClassification

if bert_src is not None:
    bert_model_attn = AutoModelForSequenceClassification.from_pretrained(
        "bert-base-uncased",
        num_labels=3,
        attn_implementation="eager"  # ตาม block เดิม
    ).to(device)

    # โหลด weights จากโมเดลที่ fine-tune แล้ว
    bert_model_attn.load_state_dict(bert_src.state_dict(), strict=False)

    def visualize_attention(text, model, tokenizer, max_len=128):
        model.eval()
        inputs = tokenizer(
            text,
            return_tensors="pt",
            truncation=True,
            max_length=max_len
        )
        inputs = {k: v.to(device) for k, v in inputs.items()}
        with torch.no_grad():
            outputs = model(**inputs, output_attentions=True)
            attentions = outputs.attentions
        if attentions is None:
            raise RuntimeError("attentions is None (check attn_implementation='eager').")

        last = attentions[-1]              # (B, heads, seq, seq)
        avg_attn = last.mean(dim=1)[0]     # (seq, seq)
        tokens = tokenizer.convert_ids_to_tokens(inputs["input_ids"][0].detach().cpu())

        cls_attn = avg_attn[0].detach().cpu().numpy()  # attention from [CLS] to all tokens

        plt.figure(figsize=(14, 4))
        plt.bar(range(len(tokens)), cls_attn)
        plt.xticks(range(len(tokens)), tokens, rotation=90)
        plt.title("BERT CLS Attention (Last Layer, avg heads)")
        plt.tight_layout()
        plt.show()

    # run
    visualize_attention(sample_text, bert_model_attn, tokenizer, max_len=128)
```

```
else:
    print("[Skip] BERT attention: no bert model found.")
```

```
Loading weights:   0%|          | 0/199 [00:00<?, ?it/s]
```

```
BertForSequenceClassification LOAD REPORT from: bert-base-uncased
Key                                          | Status     |
---------------------------------------------+------------+-
cls.predictions.transform.LayerNorm.weight | UNEXPECTED |
cls.predictions.bias                       | UNEXPECTED |
cls.seq_relationship.bias                  | UNEXPECTED |
cls.predictions.transform.dense.bias       | UNEXPECTED |
cls.seq_relationship.weight                | UNEXPECTED |
cls.predictions.transform.LayerNorm.bias   | UNEXPECTED |
cls.predictions.transform.dense.weight     | UNEXPECTED |
classifier.bias                            | MISSING    |
classifier.weight                          | MISSING    |

Notes:
- UNEXPECTED    :can be ignored when loading from different task/architecture; not ok if you expect identical arch.
- MISSING       :those params were newly initialized because missing from the checkpoint. Consider training on your
downstream task.
```



SECTION 11 - BIAS & FAIRNESS

11.0 Setup

In [112]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from IPython.display import display
from sklearn.metrics import (
    f1_score, precision_recall_fscore_support,
    confusion_matrix, ConfusionMatrixDisplay,
    accuracy_score, precision_score, recall_score
)

# label names (ให้ตรงกับงานคุณ)
LABEL_NAMES = ["low", "medium", "high"]  # class 0/1/2
y_true = test_df[LABEL_COL].astype(int).to_numpy()

# --------- dynamic pull from globals() ----------
MODEL_SPECS = {
    "LR":   {"pred": "lr_test_pred",   "conf": "lr_test_conf"},
    "SVM":  {"pred": "svm_test_pred",  "conf": "svm_test_conf"},
    "NB":   {"pred": "nb_test_pred",   "conf": "nb_test_conf"},
    "FNN":  {"pred": "fnn_test_pred",  "conf": "fnn_test_conf"},
    "BERT": {"pred": "bert_test_pred", "conf": "bert_test_conf"},
}

preds, confs = {}, {}
missing = []

for m, spec in MODEL_SPECS.items():
    if spec["pred"] in globals():
        preds[m] = np.asarray(globals()[spec["pred"]])
        confs[m] = np.asarray(globals()[spec["conf"]]) if spec["conf"] in globals() else None
    else:
        missing.append(m)

print("Models found:", list(preds.keys()))
if missing:
    print("[WARN] Missing preds for:", missing)

# sanity check length
for m, y_pred in preds.items():
    assert len(y_pred) == len(y_true), f"Length mismatch: {m} pred={len(y_pred)} vs y_true={len(y_true)}"

def metrics_basic(y_t, y_p):
```

```
    return {
        "accuracy": float(accuracy_score(y_t, y_p)),
        "macro_f1": float(f1_score(y_t, y_p, average="macro")),
        "macro_precision": float(precision_score(y_t, y_p, average="macro", zero_division=0)),
        "macro_recall": float(recall_score(y_t, y_p, average="macro", zero_division=0)),
    }
```

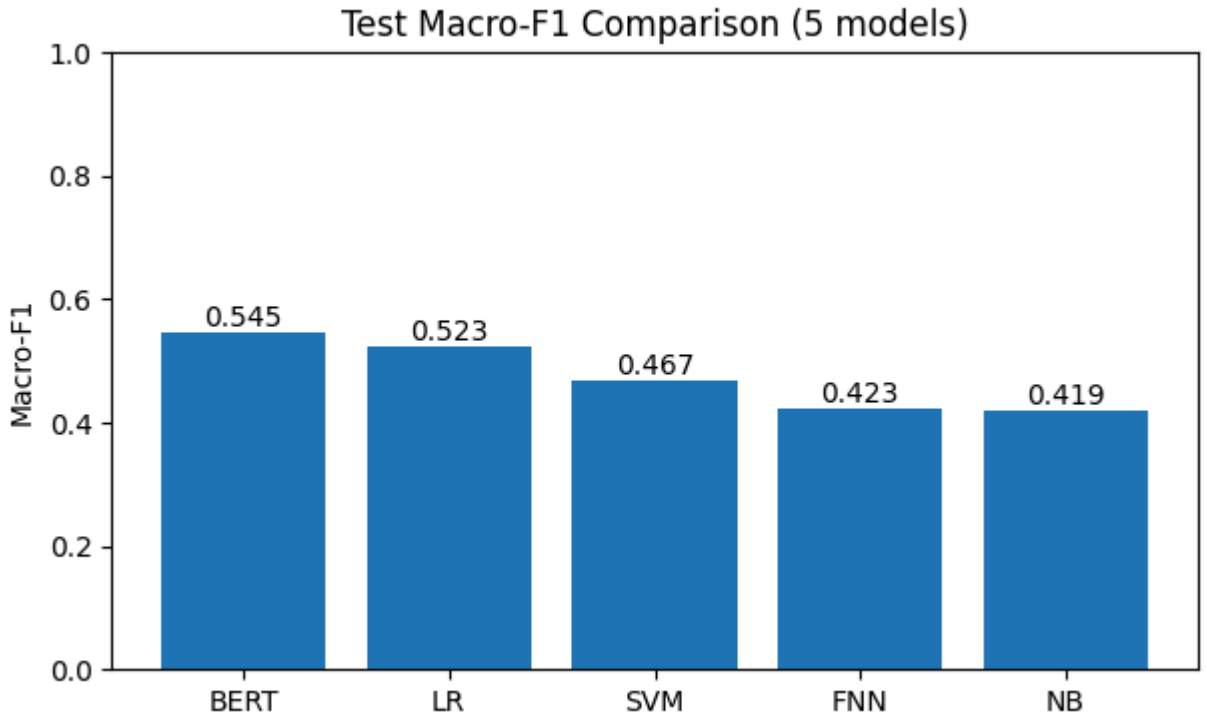
```
Models found: ['LR', 'SVM', 'NB', 'FNN', 'BERT']
```

11.1 Overall performance (Macro-F1)

In [113]:

```
# ===== 11.1 Overall performance (Macro-F1) =====
macro_f1 = {m: f1_score(y_true, y_pred, average="macro") for m, y_pred in preds.items()}
macro_df = pd.DataFrame({"model": list(macro_f1.keys()), "macro_f1": list(macro_f1.values())}) \
             .sort_values("macro_f1", ascending=False)

display(macro_df)

plt.figure(figsize=(7,4))
plt.bar(macro_df["model"], macro_df["macro_f1"])
plt.title("Test Macro-F1 Comparison (5 models)")
plt.ylabel("Macro-F1")
plt.ylim(0, 1)
for i, v in enumerate(macro_df["macro_f1"].values):
    plt.text(i, v + 0.01, f"{v:.3f}", ha="center")
plt.show()
```

	model	macro_f1
4	BERT	0.545308
0	LR	0.522610
1	SVM	0.467086
3	FNN	0.422811
2	NB	0.419425



