Do Language Models Understand Measurements?

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Abstract
Recent success of pre-trained language models (PLMs) has stimulated interest in their ability to understand and work with numbers. Yet, the numerical reasoning over measurements has not been formally studied despite their importance. In this study, we show that PLMs lack the capability required for reasoning over measurements. Furthermore, we find that a language model trained on a measurement-rich corpus shows better performance on understanding measurements. We propose a simple embedding strategy to better distinguish between numbers and units, which leads to a significant improvement in the probing tasks.

1 Introduction
The success of pre-trained language models (PLMs) has led to more research on their ability to understand commonsense. In this context, numerical reasoning over text (NRoT) is a NLP model's ability to interpret and work with numbers in either digit or word form (Spithourakis and Riedel, 2018). Recent studies on NRoT test PLMs to answer questions on numeracy (Wallace et al., 2019), scalar magnitude comparison (Zhang et al., 2020), numerical facts (Lin et al., 2020), and math word problems (Wu et al., 2021).

Despite these efforts, existing works lack an analysis of the forms in which numbers appear. In particular, we focus on the case where numbers appear as a measurement in the context. In most scientific articles, measurements are an integral part of the context for capturing its appropriate meaning. For example, the two sentences "40g of Aspirin is lethal" and "40mg of Aspirin is lethal" contain the same words except for the unit of measurement (UoM), but the second sentence is incorrect because of the UoM.

In this work, we examine the measuring skill of PLMs: the ability to understand the system of measurement and perform numerical reasoning over measurements. We design three measuring skill tests (MSTs) and study how many measuring skills can be acquired. Specifically, UNIT CONVERSION, REFERENCE RANGE DETECTION, and MEASUREMENT COMPARISON require understanding of the system of measurement, the normal range of the biomedical entity, and the ability to combine knowledge about the system of measurement and NRoT, respectively. Table 1 shows an example of each of the measuring skill tests.

MST results showed that the models struggled to find the largest (or smallest) value on the list of measurements and convert the measurement to another unit, while they performed well on other tests. Compared to other PLMs, BioBERT (Lee et al., 2020) showed superior performance on UNIT CONVERSION and REFERENCE RANGE DETECTION, which implies that pre-training with measurement-rich text helps the model understand the system of measurement. Finally, we speculate that the lack of skills to distinguish numbers, units, and other words in the context makes the models fail in some MSTs. To mitigate this, we introduce scale embedding, which provides the model with the information regarding the position and scale of the numbers in the input text. We show that scale embedding significantly improves the MST performance of all PLMs.

2 Measuring Skill Test
In this section, we describe three MSTs to carefully study the ability of PLMs to understand the system of measurement and perform numerical reasoning over the measurements.

2.1 Unit Conversion
This task requires the model to decide whether the two measurements represent the same quantity. For example, the model might correctly predict [MASK] in a sentence, such as "3.5g and 3500mg are [MASK] value" to be filled with same if it under-
stands the conversion of units correctly. In general, it is a convention to combine the unit (e.g., liter, meter) and its prefix (e.g., kilo, milli) to represent the numerical value of the measurement within a range \([10^{-3}, 10^3]\). Therefore, various unit prefixes can appear in a single passage, even if the units are the same. To handle this, UNIT CONVERSION is essential for complex reasoning over measurements. To succeed in UNIT CONVERSION, we expect the model to handle the unit and numerical value jointly, based on an understanding of the system of measurement.

### 2.2 Reference Range Detection

Given a biomedical entity and measurement, this task requires a model to predict whether the measurement falls within the reference range. Knowledge of the biomedical entity plays a crucial role in understanding measurements, since the unit is determined by the biomedical entity. For example, we measure the hemoglobin level in g/dL. In addition to understanding UoMs, PLMs must rely on domain knowledge embedded in their parameters to solve this task, as context alone does not provide sufficient clues as to what the reference range is for the given biomedical entity.

