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CLINICAL TEXT SUMMARIZATION

A Benchmark of Domain-Adapted Large Language Models for Generating Brief Hospital Course Summaries

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Problem

- Health Care providers at One Medical need to **manually** look through **hundreds** of clinical documents
- Surfacing the most relevant clinical data from these documents can be accomplished with **text summarization**
- This allows for better **health outcomes** as it helps providers:
 - Save valuable **time**
 - Build a **deeper connection** with patients

MIMIC-IV-Notes

Table 1. a) A sample of our novel pre-processed clinical notes dataset, extracted from raw MIMIC-IV notes.

Input	Example
SEX	F
SERVICE	SURGERY
ALLERGIES	No Known Allergies
CHIEF COMPLAINT	Splenic laceration
MAJOR PROCEDURE	NONE
HISTORY OF PRESENT ILLNESS	s/p routine colonoscopy this morning with polypectomy (report not available) ...
PAST MEDICAL HISTORY	Mild asthma, hypothyroid
FAMILY HISTORY	Non-contributory
PHYSICAL EXAM	Gen: Awake and alert CV: RRR Lungs: CTAB Abd: Soft, nontender, nondistended
PERTINENT RESULTS	03:45 PM BLOOD WBC-5.5 RBC-3.95 Hgb-14.1 ...
MEDICATIONS ON ADMISSION	1. Levothyroxine Sodium 100 mcg PO DAILY 2. Flovent HFA (fluticasone) ...
DISCHARGE DISPOSITION	Home
DISCHARGE DIAGNOSIS	Splenic laceration
DISCHARGE CONDITION	Mental Status: Clear and coherent. Level of Consciousness: Alert and interactive ...
DISCHARGE INSTRUCTIONS	You were admitted to ... in the intensive care unit for monitoring after a ...
Output	Example
BRIEF HOSPITAL COURSE	Ms. ... was admitted to ... on After getting a colonoscopy and polypectomy, she ...

b) Relevant statistics for the pre-processed dataset split across multiple context length ranges for adaptation tasks.

Context Range	Samples	Input Tokens	BHC Tokens
0 - 1,024	2,000	711 ± 199	104 ± 43
1,024 - 2,048	2,000	1,471 ± 275	148 ± 36
2,048 - 4,096	2,000	2,496 ± 388	225 ± 55

Expertise

You are an expert medical professional

Instruction

Summarize the clinical note into a brief hospital course

In-Context Example

Use the examples to guide word choice
input: {example clinical note}
summary: {example bhc}

Clinical Note Input

SEX: F
SERVICE: MEDICINE
ALLERGIES: No Known Allergies / Adverse Drug Reactions
ATTENDING: _____
CHIEF COMPLAINT: BRBPR
MAJOR SURGICAL OR INVASIVE PROCEDURE: None

HISTORY OF PRESENT ILLNESS: female past medical history of internal hemorrhoids, pancreatitis and prior admission with BRBPR thought to be secondary to diverticulitis who presents with BRBPR x 1 day. The patient was in her usual state of health until the day of presentation. At that time she had 5 episodes of BRBPR. This was associated with a pain located in left upper quadrant, sharp/cramping, radiating to back made worse with food intake. She states that she has had this pain intermittently a number of years. She denies fever, chills, diarrhea, light-headedness, shortness of breath, chest pain or other symptoms. She had 1 episode of emesis on _____. Denies nausea currently. She presented to _____ EM for further evaluation and management. Upon presentation to _____ initial vitals were: T97.4, HR 65, BP 151/83, RR 18, SpO2 99% RA. Stool was guaiac positive. Given abdominal pain CT scan which showed colitis at splenic flexure. Concern for infectious vs ischemic colitis. Lactate okay. Surgery and GI were consulted. Surgery recommends NPO/IVF and cipro/flagyl until abdominal pain resolves. She was given 1L NS in EW. GI will staff in AM. The patient was admitted to medicine for further evaluation and management. Currently continues to have diffuse abdominal pain. Denies lightheadedness, chest pain, shortness of breath. ROS: Denies fever, chills, night sweats, headache, vision changes, rhinorrhea, congestion, sore throat, cough, shortness of breath, chest pain, abdominal pain, nausea, constipation, BRBPR, melena, dysuria, hematuria.