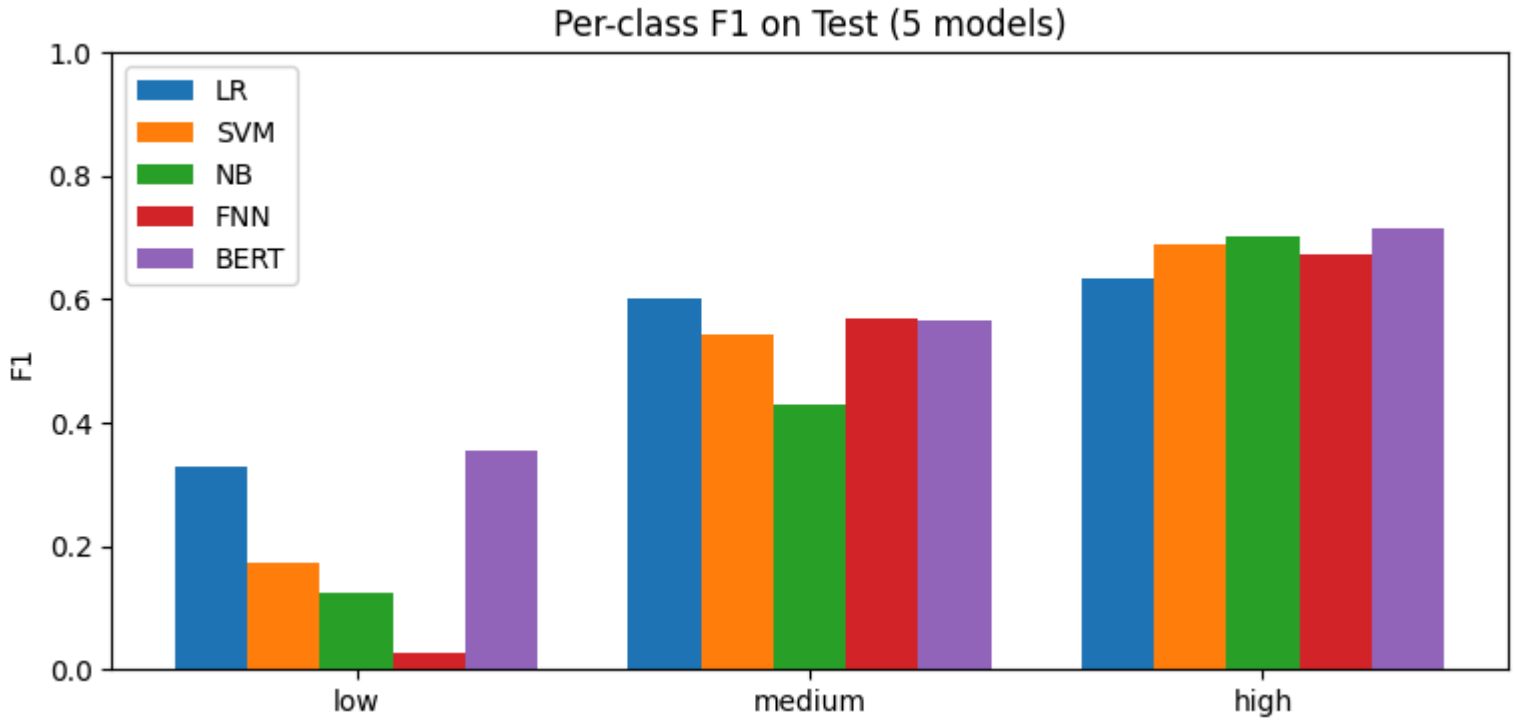
11.2 Per-class report

In [114]:

```
# ===== 11.2 Per-class report =====
rows = []
for m, y_pred in preds.items():
    p, r, f1s, sup = precision_recall_fscore_support(
        y_true, y_pred, labels=[0,1,2], zero_division=0
    )
    for cls_i, cls_name in enumerate(LABEL_NAMES):
        rows.append({
            "model": m,
            "class": cls_name,
            "support": int(sup[cls_i]),
            "precision": float(p[cls_i]),
            "recall": float(r[cls_i]),
            "f1": float(f1s[cls_i]),
        })

per_class_df = pd.DataFrame(rows)
display(per_class_df)

# --- per-class F1 plot (grouped bar) ---
models = list(preds.keys())
x = np.arange(len(LABEL_NAMES))
width = 0.8 / max(1, len(models))

plt.figure(figsize=(9,4))
for i, m in enumerate(models):
    f1s = per_class_df[per_class_df["model"] == m].sort_values("class")["f1"].values
    plt.bar(x + (i - (len(models)-1)/2)*width, f1s, width, label=m)

plt.xticks(x, LABEL_NAMES)
plt.ylim(0, 1)
plt.ylabel("F1")
plt.title("Per-class F1 on Test (5 models)")
plt.legend()
plt.show()
```

	model	class	support	precision	recall	f1
0	LR	low	161	0.616883	0.590062	0.603175
1	LR	medium	267	0.670833	0.602996	0.635108

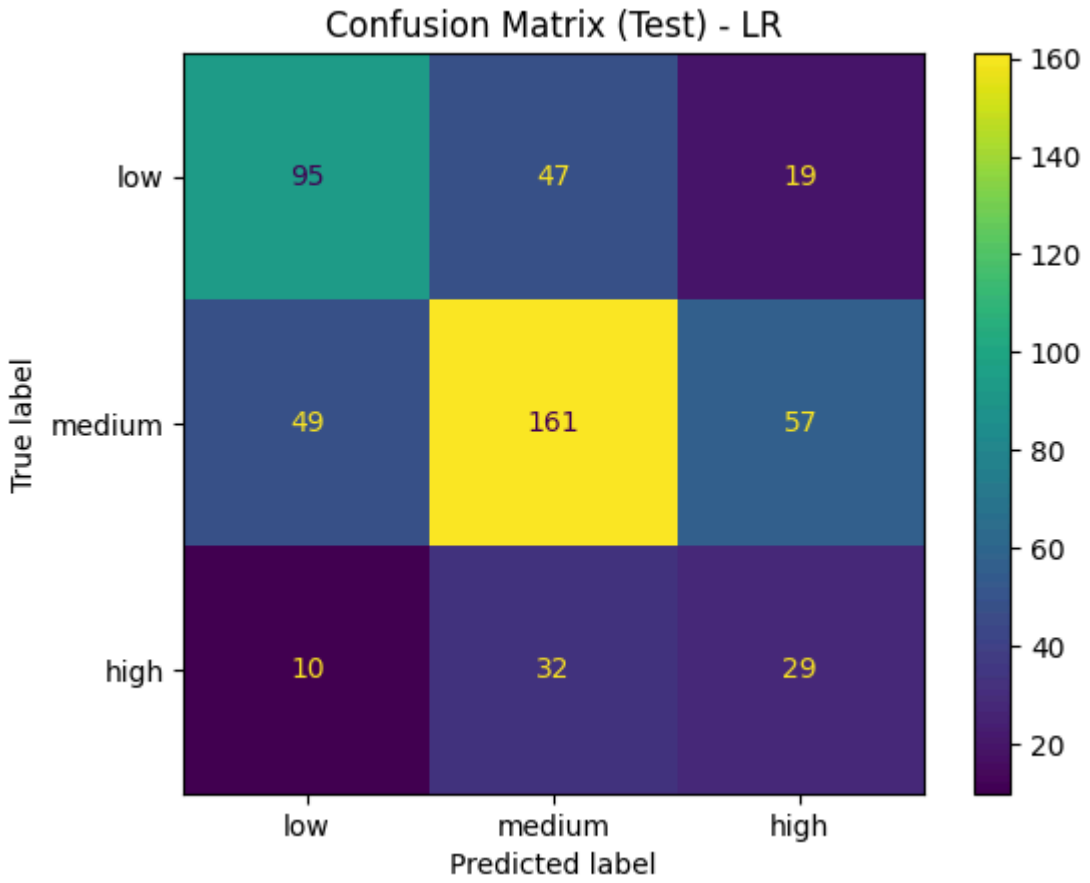
	model	class	support	precision	recall	f1
2	LR	high	71	0.276190	0.408451	0.329545
3	SVM	low	161	0.646552	0.465839	0.541516
4	SVM	medium	267	0.607450	0.794007	0.688312
5	SVM	high	71	0.264706	0.126761	0.171429
6	NB	low	161	0.623529	0.329193	0.430894
7	NB	medium	267	0.582716	0.883895	0.702381
8	NB	high	71	0.555556	0.070423	0.125000
9	FNN	low	161	0.523560	0.621118	0.568182
10	FNN	medium	267	0.628664	0.722846	0.672474
11	FNN	high	71	1.000000	0.014085	0.027778
12	BERT	low	161	0.693694	0.478261	0.566176
13	BERT	medium	267	0.636364	0.812734	0.713816
14	BERT	high	71	0.446809	0.295775	0.355932



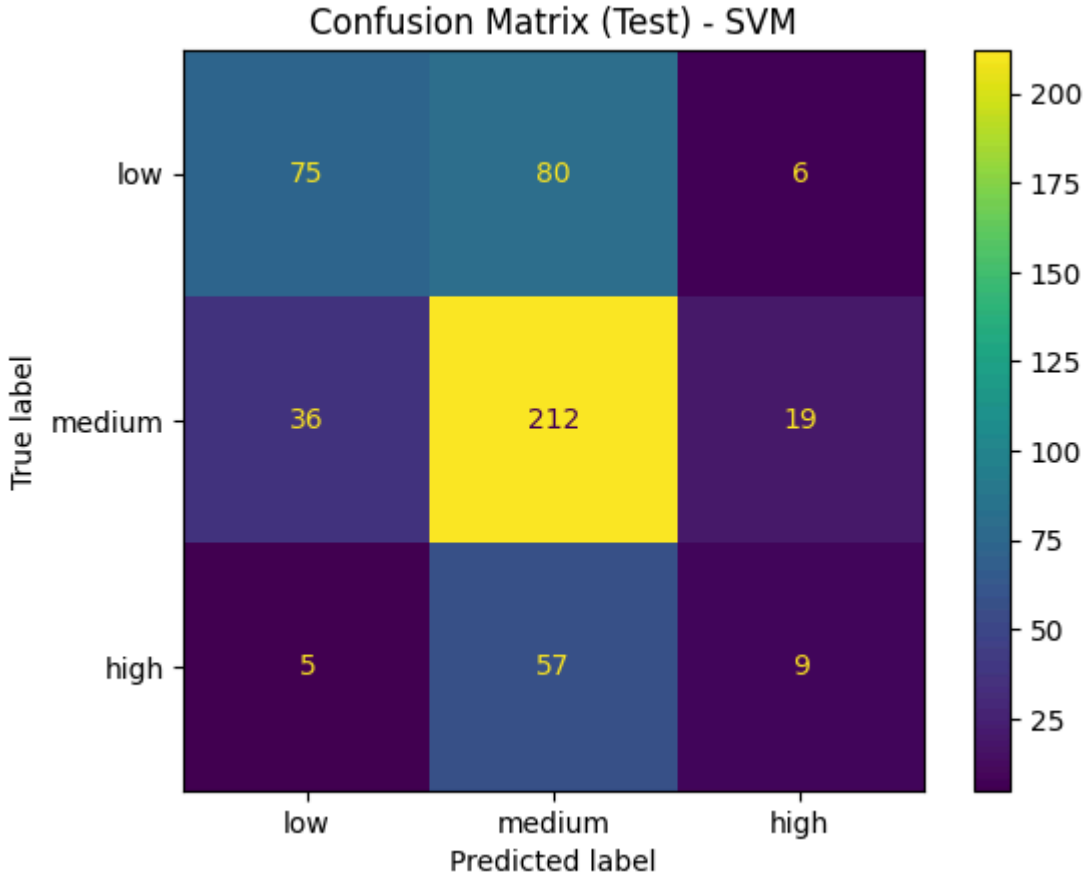
11.3 Confusion Matrix

In [115]:
```
# ===== 11.3 Confusion matrices =====
for m, y_pred in preds.items():
    cm = confusion_matrix(y_true, y_pred, labels=[0,1,2])
    disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=LABEL_NAMES)
    plt.figure(figsize=(5,4))
    disp.plot(values_format="d")
    plt.title(f"Confusion Matrix (Test) - {m}")
    plt.show()
```