### 2.3 Measurement Comparison

Given two measurements (or a series of \(n\) measurements), the task is to predict the correct relationship between them. We created the synthetic dataset following other well-known NRoT tasks. Here, we consider three numerical reasoning tasks: COMPARISON (Talmor et al., 2020), ARGMIN/MAX (Wallace et al., 2019), and SORTING (Pal and Baral, 2021), all requiring the model to compare numbers. Note that each measurement in this task can have a different unit prefix. For example, the sample “1.59mg is [MASK] than 3.8g” containing two different units ”mg” and ”g” appears in the COMPARISON dataset. This task assesses the model’s ability to combine an understanding of measurements and numerical reasoning skills.

### 3 Experiments

#### Probing Setup

We formulated MSTs as a Cloze test (Talmor et al., 2020) to fully utilize the knowledge captured by masked language modeling (MLM). Specifically, a PLM received the masked inputs given in Table 1, and the MLM head output the probability distribution of the answer candidates for [MASK]. Among the answer candidates, we chose the one with the highest probability as the final prediction.

We probed four transformer-based PLMs, BERT (Devlin et al., 2019) and ALBERT (Lan et al., 2020) were trained on Wikipedia articles and Book Corpus. BioBERT (Lee et al., 2020) was trained on biomedical articles from PubMed abstracts, and BlueBERT (Peng et al., 2020) used both clinical (MIMIC-III (Johnson et al., 2016)) and biomedical (PubMed abstracts) corpus for pre-training. We also tested a randomly initialized transformer encoder (i.e. Scratch) to evaluate the difficulty of our MSTs. For each model, we did not update the parameters during training, except for the MLM head in the last transformer layer. In all tasks, the models were trained with three random seeds and we report the mean classification accuracy for all the probing tasks. Appendix A provides further details on training and evaluation.

#### Data Preparation

We manually crafted templates in Table 2 that contained at most two slots for measurements and [MASK] token for an answer. We instantiated \([M]\) and \([LoM]\) by sampling the measurement and the list of measurements, respectively. For measurement sampling, we independently sampled a number and a unit and then combined them. Specifically, we sampled units from the predefined

| Task | Example | Answer Candidates |
|------|---------|-------------------|
| COMPARISON | 1.59mg is [MASK] than 3.8g | larger, smaller |
| ARGMIN/MAX | | largest, smallest, middle |
| SORTING | | increasing, decreasing, random |
| UNIT CONVERSION | | same, different |
| REFERENCE RANGE DETECTION | 85mg/dL of Glucose is [MASK] | normal, abnormal |

Table 1: Examples of measuring skill tests (MSTs). We underline the correct answer for each example.

| Task | Template |
|------|----------|
| COMPARISON | \([M]\) of [MASK] is [M]; [M] is \([LoM]\) than \([M]\) |
| ARGMIN/MAX | \([M]\) is [MASK] value among \([LoM]\) is \([M]\) |
| SORTING | sort \([LoM]\) in [MASK] order is \([LoM]\) |
| UNIT CONVERSION | \([M]\) and \([M]\) are [MASK] value |
| REFERENCE RANGE DETECTION | \([M]\) of \([ENT]\) is [MASK] |

Table 2: Templates which we used for data generation. \([M]\), \([LoM]\), and \([ENT]\) are the placeholder for the measurement, the list of measurements, and the biomedical entity, respectively.
PLMs performed reasonably well on COMPARISON, SORTING, and REFERENCE RANGE DETECTION, but struggled considerably on ARGMIN/MAX and UNIT CONVERSION tasks. This shows that some measuring skills are difficult to learn from an LM objective. Similar to previous NRoT studies (Wallace et al., 2019; Pal and Baral, 2021), PLMs often failed to successfully extrapolate to values outside the training range. Further, in most cases, MST results got worse when we represented numbers in scientific notation.

We observed that BioBERT outperformed other PLMs in UNIT CONVERSION, REFERENCE RANGE DETECTION, and COMPARISON, and showed comparable performance in the rest of the MSTs. Compared to BioBERT, BlueBERT was pre-trained on a larger volume of biomedical text, but showed worse performance. This shows that pre-training on measurement-rich corpora assists the model in acquiring measuring skills, but further training on the noisy clinical text could harm it when performing reasoning over measurements. We also found that ALBERT outperformed its competitors in SORTING even though it performed the same or worse on other tasks. This may be because ALBERT benefits from its sentence order prediction (SOP) objective, which predicts the ordering of two consecutive segments of text.