PAST MEDICAL HISTORY: 1. Hypertension 2. Ampullary stenosis 3. Status post cholecystectomy for gallstones 4. History of sphincterotomy 5. Osteoporosis 6. Gastroesophageal reflux disease 7. Hemorrhoids 8. Cerebral vascular accident in _____ (right pointing) 9. _____ disease 10. Chronic low back pain with sciatica 11. Urinary frequency and urge incontinence 12. Diverticulitis 13. Chronic pancreatitis 14. s/p R shoulder surgery _____. s/p removal of (non-cancerous) calcification in lungs

SOCIAL HISTORY: _____

FAMILY HISTORY: No family of MI, stroke, son prostate cancer. Daughter with _____.

PHYSICAL EXAM: On Discharge: GENERAL - elderly female looks well. HEENT - NC/AT, PERRLA, EOMI, sclerae anicteric, MMM, OP clear LUNGS - CTA bilat, no r/r/h, good air movement, resp unlabored HEART - RR, no rate, no MRG, nl S1-S2 ABDOMEN - soft/ND, no abdominal tenderness, no masses, no rebound/guarding EXTREMITIES - WWP, no c/c/e, 2+ peripheral pulses

PERTINENT RESULTS: On Admission: _____ 08:19PM BLOOD WBC-7.3 RBC-3.88* Hgb-12.8 Hct-37.2 MCV-96 MCH-32.0* MCHC-34.3 RDW-12.5 PI-_____ 08:19PM BLOOD Neut-72.7* Mon-4.8 Eos-0.6 Baso-0.4 08:19PM BLOOD _____ PTT-25.4 08:19PM BLOOD Glucose-133* UreaN-14 Creat-0.9 Na-139 K-3.6 Cl-106 CO2-23 AnGap-14 _____ 08:19PM BLOOD ALT-13 AST-16 LDH-186 AlkPhos-56 GGT-111-0.8 Hct rend-_____ 08:19PM BLOOD WBC-7.3 RBC-3.88* Hgb-12.8 Hct-37.2 MCV-96 MCH-32.0* MCHC-34.3 RDW-12.5 PI-_____ 07:40AM BLOOD WBC-6.8 RBC-3.78* Hgb-12.8 Hct-35.4 MCV-96 MCH-33.0* MCHC-35.1* RDW-12.7 PI-_____ 01:05PM BLOOD Hct-36.7 10:50PM BLOOD Hct-33.1* 06:55AM BLOOD WBC-5.8 RBC-3.38* Hgb-11.8* Hct-32.9* MCV-97 MCH-33.0* MCHC-34.0 RDW-12.7 PI-_____ 07:10AM BLOOD WBC-5.5 RBC-3.53* Hct-34.3 MCV-97 MCH-33.4* MCHC-34.4 RDW-12.6 PI-_____ 07:30AM BLOOD WBC-5.5 RBC-3.39* Hct-34.2 MCV-97 MCH-33.0* MCHC-34.6 RDW-12.9 PI-_____ 07:15AM BLOOD WBC-4.2 RBC-3.43* Hgb-11.2* Hct-32.7* MCV-96 MCH-32.7* MCHC-34.2 RDW-12.9 PI-_____ 09:46PM BLOOD Lactate-0.9 1:21AM BLOOD Lactate-1.4 08:03AM BLOOD Lactate-1.3 On Discharge: _____ 07:15AM BLOOD WBC-4.2 RBC-3.43* Hgb-11.2* Hct-32.7* MCV-96 MCH-32.7* MCHC-34.2 RDW-12.9 PI-_____ 07:15AM BLOOD Glucose-80 UreaN-9 Creat-0.8 Na-142 K-3.7 Cl-109* HCO3-25 AnGap-12 Microbiology: URINE CULTURE (Final): _____ MIXED BACTERIAL FLORA (= 3 COLONY TYPES), CONSISTENT WITH SKIN AND/OR GENITAL CONTAMINATION. BLOOD CULTURE: No growth. Imaging: CTA on admission: 1. Segmental colonic wall thickening at the level of the splenic flexure is most consistent with ischemic colitis. 2. Left ovarian mass, previously characterized by MRI as a fibroma or tumor. RUQ Ultrasound: Moderate extensive pneumobilia is unchanged compared to the recent CT of _____. The liver is normal without focal or textual abnormalities. No bile duct dilatation is present. The gallbladder is surgically absent. The portal vein is patent with normal hepatopetal flow. Visualized portions of the pancreas are unremarkable in appearance. The spleen is not enlarged measuring 7.1 cm. CXR: Small right pleural effusion could be residual of the larger pleural effusion present last year, but its chronicity is really indeterminate. There is no pneumothorax or indication of lung injury. Moderate cardiomegaly is chronic. No pulmonary vascular engorgement or edema. This study is not designed for detection of subtle trauma to the chest cage, but I see no displaced rib fracture.