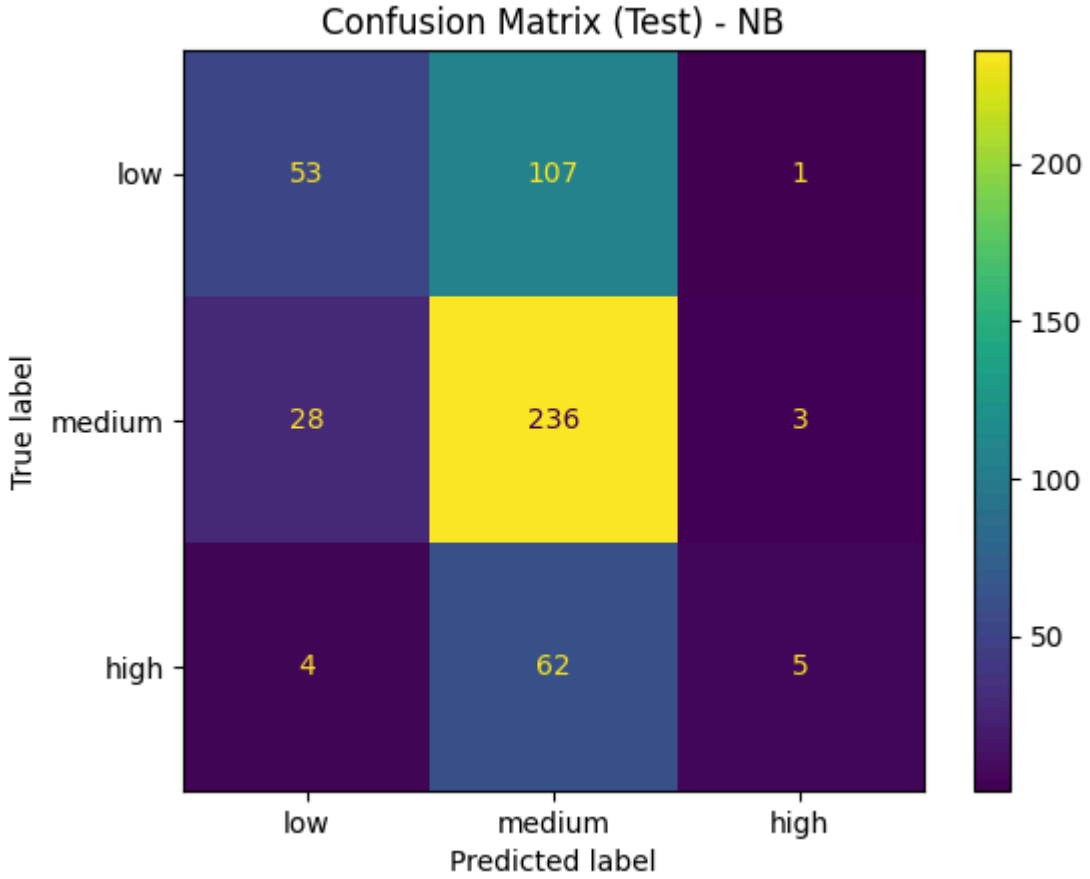
```
<Figure size 500x400 with 0 Axes>
```



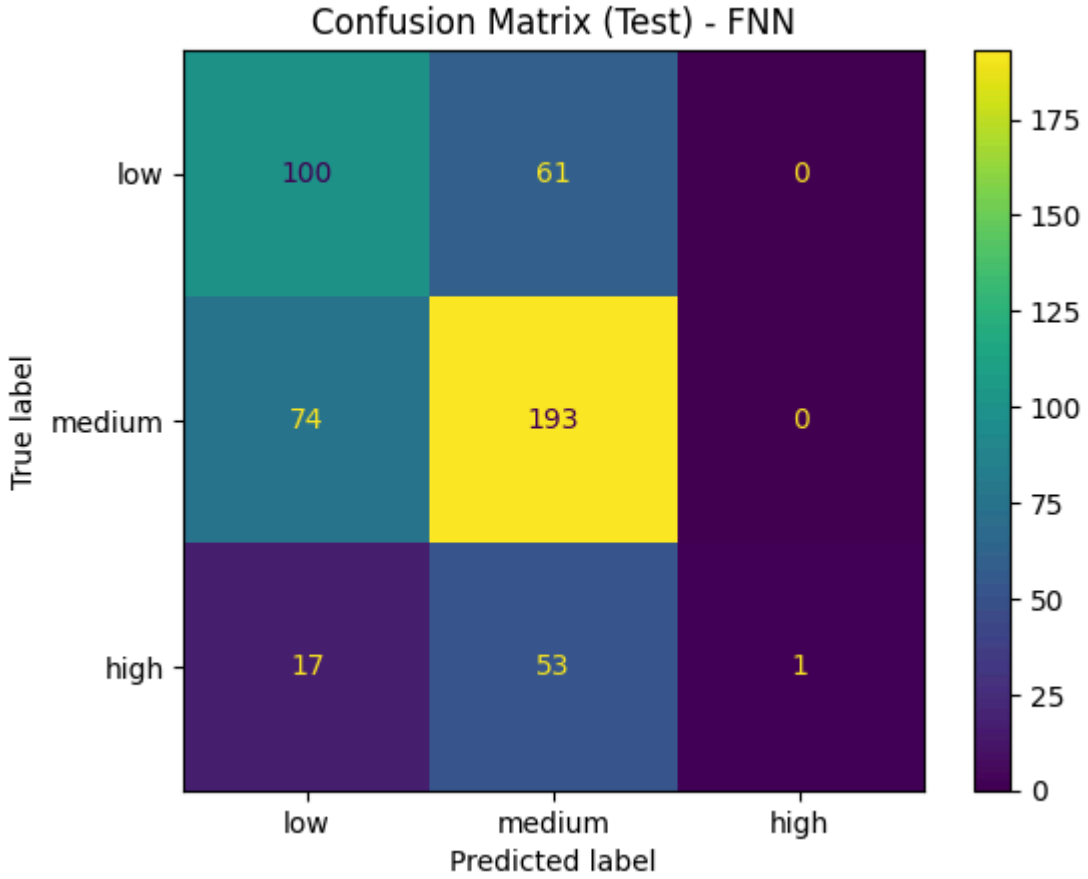

```
<Figure size 500x400 with 0 Axes>
```