Effect of using Different Prompts One can expect that the choice of prompt has an impact on the results, and recent studies (Jiang et al., 2020; Petroni et al., 2019) support this. To see whether the results

| Model  | Notation | Comp | Arg | Sort |
|--------|----------|------|-----|------|
|        |          | in   | ex  | in   | ex  | in   | ex  |
| ALBERT | Sci      | 81.2 | 77.3| **60.4** | **58.0** | 78.2 | **76.5** | 48.6 | 49.9 | 71.9 | 59.9 |
|        | Deci     | 81.8 | 72.1| 57.1 | 50.5 | **82.5** | 74.3 | 61.5 | 56.2 | 71.1 | 61.0 |
| BERT   | Sci      | 73.3 | 72.4| 55.1 | 52.2 | 45.6 | 45.0 | 52.7 | 51.2 | 73.5 | 64.3 |
|        | Deci     | 81.4 | 77.0| **60.9** | 54.3 | 54.9 | 54.5 | 61.9 | 59.2 | 77.2 | 67.5 |
| BioBERT| Sci      | 82.7 | 82.3| 55.0 | 54.4 | 68.2 | 69.1 | 58.7 | 57.3 | 81.3 | 63.7 |
|        | Deci     | **90.1** | **88.0** | 59.0 | **57.6** | 73.3 | **73.0** | **70.5** | **87.0** | 64.2 |
| BlueBERT| Sci     | 77.3 | 76.3| 46.9 | 46.9 | 63.6 | 64.3 | 53.0 | 51.3 | 73.6 | 65.4 |
|        | Deci     | 74.6 | 73.2| 57.0 | 55.5 | 73.0 | 68.0 | 59.2 | 57.1 | 77.1 | **69.0** |
| Scratch| Sci      | 50.9 | 50.8| 40.2 | 37.1 | 33.3 | 33.8 | 52.5 | 50.7 | 66.3 | 60.8 |
|        | Deci     | 57.7 | 51.3| 44.3 | 43.0 | 33.3 | 33.7 | 56.8 | 53.9 | 62.6 | 65.0 |

Table 3: Test-set results on MSTs. We report the classification accuracy on interpolation (in) and extrapolation (ex) test dataset. COMP, ARG, SORT, UNIT, and REF are abbreviations of COMPARISON, ARGMIN/MAX, SORTING, UNIT CONVERSION, and REFERENCE RANGE DETECTION, respectively. Sci and Deci stand for scientific and decimal notations, respectively.
The results with the decimal notation are shown in Table 5. The rule-based conversion increased MEASUREMENT COMPARISON performance because the converted MEASUREMENT COMPARISON does not require an understanding of unit conversion to solve the problem. However, it can be seen that almost all models became worse on REFERENCE RANGE DETECTION. This shows that the knowledge about the reference range is highly correlated with the specific UoM. Thus, the rule-based conversion is a suboptimal choice if we want to utilize the domain knowledge embedded in PLMs.