MEDICATIONS ON ADMISSION: 1. atenolol 75 mg PO daily 2. carbidope-levalopoda 25 mg-100 mg PO TID 3. lidocaine 5 % (700 mg/patch) Adhesive Patch, daily 4. lipase-protease-amylase (Creon) 12,000 unit-38,000 uH-60,000 unit Capsule, Delayed Release(C) 2 (Two) Capsule(s) by mouth with meals 5. lisinopril 40 mg PO daily 6. mirtazapine 7.5 mg PO qHS 7. nifedipine ER 30 mg PO BID 8. omeprazole 40 mg PO daily 9. ranitidine 150 mg PO Bid prn 10. tolterodine 2 mg Capsule, Ext Release 24 hr Capsule(s) by mouth once a day 11. tramadol 50 mg Tablet Sig: One (1) Tablet PO BID (2 times a day) as needed for pain 12. polyethylene glycol 3350 17 gram/dose Powder Sig: One (1) Tablet PO DAILY(Daily) 13. aspirin 81 mg Tablet Sig: One (1) Tablet PO once a day 14. ciprofloxacin 500 mg Tablet Sig: One (1) Tablet PO Q12H (every 12 hours) for 1 days. Disp: *2 *2 tablet(s) Refills: *0

DISCHARGE MEDICATIONS: 1. atenolol 50 mg Tablet Sig: 1.5 Tablets PO once a day. 2. carbidope-levalopoda _____ mg Tablet Sig: One (1) Tablet PO TID (3 times a day). 3. lidocaine 5 % (700 mg/patch) Adhesive Patch, Me dicated Sig: One (1) Adhesive Patch, Medicated Topical Daily 4. lipase-protease-amylase (Creon) 12,000-38,000-60,000 unit Capsule, Delayed Release(C) Sig: One (1) Cap PO TID W/M/MEALS (3 TIMES A DAY WITH MEALS) 5. lisinopril 20 mg Tablet Sig: Two (2) Tablet PO DAILY(Daily) 6. mirtazapine 15 mg Tablet Sig: 0.5 Tablet PO HS (at bedtime). 7. nifedipine 30 mg Tablet Extended Release Sig: One (1) Tablet Extended Release PO twice a day. 8. omeprazole 20 mg Capsule, Delayed Release(C) Sig: Two (2) Capsule, Delayed Release(C) PO DAILY(Daily) 9. ranitidine 150 mg Tablet Sig: One (1) Tablet PO twice a day as needed for heartburn 10. tolterodine 2 mg Capsule, Ext Release 24 hr Capsule Sig: One (1) Capsule, Ext Release 24 hr PO once a day 11. tramadol 50 mg Tablet Sig: One (1) Tablet PO BID (2 times a day) as needed for pain 12. polyethylene glycol 3350 17 gram/dose Powder Sig: One (1) Tablet PO Q8H (every 8 hours) for 1 days Disp: *3 *3 tablet(s) Refills: *0

DISCHARGE DISPOSITION: Home With Service Facility: _____

DISCHARGE DIAGNOSIS: Ischemic colitis Abdominal pain

DISCHARGE CONDITION: Mental Status: Clear and coherent. Level of Consciousness: Alert and interactive. Activity Status: Ambulatory - requires assistance or aid (walker or cane).

FOLLOWUP INSTRUCTIONS: _____

DISCHARGE INSTRUCTIONS: You were admitted for lower GI bleeding due to ischemic colitis. Ischemic colitis is when the bowel gets inflamed because there is decreased blood supply. You improved with fluids and bowel rest. With this condition you are at increased risk of developing a bowel infection so you were also treated with antibiotics. Your blood count was stable and you required no transfusions. Prior to discharge you did not re-develop ischemic colitis - you did not have any bleeding. In the morning your pain resolved - we don't exactly know the cause but it could have been musculoskeletal or gas. You have not had a bowel movement in a couple days. It is important to take your miralax daily. If you do not have a bowel movement we recommend a bisacodyl suppository. Please attend all your appointments scheduled below. Medication changes: NEW Antibiotics Ciprofloxacin and Flagyl - take for 1 more day for 5 days total ** We held you Aspirin when you were bleeding. Please re-start this medication but if you develop GI bleeding stop the Aspirin and call your doctor **