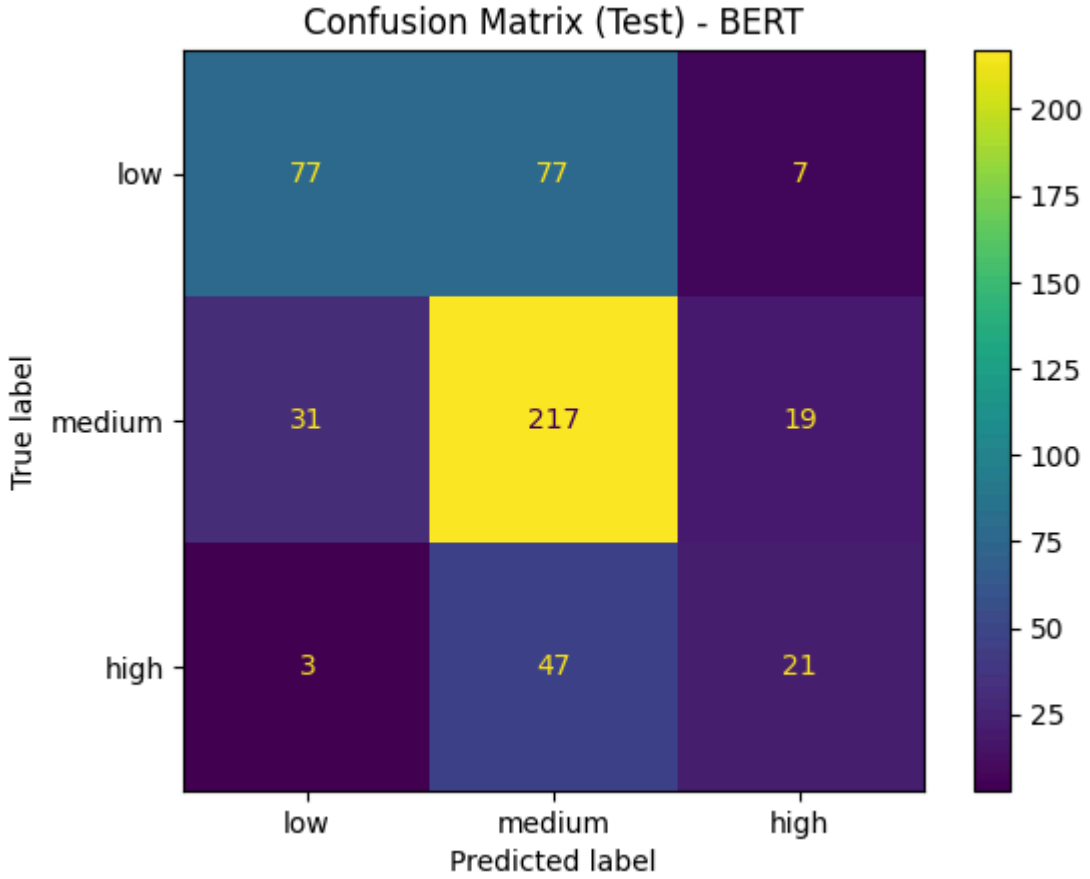
<Figure size 500x400 with 0 Axes>



<Figure size 500x400 with 0 Axes>



<Figure size 500x400 with 0 Axes>



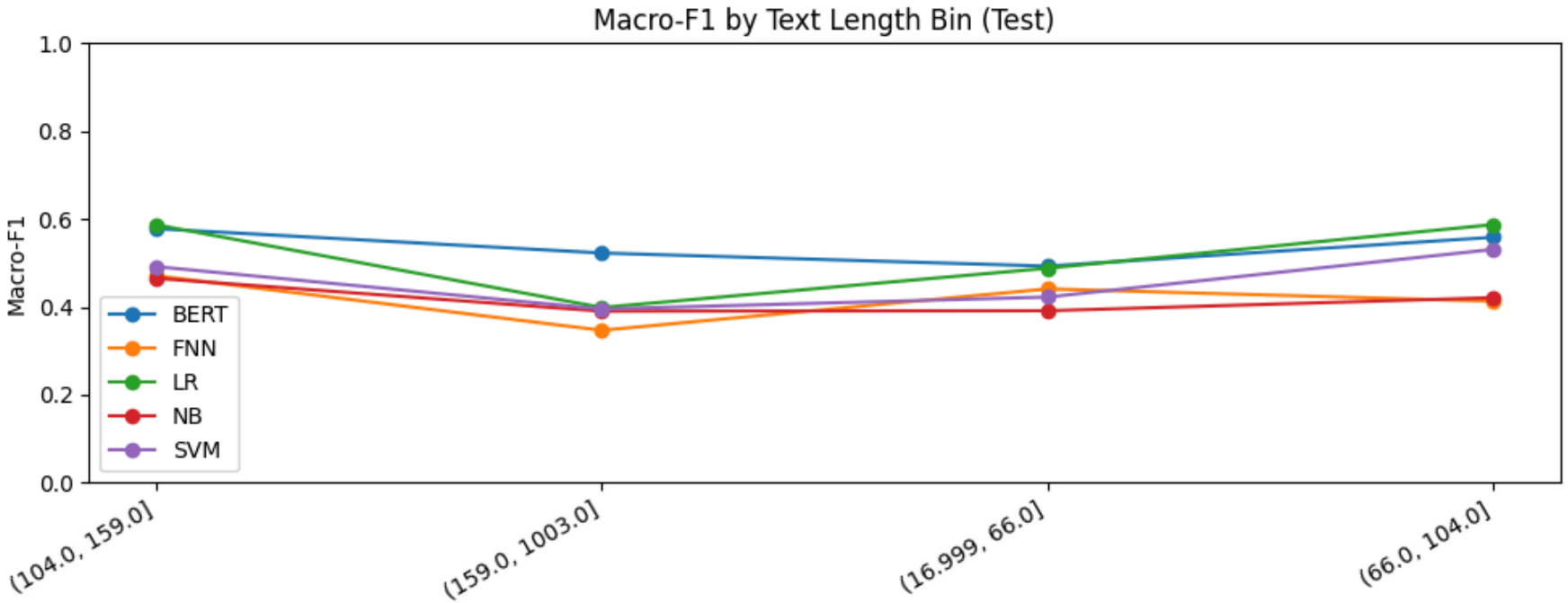
11.4 Text length bias

In [116]:

```
# ===== 11.4 Text length bias =====
test_len = test_df[TEXT_COL].astype(str).str.split().apply(len).to_numpy()
bins = pd.qcut(test_len, q=4, duplicates="drop")  # 4 กลุ่ม: สั้น -> ยาว

bin_df = pd.DataFrame({"len_bin": bins, "text_len": test_len, "y_true": y_true})

# ใส่ pred ของทุกโมเดล
for m, y_pred in preds.items():
    bin_df[f"{m}_pred"] = y_pred

# metrics by bin (รวมทุกโมเดลในตารางเดียว)
rows = []
for m in preds.keys():
    for b in sorted(bin_df["len_bin"].unique()):
        sub = bin_df[bin_df["len_bin"] == b]
        met = metrics_basic(sub["y_true"].values, sub[f"{m}_pred"].values)
        rows.append({"model": m, "len_bin": str(b), "n": len(sub), **met})

len_metrics_df = pd.DataFrame(rows)
display(len_metrics_df.sort_values(["len_bin", "model"]))

# plot macro_f1 vs bin
pivot = len_metrics_df.pivot(index="len_bin", columns="model", values="macro_f1")
x = np.arange(len(pivot.index))

plt.figure(figsize=(10,4))
for m in pivot.columns:
    plt.plot(x, pivot[m].values, marker="o", label=m)
plt.xticks(x, pivot.index, rotation=30, ha="right")
plt.ylim(0, 1)
plt.ylabel("Macro-F1")
plt.title("Macro-F1 by Text Length Bin (Test)")
plt.legend()
plt.tight_layout()
plt.show()
```

	model	len_bin	n	accuracy	macro_f1	macro_precision	macro_recall
18	BERT	(104.0, 159.0]	122	0.663934	0.577952	0.597974	0.592179
14	FNN	(104.0, 159.0]	122	0.688525	0.470912	0.449600	0.497424

	model	len_bin	n	accuracy	macro_f1	macro_precision	macro_recall
2	LR	(104.0, 159.0]	122	0.655738	0.587002	0.586022	0.640169
10	NB	(104.0, 159.0]	122	0.655738	0.465038	0.566893	0.455754
6	SVM	(104.0, 159.0]	122	0.639344	0.491565	0.538969	0.481873
19	BERT	(159.0, 1003.0]	125	0.656000	0.522574	0.565224	0.502773
15	FNN	(159.0, 1003.0]	125	0.520000	0.346645	0.318001	0.412775
3	LR	(159.0, 1003.0]	125	0.488000	0.398480	0.416346	0.392838
11	NB	(159.0, 1003.0]	125	0.616000	0.390118	0.515344	0.401273
7	SVM	(159.0, 1003.0]	125	0.592000	0.395032	0.404849	0.399305
16	BERT	(16.999, 66.0]	127	0.574803	0.492741	0.544359	0.489915
12	FNN	(16.999, 66.0]	127	0.574803	0.440906	0.719565	0.463659
0	LR	(16.999, 66.0]	127	0.535433	0.487979	0.494516	0.488364
8	NB	(16.999, 66.0]	127	0.551181	0.391135	0.750287	0.432749
4	SVM	(16.999, 66.0]	127	0.527559	0.422299	0.533333	0.431913
17	BERT	(66.0, 104.0]	125	0.632000	0.558387	0.650219	0.542940
13	FNN	(66.0, 104.0]	125	0.576000	0.412693	0.388553	0.447318
1	LR	(66.0, 104.0]	125	0.608000	0.587289	0.583198	0.611867
9	NB	(66.0, 104.0]	125	0.536000	0.420867	0.600520	0.429005
5	SVM	(66.0, 104.0]	125	0.616000	0.530808	0.561077	0.524438



11.5 Gender / Age bias (only if detectable)

In [117]:

```
# ===== 11.5 Gender / Age bias (only if detectable) =====
import re

age_pat = re.compile(r"\b(\d{1,3})\s*(?:yo|y/o|years?\s*old)\b", re.IGNORECASE)
gender_pat = re.compile(r"\b(male|female|man|woman|boy|girl)\b", re.IGNORECASE)

def extract_age(text):
    m = age_pat.search(str(text))
    return int(m.group(1)) if m else np.nan

def extract_gender(text):
    m = gender_pat.search(str(text))
    return m.group(1).lower() if m else None

test_meta = test_df.copy()
test_meta["age"] = test_meta[TEXT_COL].apply(extract_age)
test_meta["gender_word"] = test_meta[TEXT_COL].apply(extract_gender)
test_meta["y_true"] = y_true

# ใส่ pred ของทุกโมเดล
for m, y_pred in preds.items():
    test_meta[f"{m}_pred"] = y_pred

print("Age detected count:", int(test_meta["age"].notna().sum()))
print("Gender word detected count:", int(test_meta["gender_word"].notna().sum()))

def group_metrics_multi(df, group_col):
    rows = []
    for g in df[group_col].dropna().unique():
        sub = df[df[group_col] == g]
        for m in preds.keys():
            met = metrics_basic(sub["y_true"].values, sub[f"{m}_pred"].values)
            rows.append({"group": str(g), "model": m, "n": len(sub), **met})
    return pd.DataFrame(rows)

# ---- age bins ----
if test_meta["age"].notna().sum() >= 30:
    test_meta["age_bin"] = pd.cut(
        test_meta["age"], bins=[0, 12, 18, 35, 60, 120],
        labels=["child", "teen", "adult", "middle", "senior"]
    )
    age_sub = test_meta.dropna(subset=["age_bin"])
    display(age_sub["age_bin"].value_counts())
```

```
    age_metrics = group_metrics_multi(age_sub, "age_bin") \
                    .sort_values(["group", "model"])
    display(age_metrics)
else:
    print("[SKIP] Not enough age signals to analyze reliably.")

# ---- gender word ----
if test_meta["gender_word"].notna().sum() >= 30:
    gender_sub = test_meta.dropna(subset=["gender_word"])
    display(gender_sub["gender_word"].value_counts())

    gender_metrics = group_metrics_multi(gender_sub, "gender_word") \
                       .sort_values(["group", "model"])
    display(gender_metrics)
else:
    print("[SKIP] Not enough gender signals to analyze reliably.")
```

```
Age detected count: 154
Gender word detected count: 89
```

	count
age_bin	
adult	87
middle	34
senior	15
teen	13
child	5

dtype: int64

	group	model	n	accuracy	macro_f1	macro_precision	macro_recall
4	adult	BERT	87	0.655172	0.549383	0.655895	0.523288
3	adult	FNN	87	0.620690	0.430976	0.406847	0.461178

	group	model	n	accuracy	macro_f1	macro_precision	macro_recall
0	adult	LR	87	0.620690	0.486603	0.492861	0.482029
2	adult	NB	87	0.689655	0.450639	0.523909	0.464462
1	adult	SVM	87	0.666667	0.451455	0.478165	0.460239
24	child	BERT	5	0.600000	0.555556	0.555556	0.555556
23	child	FNN	5	0.400000	0.222222	0.222222	0.222222
20	child	LR	5	0.400000	0.388889	0.277778	0.666667
22	child	NB	5	0.800000	0.619048	0.583333	0.666667
21	child	SVM	5	0.600000	0.444444	0.388889	0.555556
14	middle	BERT	34	0.647059	0.596805	0.597466	0.608709
13	middle	FNN	34	0.558824	0.370370	0.330128	0.423559
10	middle	LR	34	0.647059	0.630899	0.642735	0.651003
12	middle	NB	34	0.676471	0.500928	0.544444	0.523810
11	middle	SVM	34	0.558824	0.449495	0.483333	0.447682
19	senior	BERT	15	0.866667	0.791919	0.944444	0.722222
18	senior	FNN	15	0.666667	0.266667	0.222222	0.333333
15	senior	LR	15	0.400000	0.280342	0.333333	0.355556
17	senior	NB	15	0.600000	0.375758	0.388889	0.377778
16	senior	SVM	15	0.666667	0.380952	0.356061	0.411111
9	teen	BERT	13	0.307692	0.290909	0.316667	0.362500
8	teen	FNN	13	0.769231	0.745098	0.763889	0.737500
5	teen	LR	13	0.538462	0.386946	0.433333	0.366667
7	teen	NB	13	0.538462	0.535714	0.597222	0.587500
6	teen	SVM	13	0.692308	0.690476	0.702381	0.712500

	count
gender_word	
male	45
female	30
woman	6
girl	4
boy	2
man	2

dtype: int64

	group	model	n	accuracy	macro_f1	macro_precision	macro_recall
19	boy	BERT	2	0.500000	0.333333	0.250000	0.500000
18	boy	FNN	2	0.000000	0.000000	0.000000	0.000000
15	boy	LR	2	0.000000	0.000000	0.000000	0.000000
17	boy	NB	2	0.000000	0.000000	0.000000	0.000000
16	boy	SVM	2	0.000000	0.000000	0.000000	0.000000
9	female	BERT	30	0.433333	0.358752	0.395960	0.366162
8	female	FNN	30	0.633333	0.451389	0.420814	0.486869
5	female	LR	30	0.600000	0.520609	0.525000	0.517677
7	female	NB	30	0.600000	0.380952	0.518519	0.424242
6	female	SVM	30	0.600000	0.405983	0.461111	0.432323
29	girl	BERT	4	0.250000	0.133333	0.166667	0.111111
28	girl	FNN	4	0.500000	0.266667	0.333333	0.222222
25	girl	LR	4	0.750000	0.600000	0.666667	0.555556

	group	model	n	accuracy	macro_f1	macro_precision	macro_recall
27	girl	NB	4	0.750000	0.428571	0.375000	0.500000
26	girl	SVM	4	0.500000	0.222222	0.222222	0.222222
4	male	BERT	45	0.666667	0.563034	0.623153	0.543881
3	male	FNN	45	0.577778	0.403710	0.384921	0.425121
0	male	LR	45	0.711111	0.603628	0.652338	0.584944
2	male	NB	45	0.711111	0.482109	0.546296	0.500000
1	male	SVM	45	0.666667	0.452511	0.478610	0.471014
24	man	BERT	2	1.000000	1.000000	1.000000	1.000000
23	man	FNN	2	0.500000	0.333333	0.500000	0.250000
20	man	LR	2	0.500000	0.333333	0.500000	0.250000
22	man	NB	2	1.000000	1.000000	1.000000	1.000000
21	man	SVM	2	1.000000	1.000000	1.000000	1.000000
14	woman	BERT	6	0.833333	0.841270	0.833333	0.916667
13	woman	FNN	6	0.333333	0.166667	0.166667	0.166667
10	woman	LR	6	0.833333	0.629630	0.600000	0.666667
12	woman	NB	6	0.666667	0.266667	0.222222	0.333333
11	woman	SVM	6	0.833333	0.629630	0.600000	0.666667