| Task | Model | COMP | ARG | SORT |
|------|-------|------|-----|------|
| Prompt Set | Model | ∆C | ∆R | ∆ORT | ∆EF | ∆C | ∆R | ∆ORT | ∆EF | Ref |
| **LABEL** | ALBERT | 73.1 (3.3) | 70.8 (6.2) | 54.0 (6.9) | 50.7 (13.6) | 73.6 (11.7) | 73.8 (11.9) | 62.7 (11.4) | 57.8 (13.9) | 55.0 (2.6) | 50.6 (3.2) | 51.1 (20.3) | 58.0 (25.0) |
| | BERT | 82.8 (7.3) | 80.2 (7.8) | 56.7 (2.3) | 55.7 (13.9) | 66.4 (10.9) | 62.6 (10.4) | 61.9 (11.1) | 60.4 (10.1) | 69.1 (17.9) | 59.6 (14.6) |
| | BioBERT | 75.0 (14.4) | 69.7 (3.5) | 56.9 (0.11) | 55.3 (0.2) | 70.1 (2.9) | 66.6 (1.4) | 59.4 (2.8) | 54.9 (2.2) | 76.4 (1.7) | 70.6 (1.6) |
| | BlueBERT | 67.5 (14.0) | 68.1 (0.13) | 49.1 (8.0) | 43.5 (7.0) | 72.3 (10.2) | 68.2 (6.1) | 50.4 (1.1) | 50.5 (5.7) | 65.8 (5.3) | 56.9 (4.1) |
| | CONTEXT | 70.2 (11.2) | 67.9 (9.1) | 52.4 (8.5) | 47.1 (7.2) | 51.8 (3.1) | 50.6 (3.9) | 56.1 (3.8) | 55.2 (4.0) | 66.4 (10.8) | 65.2 (4.3) |
| | BioBERT | 80.7 (9.4) | 78.4 (9.6) | 58.3 (9.9) | 55.9 (17.7) | 73.6 (3.7) | 69.7 (3.3) | 60.4 (2.6) | 59.3 (11.2) | 75.2 (11.8) | 64.8 (8.6) |
| | BlueBERT | 71.5 (3.1) | 65.6 (7.6) | 51.9 (5.1) | 48.5 (7.0) | 60.6 (12.4) | 56.4 (11.6) | 50.7 (8.5) | 50.7 (4.1) | 67.4 (9.7) | 64.9 (6.1) |
| | uOa | 87.9 (6.1) | 80.2 (8.1) | 71.0 (13.9) | 58.8 (8.3) | 905.0 (8.0) | 85.5 (11.2) | 642.2 (7.9) | 56.9 (7.0) | N/A N/A |
| | BERT | 90.0 (6.6) | 87.2 (10.2) | 69.4 (8.5) | 68.2 (13.9) | 67.1 (12.2) | 63.0 (15.5) | 67.2 (13.3) | 64.8 (13.6) | N/A N/A |
| | BioBERT | 96.5 (6.4) | 94.8 (6.8) | 72.1 (13.1) | 69.3 (11.7) | 84.0 (6.7) | 79.6 (6.6) | 82.5 (9.5) | 77.9 (7.4) | N/A N/A |
| | BlueBERT | 88.3 (13.7) | 83.8 (10.6) | 66.5 (9.5) | 63.8 (8.3) | 76.5 (3.5) | 71.7 (17.6) | 66.6 (24.3) | 62.4 (15.3) | N/A N/A |

Table 5: Test-set results on rule-based conversion experiments. We report the classification accuracy and the performance difference (Δ).
Figure 1: Our scale embedding.

Table 6: Effect of scale embedding on MSTs. We report the classification accuracy and performance improvement (Δ) after applying scale embedding.

| Scale Embedding and its Effect | In Section 4, we observed that none of the PLMs showed a perfect understanding of each MST. We suspect that such a gap originates in the deficiency of PLM’s ability to extract numerical values from measurements and compare their magnitudes. To this end, we propose scale embedding, an additional embedding that provides the model with the information of the position and scale of numbers in the input text. As described in Figure 1, we incrementally assigned the index to each token from the end to the beginning of a sentence. If we encounter a token that is not included in the numerical value, then we reset the index to zero and keep assigning the index zero to tokens until another numerical value appears. We distinguished between numerical and nonnumerical subwords using the regular expression. Note that we trained only the scale embedding and MLM head while freezing other pre-trained weights of the language model. This allows us to adapt the model to any numerical reasoning tasks simply by plugging a different scale embedding into them. Table 6 shows the MST results after the scale embedding is applied to all models, where we can see significantly improved test results, even for COMPARISON/UNIT CONVERSION. Note that the scale embedding is minimally effective for Scratch, except for COMPARISON. This shows that solving our MSTs requires more than just simple embeddings, and a PLM that understands context is an essential element. |