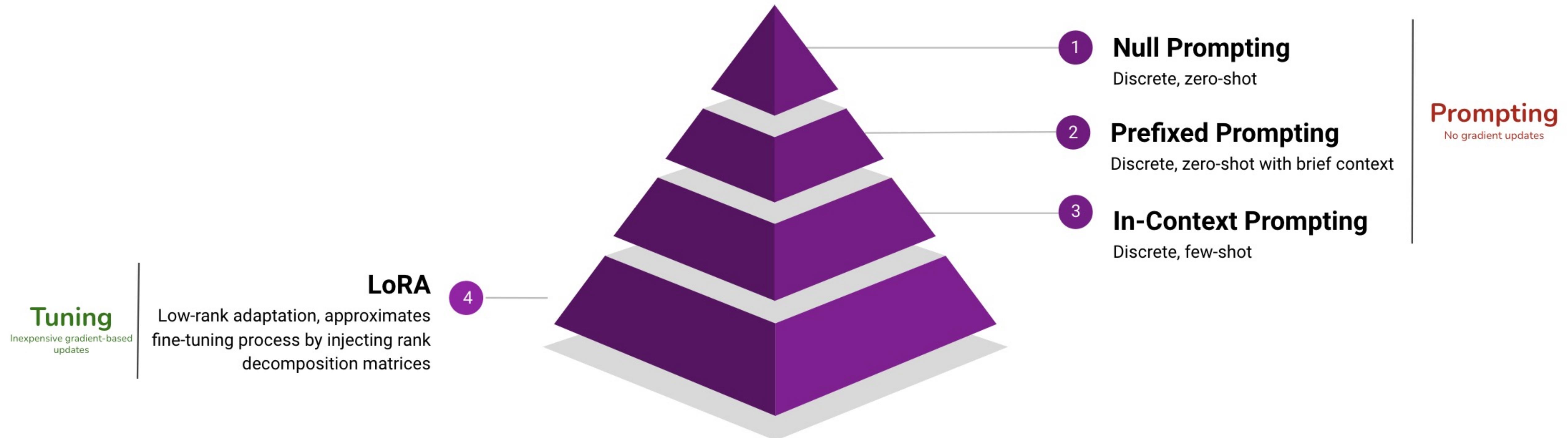
BHC Reference Clinician

BHC Output GPT-4

Reader Feedback

Summary 2 is more readable and comprehensive. The only things I would add to summary 2 would be more specifics of her BRBPR day 1, and LUQ abdominal pain. Both summaries are missing hx of cholecystectomy and pancreatitis which are relevant in the case of abdominal pain.

Adaptation Methods



Evaluation Metrics

Human Evaluation

1. Radiologists
 - a. Lost information
 - b. Misinterpreted information
 - c. Overall Score
2. Domain Experts
 - a. Faithfulness
 - b. Simplification
 - c. Aggregation
 - d. Coherence
 - e. Relevance
 - f. Factual Mistakes