11.6 Deployment risk + Ethical safeguards (**เขียนเป็น** bullet **ตาม** rubric)

In [118]:
```
# ===== 11.6 Deployment risk + Ethical safeguards (ใส่ใน report/slide) =====
# - This model is NOT a medical diagnosis system; it only predicts "urgency/severity label" from text.
# - Risk: False Negative (predict low/medium แต่จริง high) อาจทำให้เคสเร่งด่วนถูกจัดลำดับช้า -> harm สูง
# - Risk: Dataset label noise / subjective severity boundary (low vs medium vs high) ทำให้ขอบเขตคลุมเครือ
# - Risk: Bias from text patterns (ยาว/สั้น), demographic cues (age/gender words) — สรุปได้แค่ "signal" ไม่ใช่ ground truth
# - Safeguards:
#   (1) Human-in-the-loop: ใช้โมเดลเป็น decision support เท่านั้น
#   (2) Thresholding / reject option: ถ้า confidence ต่ำ -> ส่งให้ human review
#   (3) Monitoring: track error rate โดยเฉพาะคลาส "high"
#   (4) Data governance: de-identification, no personal data storage, audit logs
#   (5) Continuous evaluation: re-train/validate เมื่อ data drift
```

SECTION 12 - Computational Cost Analysis

In [125]:
```
import io, time
import numpy as np
import pandas as pd
import joblib
```

12.1 Helper: safe getter

In [126]:

```
def _safe_float(x):
    try:
        return float(x)
    except Exception:
        return None

def get_first_global(names):
    """
    คืนค่า global ตัวแรกที่พบใน names (list of str) ถ้าไม่เจอคืน None
    """
    for n in names:
        if n in globals() and globals()[n] is not None:
            return globals()[n]
    return None

def sizeof_joblib_mb(obj):
    """
    ขนาดโมเดลแบบคร่าว ๆ: serialize ด้วย joblib -> bytes -> MB
    """
    try:
        buf = io.BytesIO()
        joblib.dump(obj, buf)
        return float(buf.getbuffer().nbytes / (1024**2))
    except Exception as e:
        print("[WARN] joblib size failed:", e)
        return None
```

12.2 Torch helpers (FNN/BERT)

In [127]:

```
try:
    import torch
    TORCH_OK = True
except Exception as e:
    TORCH_OK = False
    print("[WARN] torch not available -> FNN/BERT cost will be partial:", e)

def count_trainable_params_torch(model):
    if not TORCH_OK or model is None:
        return None
    return int(sum(p.numel() for p in model.parameters() if p.requires_grad))

def sizeof_model_state_dict_mb_torch(model):
    if not TORCH_OK or model is None:
        return None
    total_bytes = 0
    for _, t in model.state_dict().items():
        if torch.is_tensor(t):
            total_bytes += t.numel() * t.element_size()
    return float(total_bytes / (1024**2))
```

12.3 Inference benchmarks

In [128]:

```
def benchmark_sklearn_inference(pipe, texts, n_runs=3):
    # warmup
    _ = pipe.predict(texts[:32])
    times = []
    for _ in range(n_runs):
        t0 = time.perf_counter()
        _ = pipe.predict(texts)
        t1 = time.perf_counter()
        times.append(t1 - t0)
    mean_t = float(np.mean(times))
    return mean_t, float(len(texts) / mean_t)

def benchmark_fnn_inference(fnn_model, texts, batch_size=256, n_runs=3):
    """
    ต้องมีฟังก์ชัน glove_vector(text) ที่คืน vector (เช่น dim=100)
    ถ้าไม่มีก็จะ fallback เป็นศูนย์ (ยังรันได้ แต่เวลาที่วัดอาจไม่สะท้อนจริง)
    """
    if not TORCH_OK or fnn_model is None:
        return None, None

    # หา embedding function
    if "glove_vector" in globals():
        vec_fn = globals()["glove_vector"]
    else:
        def vec_fn(_):
            return np.zeros(100, dtype=np.float32)

    X = np.vstack([vec_fn(t) for t in texts]).astype(np.float32)

    device = next(fnn_model.parameters()).device
    fnn_model.eval()

    def run_once():
        t0 = time.perf_counter()
        with torch.no_grad():
            for i in range(0, len(X), batch_size):
                xb = torch.tensor(X[i:i+batch_size], dtype=torch.float32).to(device)
                _ = fnn_model(xb)
        return time.perf_counter() - t0

    _ = run_once()  # warmup
    times = [run_once() for _ in range(n_runs)]
    mean_t = float(np.mean(times))
```

```
    return mean_t, float(len(texts) / mean_t)

def get_bert_model_obj():
    """
    รองรับหลาย naming ที่มักเจอใน notebook:
    - trainer.model (HuggingFace Trainer)
    - bert_trainer.model
    - bert_model / model (ตรง ๆ)
    """
    tr = get_first_global(["trainer", "bert_trainer", "bertTrainer", "bert_final_trainer"])
    if tr is not None and hasattr(tr, "model"):
        return tr.model
    return get_first_global(["bert_model", "model_bert", "model", "bertModel"])

def benchmark_bert_inference(tokenizer, bert_model, texts, max_length=256, batch_size=32, n_runs=3):
    if not TORCH_OK or bert_model is None or tokenizer is None:
        return None, None

    device = next(bert_model.parameters()).device
    bert_model.eval()

    def run_once():
        t0 = time.perf_counter()
        with torch.no_grad():
            for i in range(0, len(texts), batch_size):
                batch_texts = texts[i:i+batch_size]
                enc = tokenizer(
                    batch_texts,
                    return_tensors="pt",
                    padding=True,
                    truncation=True,
                    max_length=max_length
                ).to(device)
                _ = bert_model(**enc)
        return time.perf_counter() - t0

    _ = run_once()  # warmup
    times = [run_once() for _ in range(n_runs)]
    mean_t = float(np.mean(times))
    return mean_t, float(len(texts) / mean_t)
```

12.4 Collect training times (Dynamic)

In [129]:

```
TRAIN_TIME_KEYS = {
    "LR":   ["LR_TRAIN_TIME_SEC", "lr_train_time_sec", "lr_train_time"],
    "SVM":  ["SVM_TRAIN_TIME_SEC", "svm_train_time_sec", "svm_train_time"],
    "NB":   ["NB_TRAIN_TIME_SEC", "nb_train_time_sec", "nb_train_time"],
    "FNN":  ["FNN_TRAIN_TIME_SEC", "fnn_train_time_sec", "fnn_train_time"],
    "BERT": ["BERT_TRAIN_TIME_SEC", "bert_train_time_sec", "bert_train_time"],
}

train_time = {}
for k, cand in TRAIN_TIME_KEYS.items():
    v = get_first_global(cand)
    train_time[k] = _safe_float(v)

print("=== [DEBUG] Loaded training times (sec) ===")
for k in ["LR","SVM","NB","FNN","BERT"]:
    print(k, "=>", train_time[k])
```

```
=== [DEBUG] Loaded training times (sec) ===
LR => 4.462953448999542
SVM => 1.0090705329985212
NB => 0.3279013000010309
FNN => 1.529279647000294
BERT => 490.7961654789997
```

12.5 Build cost table

In [132]:

```
# ต้องมี: test_df, TEXT_COL
if "test_df" not in globals():
    raise RuntimeError("ไม่พบ test_df (กรุณารัน Section split/test ก่อน)")
if "TEXT_COL" not in globals():
    TEXT_COL = "text_raw"  # fallback

test_texts = test_df[TEXT_COL].astype(str).tolist()

rows = []

# ---- LR ----
if "lr_pipe" in globals():
    lr_pipe = globals()["lr_pipe"]
    lr_clf = lr_pipe.named_steps.get("clf", None)
    lr_params = int(lr_clf.coef_.size + lr_clf.intercept_.size) if hasattr(lr_clf, "coef_") else None
    lr_size_mb = sizeof_joblib_mb(lr_pipe)
    lr_inf_t, lr_sps = benchmark_sklearn_inference(lr_pipe, test_texts, n_runs=3)

    rows.append({
        "model_key": "LR",
        "train_time_sec": train_time["LR"],
        "num_params": lr_params,
        "model_size_mb": lr_size_mb,
        "inf_time_sec": lr_inf_t,
        "samples_per_sec": lr_sps
    })
else:
    print("[WARN] lr_pipe not found -> skip LR in Section 12")

# ---- SVM ----
if "svm_pipe" in globals():
    svm_pipe = globals()["svm_pipe"]
    svm_clf = svm_pipe.named_steps.get("clf", None)
    svm_params = int(svm_clf.coef_.size + svm_clf.intercept_.size) if hasattr(svm_clf, "coef_") else None
    svm_size_mb = sizeof_joblib_mb(svm_pipe)
    svm_inf_t, svm_sps = benchmark_sklearn_inference(svm_pipe, test_texts, n_runs=3)

    rows.append({
        "model_key": "SVM",
        "train_time_sec": train_time["SVM"],
        "num_params": svm_params,
        "model_size_mb": svm_size_mb,
        "inf_time_sec": svm_inf_t,
```

```
        "samples_per_sec": svm_sps
    })
else:
    print("[WARN] svm_pipe not found -> skip SVM in Section 12")

# ---- NB ----
if "nb_pipe" in globals():
    nb_pipe = globals()["nb_pipe"]
    nb_clf = nb_pipe.named_steps.get("clf", None)
    # NB ไม่มี coef_ แต่มี feature_log_prob_
    nb_params = None
    if hasattr(nb_clf, "feature_log_prob_"):
        nb_params = int(nb_clf.feature_log_prob_.size + getattr(nb_clf, "class_log_prior_", np.array([])).size)
    nb_size_mb = sizeof_joblib_mb(nb_pipe)
    nb_inf_t, nb_sps = benchmark_sklearn_inference(nb_pipe, test_texts, n_runs=3)

    rows.append({
        "model_key": "NB",
        "train_time_sec": train_time["NB"],
        "num_params": nb_params,
        "model_size_mb": nb_size_mb,
        "inf_time_sec": nb_inf_t,
        "samples_per_sec": nb_sps
    })
else:
    print("[WARN] nb_pipe not found -> skip NB in Section 12")

# ---- FNN ----
fnn_model = get_first_global(["fnn_model", "model_fnn"])
if fnn_model is not None and TORCH_OK:
    fnn_params = count_trainable_params_torch(fnn_model)
    fnn_size_mb = sizeof_model_state_dict_mb_torch(fnn_model)
    fnn_inf_t, fnn_sps = benchmark_fnn_inference(fnn_model, test_texts, batch_size=256, n_runs=3)

    rows.append({
        "model_key": "FNN",
        "train_time_sec": train_time["FNN"],
        "num_params": fnn_params,
        "model_size_mb": fnn_size_mb,
        "inf_time_sec": fnn_inf_t,
        "samples_per_sec": fnn_sps
    })
else:
```

```
    print("[WARN] fnn_model not found (or torch missing) -> skip FNN in Section 12")

# ---- BERT ----
tokenizer = get_first_global(["tokenizer"])
bert_model = get_bert_model_obj()

if bert_model is not None and tokenizer is not None and TORCH_OK:
    bert_params = count_trainable_params_torch(bert_model)
    bert_size_mb = sizeof_model_state_dict_mb_torch(bert_model)
    bert_inf_t, bert_sps = benchmark_bert_inference(tokenizer, bert_model, test_texts, max_length=256, batch_size=32, n_runs=3)

    rows.append({
        "model_key": "BERT",
        "train_time_sec": train_time["BERT"],
        "num_params": bert_params,
        "model_size_mb": bert_size_mb,
        "inf_time_sec": bert_inf_t,
        "samples_per_sec": bert_sps
    })
else:
    print("[WARN] BERT model/tokenizer not found (or torch missing) -> skip BERT in Section 12")

cost_df = pd.DataFrame(rows)
display(cost_df.sort_values("inf_time_sec", ascending=True))
```