5 Related Works

Over the years, numerical reasoning has been an active research area. Some works investigate the numeracy of static word embeddings (Naik et al., 2019), contextualized language embeddings (Wallace et al., 2019), and multilingual words (Johnson et al., 2020). Wallace et al. (2019) shows that ELMo, BERT, and GloVe embeddings are capable of capturing numeracy, but only within the range of numbers seen during training. GenBERT (Geva et al., 2020), NumGPT (Jin et al., 2021), and NT5 (Yang et al., 2021) focus on incorporating arithmetic skills into pre-trained models. Another task that deals with numerical quantities is measurement estimation. VerbPhysics (Forbes and Choi, 2017) proposes the dataset to compare the relative scales between the physical attributes of various objects. DoQ (Elazar et al., 2019) provides an empirical distribution over possible values of quantitative attributes. Zhang et al. (2020) tests that NLP models contain information about the scalar magnitudes of physical objects. Although previous studies probed numerical reasoning over numeral and physical attributes, no attempt has been made to investigate reasoning over measurements.

6 Conclusion

To the best of our knowledge, our study is the first to investigate reasoning over measurements. Our analysis shows that PLMs lack the capability required for reasoning over measurements. We propose a scale embedding approach that provides information on the position and scale of numbers, and it significantly increases the MST performance.
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Limitations

Our scale embedding can make mistakes when the unit itself contains numbers (e.g. mg/100ml). Therefore, scale embedding should not be applied to UoM containing numbers through exception handling.

Our work will be largely affected by the created prompts. If the prompt is not obvious for PLMs to understand, although they have such reasoning ability, they may not give the correct answer. To mitigate this problem, we conducted experiments with different sets of prompts in Section 4 and showed that the results maintain their tendency across the prompts. Despite these efforts, it is still unclear what the optimal choice of the prompt is. We remain this problem as a future work.

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A Further Details of Measuring Skill Test

A.1 Data Statistics

Table 8 shows the statistics of MSTs we used for experiments.

A.2 Training and Evaluation

The BERT configuration of all models is the same as the base model (L=12, H=768, A=12, Total Parameters=110M) in (Devlin et al., 2019). Maximum sequence length is 512.

We trained the model with batch size 256 for 30 epochs. We used the Adam optimizer for training. The learning rate started from 5e-5 and linearly decayed towards 1e-8. We early stopped the training when the validation accuracy did not increase for 2 epochs. We found the optimal hyperparameters using the grid search, where we evaluated the learning rate [1e-5, 2e-5, 5e-5, 1e-4], batch size [16,32,64,128].

B More Details of Prompt Sets

The results with both decimal and scientific notation are shown in Table 9.

B.1 LABEL

Inspired by Yuan et al. (2021), we included synonyms as an answer to make the prompt diverse. We used the website https://www.wordhippo.com/ to search for synonyms. Among the search results, we chose two words that match the context. We report the list of synonyms in Table 10.

B.2 CONTEXT

If the context differs from what PLM saw during pre-training, then PLMs will struggle to solve MSTs even if they understand the measuring skills. To mitigate this, we prepared four additional prompts with the same meaning. Additional prompts are listed in Table 11.

B.3 UoM

In the general domain, some UoMs listed in Table 7 rarely appear in the context. For example, international units per liter (IU/l) is frequently used in pharmacology, but not in other scientific articles. Therefore, we can wonder if some rare biomedical units disrupt the understanding of general domain PLMs (e.g., BERT and ALBERT). To answer this question, we replaced all UoMs in the dataset with the commonly used UoMs: g, l, m, and s.

C Additional Results on Rule-based Conversion

Table 12 describes the complete set of MST results after applying rule-based conversion.

D Additional Results on Scale Embedding

Table 13 describes the MST results of scale embedding with decimal and scientific notation.