Reference-Based¹

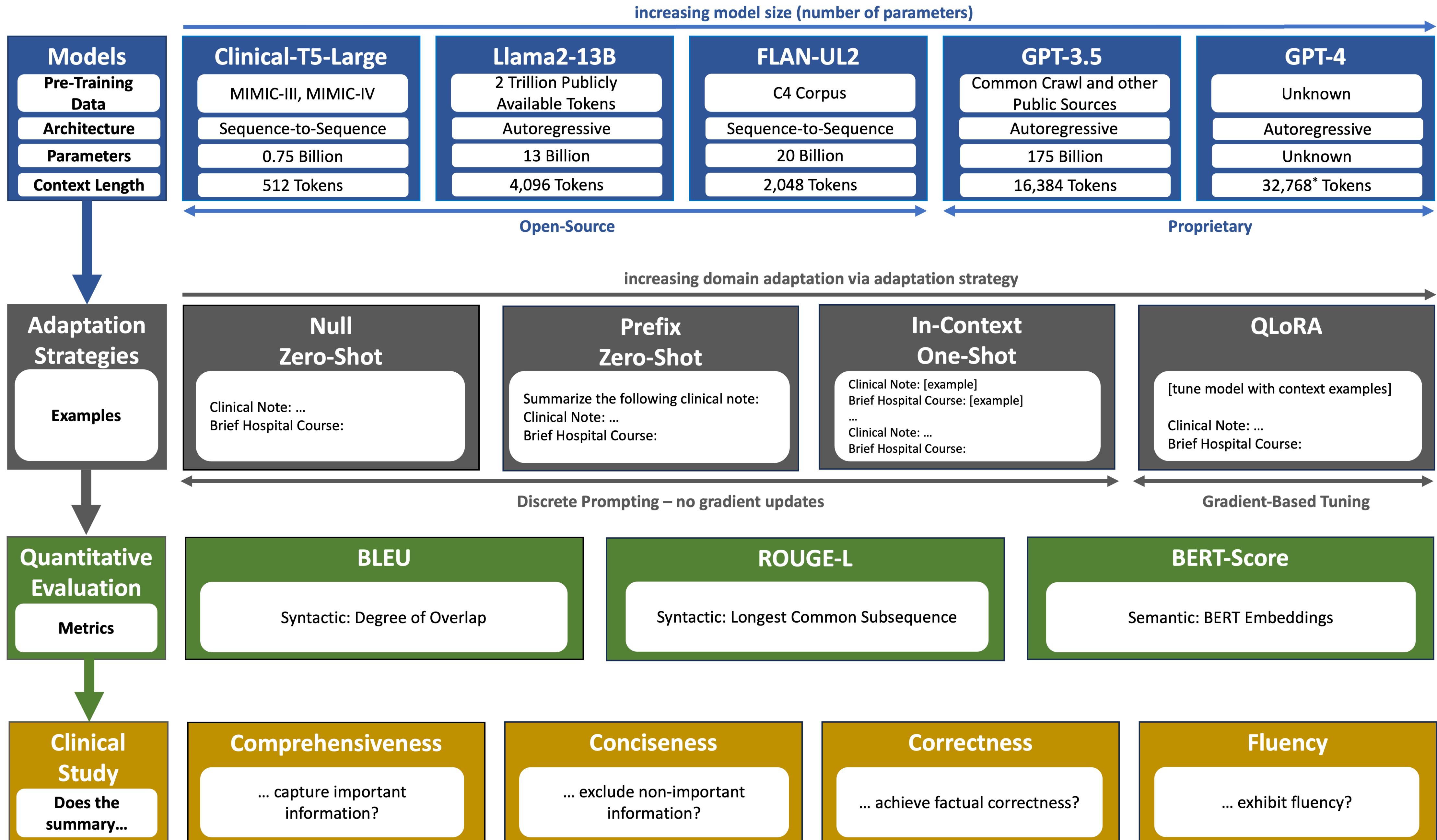
1. Overlap-Based:
 - a. ROUGE-L
 - b. BLEU
2. Similarity-Based
 - a. Jaccard Similarity
 - b. TF-IDF Similarity
 - c. Sentence-BERT Similarity
 - d. BERTScore
 - e. Neural CRF Alignment