	model_key	train_time_sec	num_params	model_size_mb	inf_time_sec	samples_per_sec
3	FNN	1.529280	26627	0.101574	0.000464	1.076339e+06
2	NB	0.327901	20058	0.440515	0.034484	1.447052e+04
1	SVM	1.009071	110970	1.682220	0.073881	6.754062e+03
0	LR	4.462953	1114437	19.110523	0.127847	3.903101e+03
4	BERT	490.796165	109484547	417.650402	8.301080	6.011266e+01

SECTION 13 - Final Summary + Recommendation

In [133]:
```
import numpy as np
import pandas as pd

# ต้องมี results_df (จาก Section สรุปผล model)
if "results_df" not in globals():
    raise RuntimeError("ไม่พบ results_df (กรุณารัน Section สรุปผลโมเดลก่อน)")
```

13.1 Normalize model names -> model_key

In [136]:
```
NAME_TO_KEY = {
    "Logistic Regression": "LR",
    "Logistic Regression (TF-IDF)": "LR",
    "LR": "LR",

    "Linear SVM": "SVM",
    "SVM": "SVM",

    "Multinomial NB": "NB",
    "Naive Bayes": "NB",
    "NB": "NB",

    "FNN (GloVe mean)": "FNN",
    "FNN": "FNN",

    "BERT": "BERT",
    "BERT (bert-base-uncased)": "BERT",
}

m = results_df.copy()
m["model_key"] = m["Model"].map(NAME_TO_KEY).fillna(m["Model"])
```

13.2 Merge: metrics + robustness + cost

In [137]:

```
final_df = m.copy()

# robustness (ถ้ามี)
if "robust_summary" in globals():
    rs = robust_summary.copy()
    # robust_summary บางทีคอลัมน์ชื่อ "model" อยู่แล้ว
    if "model_key" not in rs.columns:
        if "model" in rs.columns:
            rs = rs.rename(columns={"model": "model_key"})
    # rename ให้ชัด
    rs = rs.rename(columns={
        "mean_macro_f1": "robust_mean_macro_f1",
        "std_macro_f1": "robust_std_macro_f1"
    })
    final_df = final_df.merge(rs[["model_key","robust_mean_macro_f1","robust_std_macro_f1"]],
                              on="model_key", how="left")
else:
    print("[INFO] robust_summary not found -> skip robustness merge")

# cost (ต้องมี cost_df จาก Section 12)
if "cost_df" in globals():
    c = cost_df.copy()
    final_df = final_df.merge(
        c[["model_key","train_time_sec","num_params","model_size_mb","inf_time_sec","samples_per_sec"]],
        on="model_key", how="left"
    )
else:
    print("[INFO] cost_df not found -> skip cost merge")
```

13.3 Simple efficiency score

In [138]:

```
eps = 1e-9
if "inf_time_sec" in final_df.columns:
    final_df["efficiency_f1_per_sec"] = final_df["Macro_F1"] / (final_df["inf_time_sec"] + eps)

display(final_df.sort_values("Macro_F1", ascending=False))

# -------------------------
# 13.4 Auto-pick recommendations
# -------------------------
best_perf = final_df.sort_values("Macro_F1", ascending=False).iloc[0]

print("\n====================")
print("SECTION 13 — Recommendation (auto summary)")
print("====================")

print(f"- Best performance (Macro_F1 สูงสุด): {best_perf['Model']} | Macro_F1={best_perf['Macro_F1']:.4f}")

if "inf_time_sec" in final_df.columns and final_df["inf_time_sec"].notna().any():
    best_fast = final_df.sort_values("inf_time_sec", ascending=True).dropna(subset=["inf_time_sec"]).iloc[0]
    print(f"- Fastest inference (บน TEST): {best_fast['Model']} | inf_time_sec={best_fast['inf_time_sec']:.4f} | samples/s=
{best_fast['samples_per_sec']:.1f}")

if "efficiency_f1_per_sec" in final_df.columns and final_df["efficiency_f1_per_sec"].notna().any():
    best_eff = final_df.sort_values("efficiency_f1_per_sec", ascending=False).dropna(subset=["efficiency_f1_per_sec"]).iloc[0]
    print(f"- Best efficiency (Macro_F1 / sec): {best_eff['Model']} | score={best_eff['efficiency_f1_per_sec']:.4f}")

# robustness line (ถ้ามี)
if "robust_mean_macro_f1" in final_df.columns:
    print("\n[Robustness] mean±std (macro_f1):")
    show_cols = ["Model","robust_mean_macro_f1","robust_std_macro_f1"]
    display(final_df[show_cols].sort_values("robust_mean_macro_f1", ascending=False))
```

	Model	Accuracy	Macro_F1	Macro_Precision	Macro_Recall	model_key	robust_mean_macro_f1	robust_std_macro_f1	tr
4	BERT	0.578313	0.505512	0.528295	0.494542	BERT	0.529662	0.030122	4
0	Logistic Regression	0.540161	0.479090	0.477200	0.481675	LR	0.478952	0.024311	4.
1	Linear SVM	0.534137	0.405891	0.424307	0.408701	SVM	0.421986	0.013989	1.

	Model	Accuracy	Macro_F1	Macro_Precision	Macro_Recall	model_key	robust_mean_macro_f1	robust_std_macro_f1	tr
3	FNN (GloVe mean)	0.564257	0.337035	0.385527	0.379198	FNN	0.374628	0.011617	1.
2	Multinomial NB	0.536145	0.232680	0.178715	0.333333	NB	0.380773	0.025748	0.

```
====================
SECTION 13 — Recommendation (auto summary)
====================
- Best performance (Macro_F1 สูงสุด): BERT | Macro_F1=0.5055
- Fastest inference (บน TEST): FNN (GloVe mean) | inf_time_sec=0.0005 | samples/s=1076338.8
- Best efficiency (Macro_F1 / sec): FNN (GloVe mean) | score=726.9795

[Robustness] mean±std (macro_f1):
```

	Model	robust_mean_macro_f1	robust_std_macro_f1
4	BERT	0.529662	0.030122
0	Logistic Regression	0.478952	0.024311
1	Linear SVM	0.421986	0.013989
2	Multinomial NB	0.380773	0.025748
3	FNN (GloVe mean)	0.374628	0.011617

In [142]:
```
print("\n[Report bullets template]")
print("1) ภาพรวม: เปรียบเทียบ 5 โมเดล (LR/SVM/NB/FNN/BERT) บนงานจัดระดับความเร่งด่วน 3 คลาส")
print(f"2) โมเดลที่ทำคะแนนดีที่สุดคือ {best_perf['Model']} (Macro_F1 สูงสุด)")
print("3) โมเดลเชิงเส้น (LR/SVM/NB) มักเบาและ inference เร็ว เหมาะกับงานที่ต้อง latency ต่ำ")
print("4) FNN ใช้ embedding (GloVe mean) จับ semantics ได้บางส่วน แต่ขึ้นกับคุณภาพ embedding และข้อมูล")
print("5) BERT จับ context ได้ดี แต่ cost สูงกว่า (params/size/inference) เหมาะเมื่อเน้น performance มากกว่า compute")
print("6) ข้อจำกัด: label boundary อาจทับซ้อน (low/medium/high) + ความกำกวมทางภาษา/negation ทำให้ error")
print("7) งานอนาคต: เพิ่ม data / ทำ domain adaptation / calibrate confidence / ทำ error-driven augmentation")
```

```
[Report bullets template]
1) ภาพรวม: เปรียบเทียบ 5 โมเดล (LR/SVM/NB/FNN/BERT) บนงานจัดระดับความเร่งด่วน 3 คลาส
2) โมเดลที่ทำคะแนนดีที่สุดคือ BERT (Macro_F1 สูงสุด)
3) โมเดลเชิงเส้น (LR/SVM/NB) มักเบาและ inference เร็ว เหมาะกับงานที่ต้อง latency ต่ำ
4) FNN ใช้ embedding (GloVe mean) จับ semantics ได้บางส่วน แต่ขึ้นกับคุณภาพ embedding และข้อมูล
5) BERT จับ context ได้ดี แต่ cost สูงกว่า (params/size/inference) เหมาะเมื่อเน้น performance มากกว่า compute
6) ข้อจำกัด: label boundary อาจทับซ้อน (low/medium/high) + ความกำกวมทางภาษา/negation ทำให้ error
7) งานอนาคต: เพิ่ม data / ทำ domain adaptation / calibrate confidence / ทำ error-driven augmentation
```