E Experimental Environment

We trained the models with Google TPU v2-8 and v3-8. We used PyTorch 1.10.0 (Paszke et al., 2019) and Huggingface Transformers (Wolf et al., 2020) 4.3.3 for experiments.
| Task                          | Split | Number Range | # Samples | Label Distribution |
|-------------------------------|-------|--------------|-----------|--------------------|
| **COMPARISON**                |       |              |           |                    |
| train                         |       | interpolation | 299,394   | smaller: 0.5, larger: 0.5 |
| valid                         |       | interpolation | 29,986    | smaller: 0.498, larger: 0.502 |
| test                          |       | interpolation | 29,988    | smaller: 0.501, larger: 0.499 |
| **ARGMIN/MAX**                |       |              |           |                    |
| train                         |       | interpolation | 300,000   | smallest: 0.333, middle: 0.334, largest: 0.333 |
| valid                         |       | interpolation | 30,000    | smallest: 0.333, middle: 0.334, largest: 0.333 |
| test                          |       | interpolation | 30,000    | smallest: 0.333, middle: 0.334, largest: 0.333 |
| **SORTING**                   |       |              |           |                    |
| train                         |       | interpolation | 300,000   | decreasing: 0.333, random: 0.332, increasing: 0.335 |
| valid                         |       | interpolation | 30,000    | decreasing: 0.333, random: 0.332, increasing: 0.335 |
| test                          |       | interpolation | 30,000    | decreasing: 0.333, random: 0.332, increasing: 0.335 |
| **UNIT CONVERSION**           |       |              |           |                    |
| train                         |       | interpolation | 259,588   | same: 0.489, different: 0.511 |
| valid                         |       | interpolation | 23,931    | same: 0.489, different: 0.511 |
| test                          |       | interpolation | 23,538    | same: 0.483, different: 0.517 |

Table: Statistics of MSTs used for experiments.

Table 8: Statistics of MSTs used for experiments.

| Task                          | Split | Number Range | # Samples | Label Distribution |
|-------------------------------|-------|--------------|-----------|--------------------|
| **REFERENCE RANGE DETECTION** |       |              |           |                    |
| train                         |       | interpolation | 201,061   | normal: 0.575, abnormal: 0.425 |
| valid                         |       | interpolation | 17,111    | normal: 0.393, abnormal: 0.407 |
| test                          |       | interpolation | 21,212    | normal: 0.618, abnormal: 0.382 |
| **Table 9: Test-set results on different sets of prompts. We report the classification accuracy and the performance difference (Δ). We obtain Δ by subtracting the results in Table 3 from this table.**

| Prompt Set | Model | Test Measure | COMPARISON | UNIT Conversion | Reference |
|------------|-------|--------------|------------|-----------------|-----------|
|            |       |              |            |                 |           |
| **EALBE**  |       |              |            |                 |           |
| ScE        | Albert| 77.1 (+1.4) | 73.8 (+3.5)| 40.5 (+19.4)  | 32.4 (+21.8)|           |
| Deco       | 78.3 (+1.3)| 70.8 (+1.3)| 40.9 (+16.2)| 33.1 (+17.4)| 73.8 (+9.9)|           |
|            |       |              |            |                 |           |
| **BERT**   |       |              |            |                 |           |
| ScE        | 68.9 (+4.4)| 68.7 (+3.7)| 42.9 (+12.2)| 42.8 (+9.3)| 47.1 (+1.7)|           |
| Deco       | 73.1 (+8.3)| 70.6 (+8.2)| 54.0 (+6.9)| 50.7 (+3.6)| 54.0 (+4.9)|           |
|            |       |              |            |                 |           |
| **BioBERT**|       |              |            |                 |           |
| ScE        | 74.0 (+3.7)| 73.3 (+3.9)| 50.6 (+4.1)| 50.8 (+3.6)| 84.6 (+6.4)|           |
| Deco       | 82.6 (+7.3)| 80.2 (+7.8)| 56.7 (+2.3)| 55.7 (+1.9)| 66.4 (+10.9)|           |
|            |       |              |            |                 |           |
| **BlueBERT**|       |              |            |                 |           |
| ScE        | 77.0 (+6.3)| 76.3 (+6.0)| 44.7 (+1.2)| 44.3 (+2.6)| 46.6 (+1.6)|           |
| Deco       | 75.0 (+6.4)| 69.7 (+5.5)| 56.9 (+0.1)| 55.3 (+0.2)| 70.1 (+2.9)|           |