3. QA-Based:
 - a. Exact Match (EM)
 - b. F1-RadGraph

Reference-Free²:

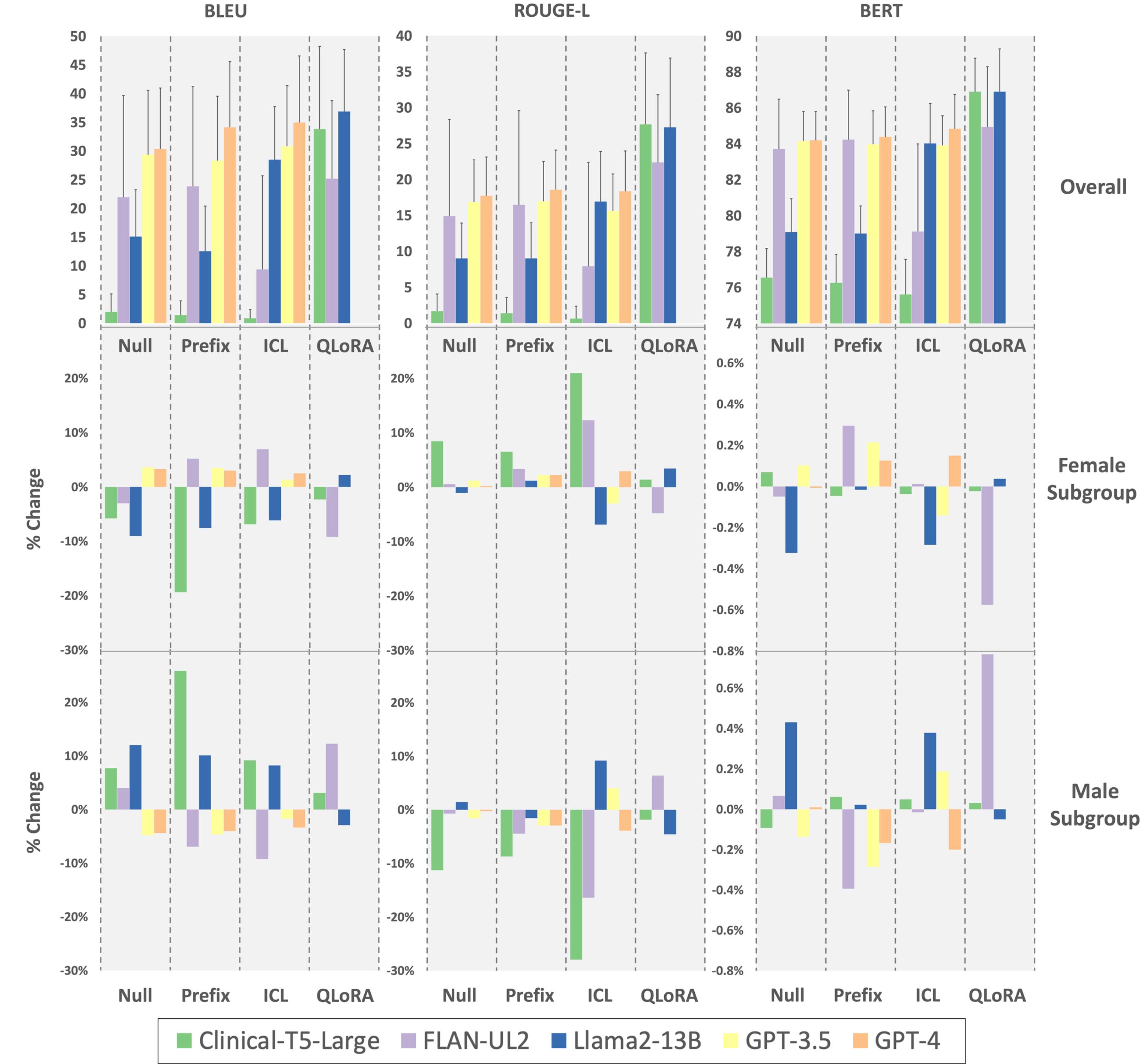
1. Quality Metrics:
 - a. SUPERT
 - b. BLANC
2. Factuality Metrics:
 - a. QuestVal
 - b. QAFactEval
 - c. FactCC
 - d. DAE
 - e. SummaC