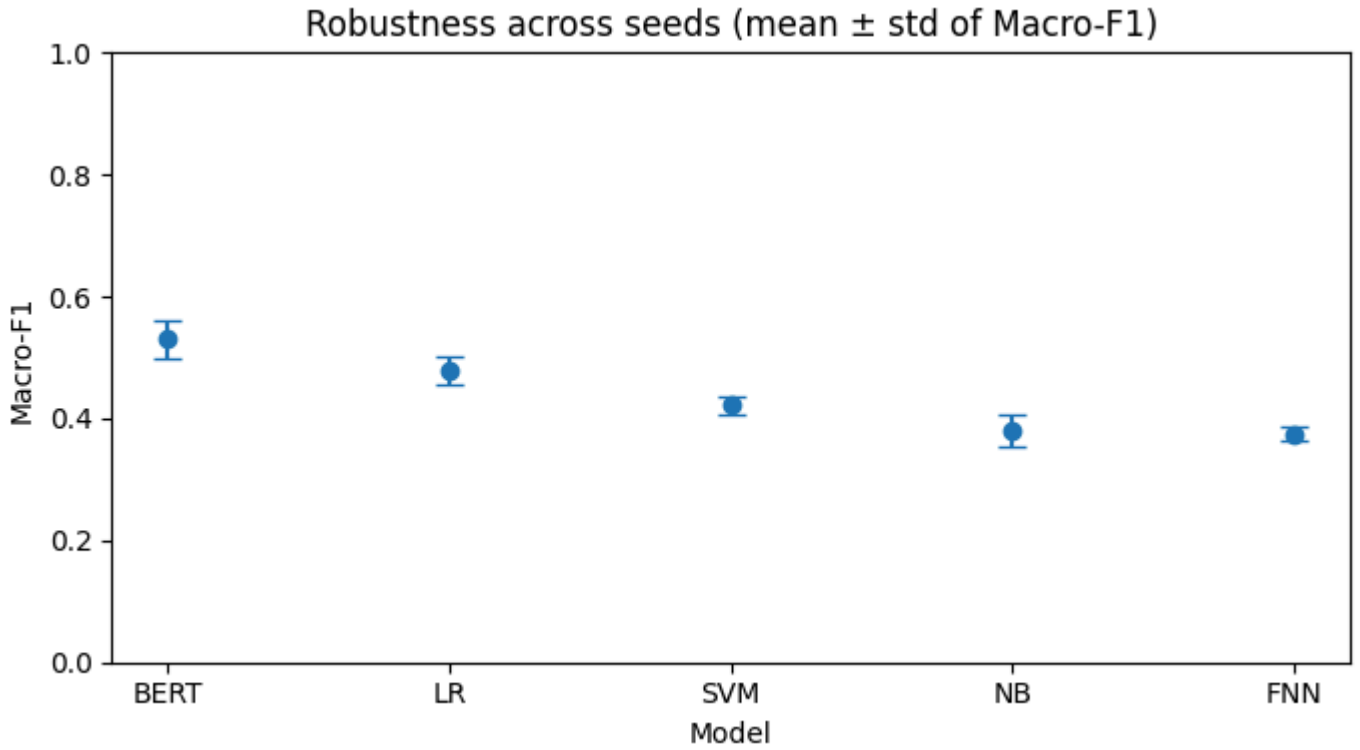
SECTION 14 - Visualization Pack (Recommended add-on)

In [ ]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

14.1 Robustness: mean ± std (errorbar)

In [143]:

```
# requires: robust_summary with columns [model, mean_macro_f1, std_macro_f1]
if "robust_summary" in globals() and isinstance(robust_summary, pd.DataFrame):
    rs = robust_summary.copy()
    # expected cols: model, mean_macro_f1, std_macro_f1
    if {"model","mean_macro_f1","std_macro_f1"}.issubset(rs.columns):
        rs = rs.sort_values("mean_macro_f1", ascending=False)
        plt.figure(figsize=(7,4))
        plt.errorbar(
            rs["model"].astype(str),
            rs["mean_macro_f1"].astype(float),
            yerr=rs["std_macro_f1"].astype(float),
            fmt="o",
            capsize=5
        )
        plt.ylim(0, 1)
        plt.title("Robustness across seeds (mean ± std of Macro-F1)")
        plt.ylabel("Macro-F1")
        plt.xlabel("Model")
        plt.tight_layout()
        plt.show()
    else:
        print("[SKIP] robust_summary found but missing expected columns")
else:
    print("[SKIP] robust_summary not found (run Section 8.5 first)")
```

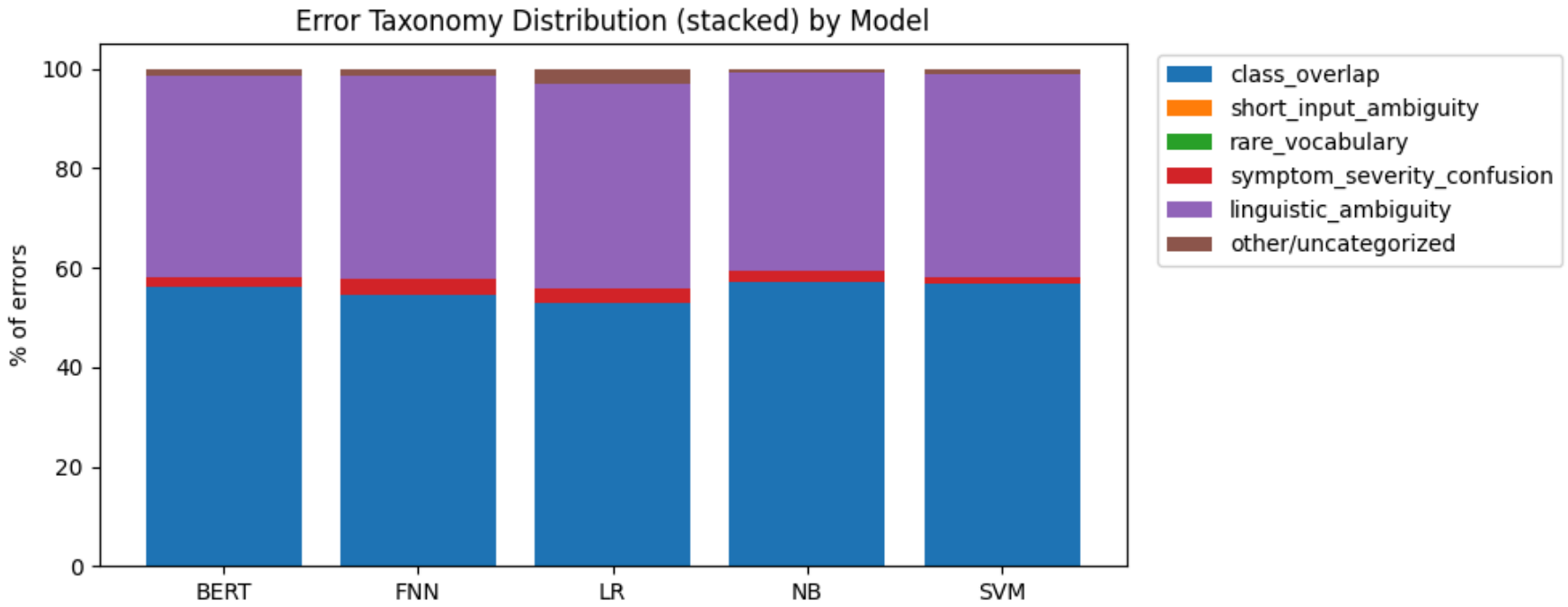


14.2 Error Taxonomy: stacked bar (% of errors by category per model)

In [144]:

```
# requires: summary from Section 9.5 (exploded grouping) with columns:
# [model, categories, pct_of_errors]
if "summary" in globals() and isinstance(summary, pd.DataFrame):
    s = summary.copy()
    if {"model","categories","pct_of_errors"}.issubset(s.columns):
        pivot = s.pivot_table(
            index="model",
            columns="categories",
            values="pct_of_errors",
            aggfunc="sum",
            fill_value=0
        )
        # keep stable category order (optional)
        cat_order = [
            "class_overlap",
            "short_input_ambiguity",
            "rare_vocabulary",
            "symptom_severity_confusion",
            "linguistic_ambiguity",
            "other/uncategorized"
        ]
        cols = [c for c in cat_order if c in pivot.columns] + [c for c in pivot.columns if c not in cat_order]
        pivot = pivot[cols]

        # stacked bar
        plt.figure(figsize=(10,4))
        bottom = np.zeros(len(pivot))
        x = np.arange(len(pivot.index))
        for c in pivot.columns:
            vals = pivot[c].values
            plt.bar(x, vals, bottom=bottom, label=str(c))
            bottom += vals

        plt.xticks(x, pivot.index.astype(str))
        plt.ylabel("% of errors")
        plt.title("Error Taxonomy Distribution (stacked) by Model")
        plt.legend(bbox_to_anchor=(1.02, 1), loc="upper left")
        plt.tight_layout()
        plt.show()
    else:
        print("[SKIP] summary found but missing expected columns")
```

```
else:
    print("[SKIP] summary not found (run Section 9.5 first)")
```