Table 9: Test-set results on different sets of prompts. We report the classification accuracy and the performance difference (Δ). We obtain Δ by subtracting the results in Table 3 from this table.
| Task                  | Answer Candidates | Synonyms               |
|----------------------|-------------------|------------------------|
| COMPARISON           | larger smaller    | higher, bigger lower, less |
| ARGMIN/MAX           | largest middle smallest | biggest, maximum medium, intermediate lowest, minimum |
| SORTING              | increasing random decreasing | growing, ascending reducing, descending |
| UNIT CONVERSION      | same different    | equal, identical distinct, unlike |
| REFERENCE RANGE DETECTION | normal abnormal | regular, safe irregular, lethal |

Table 10: Synonyms of the answer candidates we used for LABEL.

| Task                  | Template                                                                 |
|----------------------|--------------------------------------------------------------------------|
| COMPARISON           | [M] is [MASK] than [M] compared to [M]. [M] is [MASK] value the measurement of control group (M) is [MASK] than [M] comparison: [M], [M], result: [MASK] [M], [MASK], [M] |
| ARGMIN/MAX           | The [MASK] value among [LoM] is [M] [M] is the [MASK] value of [LoM] Among the list of measurements [LoM], the [MASK] value is [M] argmin, argmax: [LoM], [M], result: [MASK] [MASK], [LoM], [M] |
| SORTING              | sort [LoM] in [MASK] order is [LoM] arranging [LoM] in [MASK] order is [LoM] [LoM] is obtained by sorting [LoM] in [MASK] order sort: [LoM], [LoM], result: [MASK] [LoM], [LoM], [LoM] |
| UNIT CONVERSION      | [M] and [M] are the [MASK] value convert [M] to [MASK] value, then the result is [M] compare [M] to [M], the two are the [MASK] value measurement comparison: [M], [M], result: [MASK] [M], [M], [MASK] |
| REFERENCE RANGE DETECTION | [M] of [ENT] is [MASK] [M] of [ENT] falls into [MASK] range The physician decides [M] of [ENT] as [MASK] reference range: [ENT], [M], result: [MASK] [ENT], [M], [MASK] |

Table 11: Templates for CONTEXT. [M] is the measurement and [LoM] is the list of measurements.
Table 12: Test-set results on rule-based conversion experiments. We report the classification accuracy and the performance difference.

| Model | Notation | Sci | Deci |
|-------|----------|-----|------|
| ALBERT | Sci | 73.8 (-7.4) | 73.0 (-4.3) | 54.7 (-5.7) | 51.0 (-7.0) | 80.4 (2.2) | 77.7 (1.2) | 71.8 (-0.1) | 62.3 (2.4) |
|        | Deci | 87.5 (5.7) | 85.3 (13.2) | 71.8 (14.7) | 68.2 (17.7) | 87.3 (4.8) | 85.3 (11.0) | 65.6 (-5.5) | 53.8 (-7.2) |
| BERT   | Sci | 69.2 (-4.1) | 68.6 (-3.8) | 53.7 (-1.4) | 52.4 (0.2) | 53.4 (7.8) | 53.4 (8.4) | 73.2 (-0.3) | 63.5 (-0.8) |
|        | Deci | 88.3 (6.9) | 86.8 (9.8) | 59.3 (-1.6) | 60.6 (6.3) | 77.5 (22.6) | 77.5 (23.0) | 69.6 (-7.6) | 64.2 (-3.3) |
| BioBERT| Sci | 80.6 (-2.1) | 80.1 (-2.2) | 50.4 (-4.6) | 47.0 (-7.4) | 69.0 (0.8) | 68.1 (-1.0) | 79.0 (-2.3) | 64.3 (0.6) |
|        | Deci | 94.7 (4.6) | 93.5 (5.5) | 70.7 (11.7) | 68.3 (10.7) | 83.6 (6.3) | 82.9 (9.9) | 77.6 (-9.4) | 65.7 (1.5) |
| BlueBERT| Sci | 68.3 (-9.0) | 65.8 (-10.5) | 40.2 (-6.7) | 40.1 (-6.8) | 66.9 (3.3) | 67.0 (2.7) | 74.0 (0.4) | 65.0 (-0.4) |
|        | Deci | 88.7 (14.1) | 86.1 (12.9) | 64.8 (7.8) | 60.9 (5.4) | 75.2 (2.2) | 74.2 (6.2) | 70.3 (-6.8) | 66.0 (3.0) |
| Scratch| Sci | 58.2 (7.3) | 54.6 (3.8) | 43.0 (2.8) | 41.0 (3.9) | 33.3 (0.0) | 33.7 (-0.1) | 64.7 (-1.6) | 62.8 (2.0) |
|        | Deci | 78.8 (21.1) | 73.9 (22.6) | 43.5 (-0.8) | 42.9 (-0.1) | 33.2 (-0.1) | 33.9 (0.2) | 63.6 (1.0) | 64.3 (-0.7) |