¹ Comparison of LLM generated summary with reference summary

² Comparison of LLM generated summary with source material



Model Performance Analysis

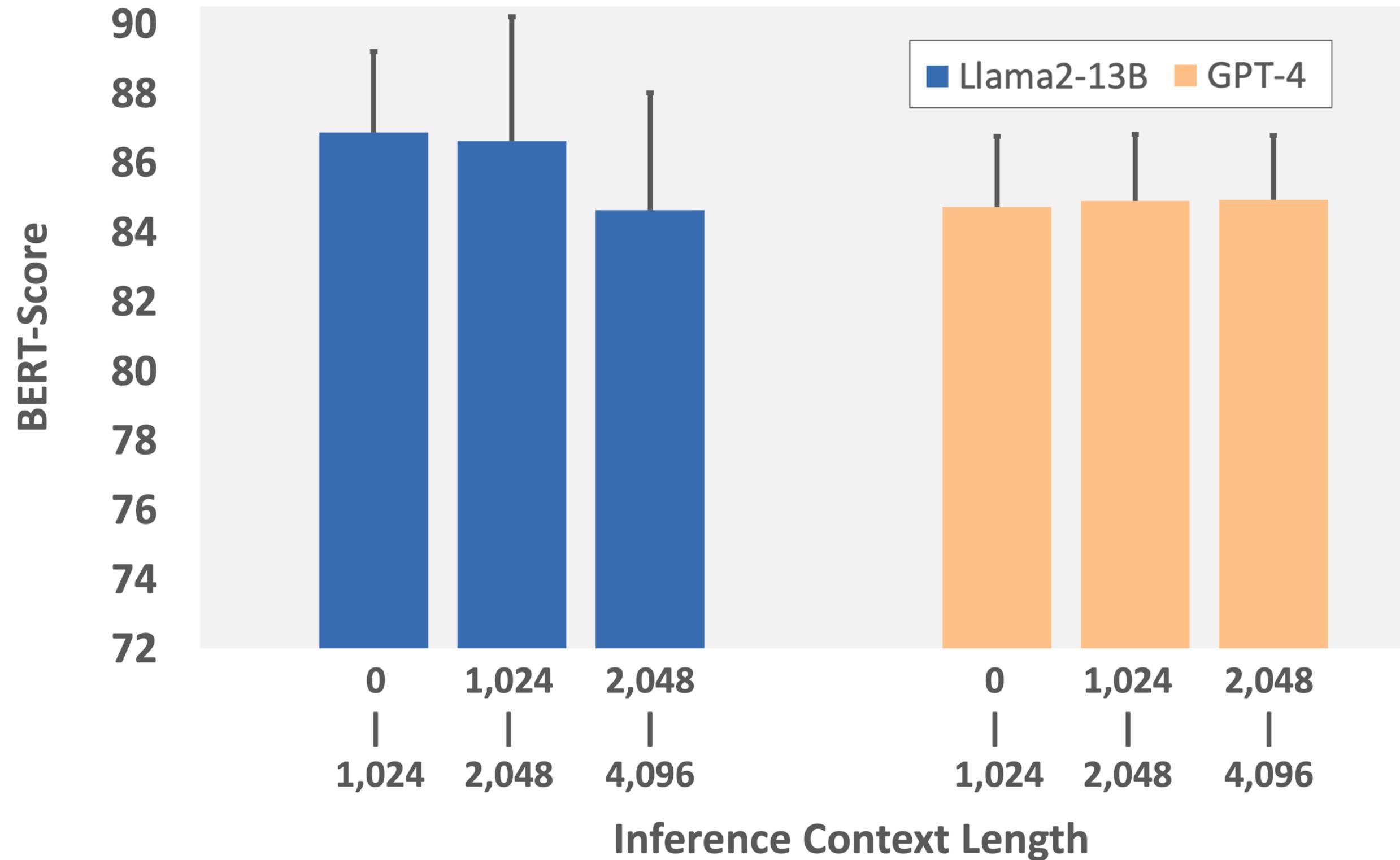


Overall

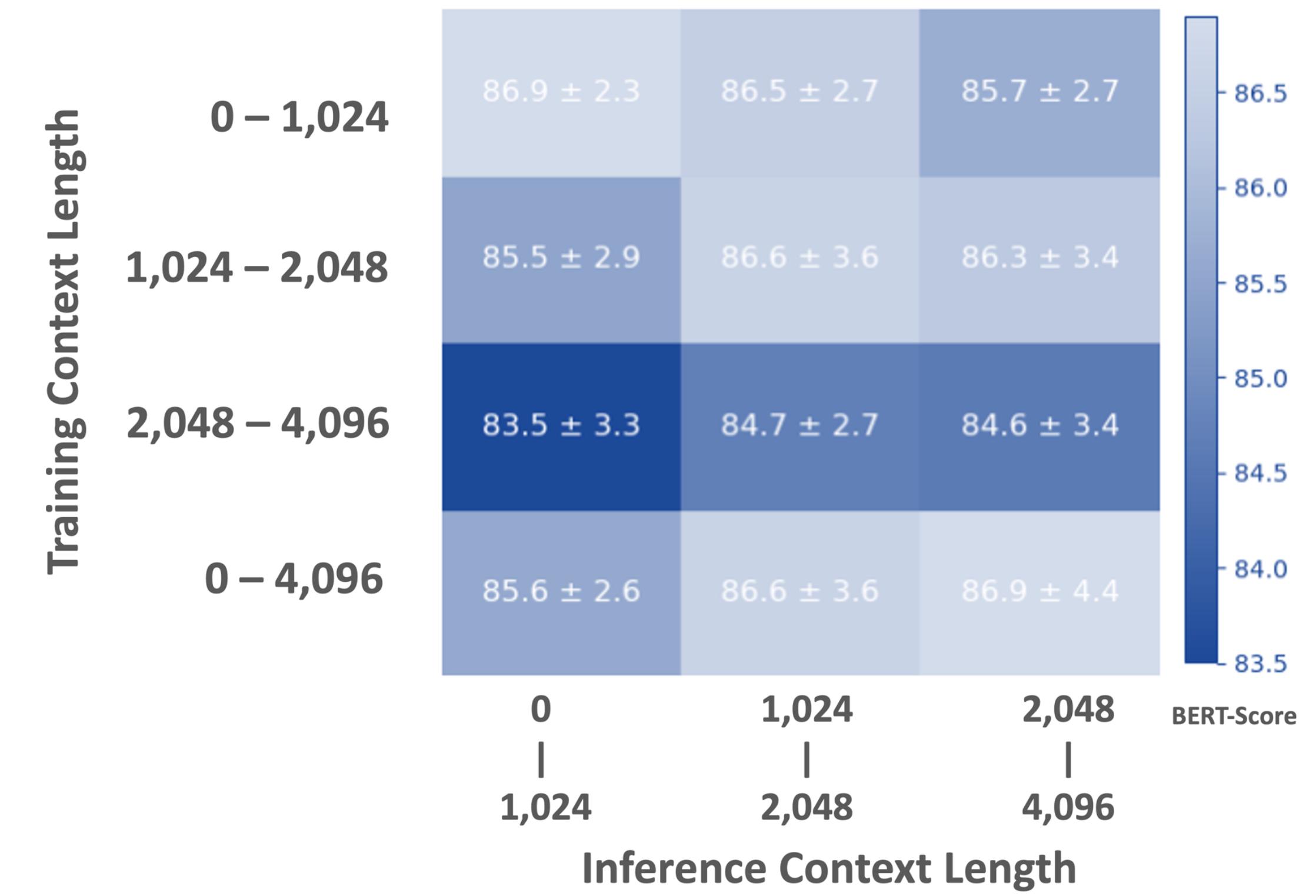
Female
Subgroup

Male