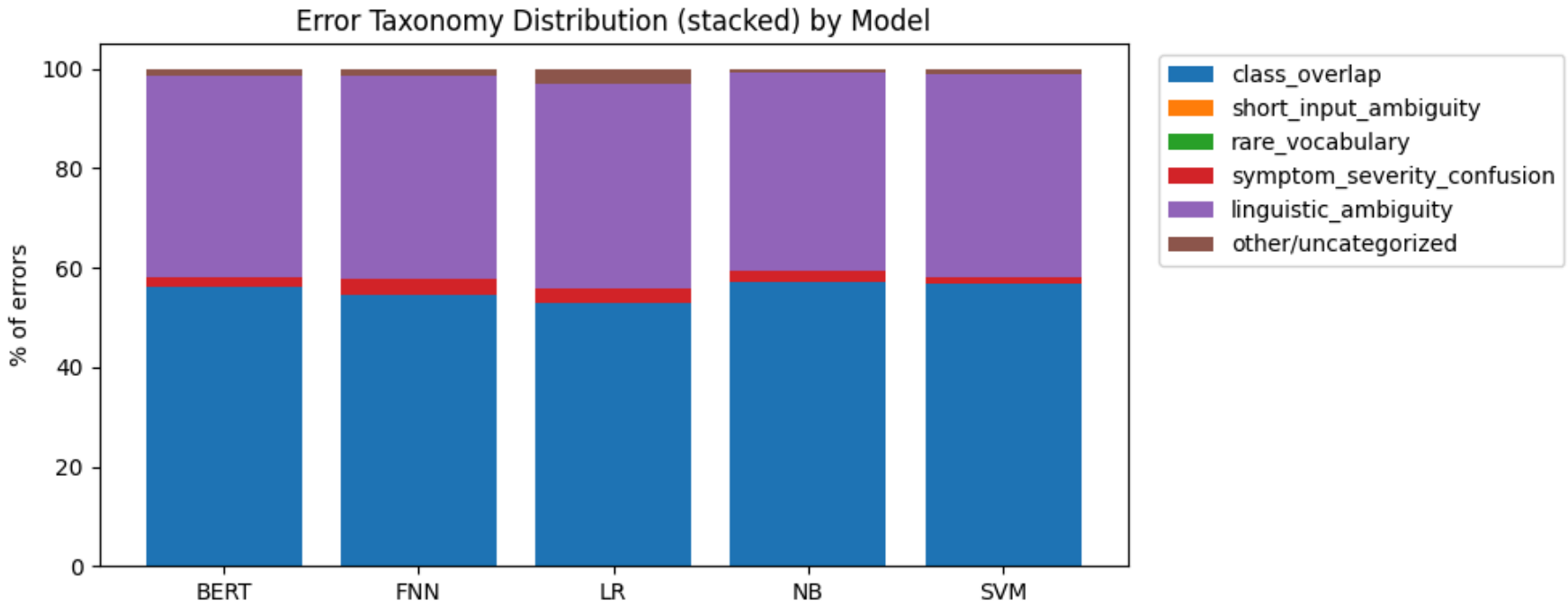


14.3 Cost vs Performance: scatter

In [146]:

```
# requires: summary from Section 9.5 (exploded grouping) with columns:
# [model, categories, pct_of_errors]
if "summary" in globals() and isinstance(summary, pd.DataFrame):
    s = summary.copy()
    if {"model","categories","pct_of_errors"}.issubset(s.columns):
        pivot = s.pivot_table(
            index="model",
            columns="categories",
            values="pct_of_errors",
            aggfunc="sum",
            fill_value=0
        )
        # keep stable category order (optional)
        cat_order = [
            "class_overlap",
            "short_input_ambiguity",
            "rare_vocabulary",
            "symptom_severity_confusion",
            "linguistic_ambiguity",
            "other/uncategorized"
        ]
        cols = [c for c in cat_order if c in pivot.columns] + [c for c in pivot.columns if c not in cat_order]
        pivot = pivot[cols]

        # stacked bar
        plt.figure(figsize=(10,4))
        bottom = np.zeros(len(pivot))
        x = np.arange(len(pivot.index))
        for c in pivot.columns:
            vals = pivot[c].values
            plt.bar(x, vals, bottom=bottom, label=str(c))
            bottom += vals

        plt.xticks(x, pivot.index.astype(str))
        plt.ylabel("% of errors")
        plt.title("Error Taxonomy Distribution (stacked) by Model")
        plt.legend(bbox_to_anchor=(1.02, 1), loc="upper left")
        plt.tight_layout()
        plt.show()
    else:
        print("[SKIP] summary found but missing expected columns")
```

```
else:
    print("[SKIP] summary not found (run Section 9.5 first)")
```



SECTION 15 - BACKUP: export tables + save models + zip + download

In [147]:
```
import os, json, zipfile, shutil
import numpy as np
import pandas as pd

OUT_DIR = "pj_nlp_backup"
TABLE_DIR = os.path.join(OUT_DIR, "tables")
MODEL_DIR = os.path.join(OUT_DIR, "models")

# reset folder
if os.path.isdir(OUT_DIR):
    shutil.rmtree(OUT_DIR)
os.makedirs(TABLE_DIR, exist_ok=True)
os.makedirs(MODEL_DIR, exist_ok=True)
```

15.1 Export tables (DataFrames) -> CSV

In [148]:
```
# "ตารางทุกอัน" แบบ practical: export DataFrame เกือบทั้งหมด ยกเว้น raw splits ถ้าใหญ่เกินไป
# ----------------------------
DENY_NAMES = {
    "df", "train_df", "val_df", "test_df", "temp_df", "trainval_df", "FULL_DF"
}

saved_tables = []
for name, obj in list(globals().items()):
    if isinstance(obj, pd.DataFrame):
        if name in DENY_NAMES:
            continue
        # heuristic: ชื่อที่เป็นตารางสรุปมักลงท้าย _df หรือเป็น summary/errors_all
        if name.endswith("_df") or name in
{"summary","errors_all","final_df","macro_df","per_class_df","len_metrics_df","ttest_df","robust_summary"}:
            path = os.path.join(TABLE_DIR, f"{name}.csv")
            obj.to_csv(path, index=False)
            saved_tables.append({"name": name, "path": path, "shape": list(obj.shape)})

print(f"Saved tables: {len(saved_tables)}")
for t in saved_tables[:10]:
    print(" -", t["name"], t["shape"])
```

```
Saved tables: 22
 - eda_df [3, 4]
 - ablation_df [4, 4]
 - results_df [5, 5]
 - tuned_ml_df [3, 5]
 - fnn_tune_df [36, 5]
 - bert_tune_df [4, 6]
 - tr_df [2323, 8]
 - va_df [498, 8]
 - te_df [499, 8]
 - robust_df [5, 7]
```

15.2 Save configs/metadata -> JSON

In [149]:

```
meta = {
    "CONFIG": globals().get("CONFIG", None),
    "BEST_LR_PARAMS": globals().get("BEST_LR_PARAMS", None),
    "BEST_SVM_PARAMS": globals().get("BEST_SVM_PARAMS", None),
    "BEST_NB_PARAMS": globals().get("BEST_NB_PARAMS", None),
    "FNN_CONFIG": globals().get("FNN_CONFIG", None),
    "BEST_BERT": globals().get("BEST_BERT", None),
    "SEEDS": globals().get("SEEDS", None),
}
with open(os.path.join(TABLE_DIR, "metadata.json"), "w") as f:
    json.dump(meta, f, indent=2)

print("Saved metadata.json")
```

```
Saved metadata.json
```

15.3 Save models

In [150]:

```
import joblib

def try_joblib_dump(obj, out_path):
    try:
        joblib.dump(obj, out_path)
        print("Saved:", out_path)
    except Exception as e:
        print("[WARN] joblib dump failed:", out_path, "|", e)

if "lr_pipe" in globals():
    try_joblib_dump(lr_pipe, os.path.join(MODEL_DIR, "LR_pipe.joblib"))
if "svm_pipe" in globals():
    try_joblib_dump(svm_pipe, os.path.join(MODEL_DIR, "SVM_pipe.joblib"))
if "nb_pipe" in globals():
    try_joblib_dump(nb_pipe, os.path.join(MODEL_DIR, "NB_pipe.joblib"))

# (B) FNN (PyTorch) -> state_dict + config
try:
    import torch
    TORCH_OK = True
except Exception:
    TORCH_OK = False

if TORCH_OK and "fnn_model" in globals():
    fnn_dir = os.path.join(MODEL_DIR, "FNN")
    os.makedirs(fnn_dir, exist_ok=True)
    torch.save(fnn_model.state_dict(), os.path.join(fnn_dir, "fnn_state_dict.pt"))
    with open(os.path.join(fnn_dir, "fnn_config.json"), "w") as f:
        json.dump(globals().get("FNN_CONFIG", {}), f, indent=2)
    print("Saved: FNN state_dict + config")

# (C) BERT (HF) -> save_pretrained (model + tokenizer)
def get_bert_model_obj():
    if "bert_model_final" in globals() and globals()["bert_model_final"] is not None:
        return globals()["bert_model_final"]
    if "bert_model" in globals() and globals()["bert_model"] is not None:
        return globals()["bert_model"]
    if "bert_trainer" in globals() and hasattr(bert_trainer, "model"):
        return bert_trainer.model
    if "trainer" in globals() and hasattr(trainer, "model"):
        return trainer.model
    return None
```

```
bert_obj = get_bert_model_obj()
tok_obj = globals().get("tokenizer", None)

if bert_obj is not None and tok_obj is not None:
    bert_dir = os.path.join(MODEL_DIR, "BERT")
    os.makedirs(bert_dir, exist_ok=True)
    try:
        bert_obj.save_pretrained(bert_dir)
        tok_obj.save_pretrained(bert_dir)
        print("Saved: BERT save_pretrained (model + tokenizer)")
    except Exception as e:
        print("[WARN] BERT save_pretrained failed:", e)
else:
    print("[WARN] BERT model/tokenizer not found -> skip BERT saving")
```

```
Saved: pj_nlp_backup/models/LR_pipe.joblib
Saved: pj_nlp_backup/models/SVM_pipe.joblib
Saved: pj_nlp_backup/models/NB_pipe.joblib
Saved: FNN state_dict + config

Writing model shards:   0%|          | 0/1 [00:00<?, ?it/s]

Saved: BERT save_pretrained (model + tokenizer)
```

15.4 Save all figures (Matplotlib)

In [151]:

```
import os
import matplotlib.pyplot as plt

FIG_DIR = os.path.join(OUT_DIR, "figures")
os.makedirs(FIG_DIR, exist_ok=True)

fig_nums = plt.get_fignums()
print("Matplotlib figures in memory:", fig_nums)

saved_figs = []
for idx, num in enumerate(fig_nums, start=1):
    fig = plt.figure(num)
    # เซฟทั้ง png และ pdf (เผื่อรายงาน)
    png_path = os.path.join(FIG_DIR, f"fig_{idx:02d}.png")
    pdf_path = os.path.join(FIG_DIR, f"fig_{idx:02d}.pdf")
    try:
        fig.savefig(png_path, dpi=200, bbox_inches="tight")
        fig.savefig(pdf_path, bbox_inches="tight")
        saved_figs.append((png_path, pdf_path))
    except Exception as e:
        print(f"[WARN] Save figure {num} failed:", e)

print(f"Saved figures: {len(saved_figs)}")
if len(saved_figs) > 0:
    print("Example:", saved_figs[0])
```

```
Matplotlib figures in memory: []
Saved figures: 0
```

15.4 Zip everything

In [152]:
```
ZIP_PATH = "pj_nlp_backup.zip"
with zipfile.ZipFile(ZIP_PATH, "w", zipfile.ZIP_DEFLATED) as z:
    for root, _, files in os.walk(OUT_DIR):
        for fn in files:
            full = os.path.join(root, fn)
            arc = os.path.relpath(full, OUT_DIR)
            z.write(full, arcname=arc)

print("Created zip:", ZIP_PATH)
```

```
Created zip: pj_nlp_backup.zip
```

15.5 Download (Colab) / Local note

In [153]:
```
try:
    from google.colab import files
    files.download(ZIP_PATH)
except Exception as e:
    print("[INFO] Not running in Colab. Download manually from:", os.path.abspath(ZIP_PATH))
```

```
<IPython.core.display.Javascript object>


<IPython.core.display.Javascript object>
```