Table 13: Effect of scale embedding on MSTs. We report the classification accuracy and performance improvement (∆) after applying scale embedding.

| Model | Notation | Sci | Deci |
|-------|----------|-----|------|
| ALBERT | Sci | 93.4 (12.2) | 86.3 (9.0) | 73.2 (12.8) | 66.0 (8.0) | 92.7 (14.5) | 90.1 (13.6) | 74.8 (26.2) | 61.6 (11.7) | 87.0 (15.1) | 63.4 (3.5) |
|        | Deci | 92.9 (11.1) | 79.9 (6.6) | 73.6 (16.5) | 63.5 (13.0) | 92.9 (10.4) | 86.8 (12.5) | 75.7 (14.2) | 68.0 (11.8) | 83.5 (12.4) | 63.9 (2.9) |
| BERT   | Sci | 96.4 (23.1) | 95.0 (22.6) | 80.9 (25.8) | 80.5 (28.3) | 89.8 (44.2) | 89.5 (44.5) | 79.9 (37.2) | 71.5 (16.3) | 92.4 (18.9) | 61.9 (-2.4) |
|        | Deci | 95.9 (14.5) | 89.0 (12.0) | 79.8 (18.9) | 73.6 (21.3) | 91.7 (36.8) | 90.9 (36.4) | 87.9 (26.0) | 80.2 (21.0) | 95.3 (18.1) | 62.6 (-4.9) |
| BioBERT| Sci | 98.3 (15.6) | 96.3 (14.0) | 81.3 (26.3) | 80.7 (26.3) | 94.0 (25.8) | 93.6 (24.5) | 89.3 (30.6) | 66.7 (9.4) | 96.0 (14.7) | 64.7 (1.0) |
|        | Deci | 98.4 (4.3) | 93.2 (5.2) | 85.9 (26.9) | 83.0 (25.4) | 94.0 (16.7) | 93.0 (20.0) | 90.1 (17.1) | 85.7 (15.2) | 98.4 (11.4) | 61.9 (2.3) |
| BlueBERT| Sci | 96.0 (18.7) | 93.1 (16.1) | 76.0 (29.1) | 74.9 (28.0) | 86.2 (22.6) | 85.8 (23.5) | 77.4 (24.4) | 63.1 (12.0) | 91.1 (17.5) | 66.1 (1.3) |
|        | Deci | 97.4 (22.8) | 88.1 (14.9) | 75.9 (18.9) | 67.7 (12.2) | 91.8 (18.8) | 90.3 (22.3) | 80.0 (20.8) | 76.2 (19.1) | 94.3 (17.2) | 66.1 (-2.9) |
| Scratch| Sci | 59.5 (8.6) | 57.4 (6.6) | 41.4 (12.8) | 39.9 (2.8) | 33.4 (0.1) | 33.8 (0.0) | 52.5 (0.0) | 50.6 (-0.1) | 80.0 (13.7) | 61.8 (1.0) |
|        | Deci | 70.2 (12.5) | 60.3 (9.0) | 45.5 (1.2) | 44.1 (1.1) | 33.2 (-0.1) | 33.8 (0.1) | 60.3 (3.5) | 56.1 (2.2) | 69.0 (6.4) | 66.3 (1.3) |