Subgroup

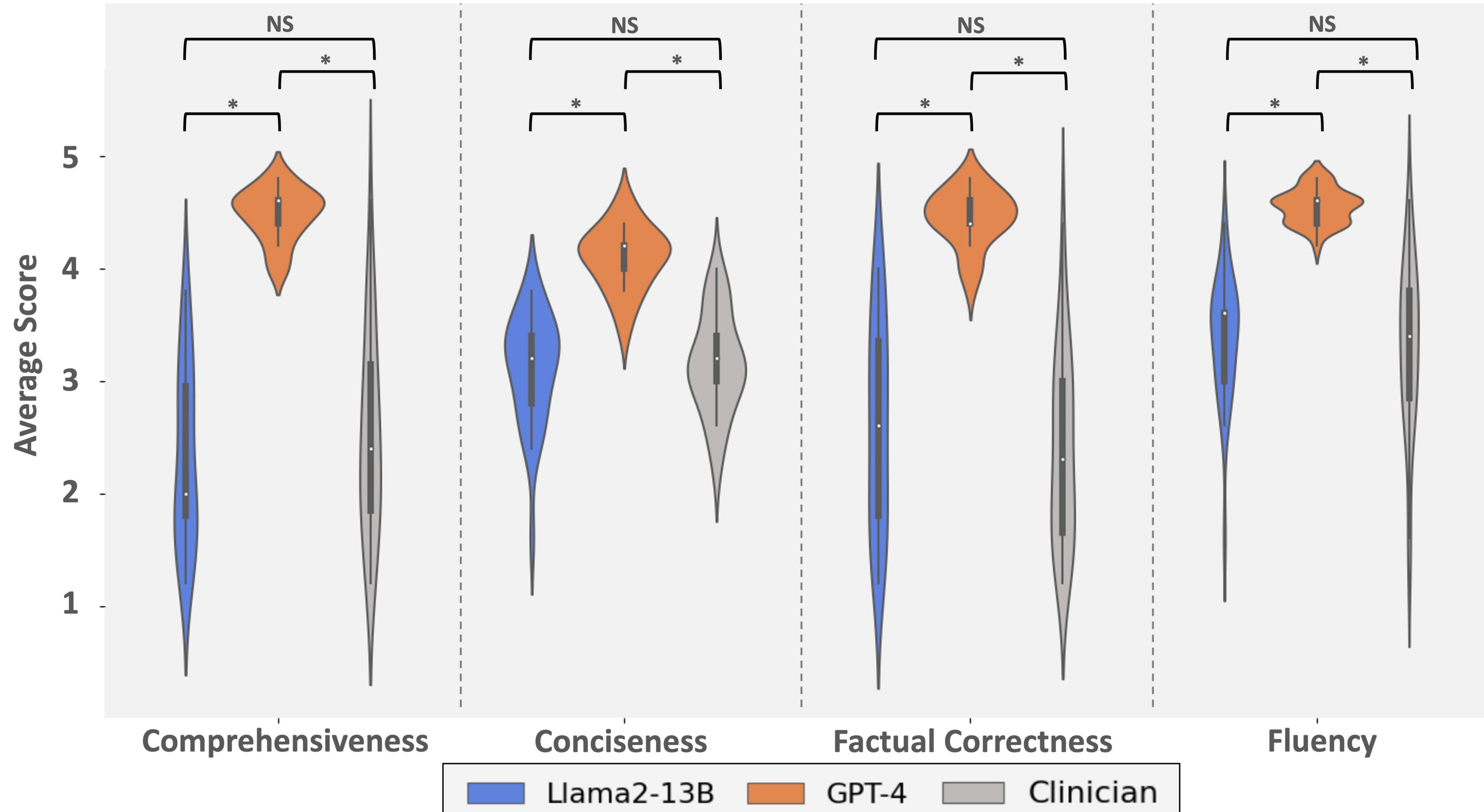
a) In-Distribution Context Length Analysis



b) Out-of-Distribution Context Length Analysis



Reader Study Outcomes





The University of Texas at Austin
Cockrell School of Engineering

Innovation starts **here**