ER-TEST: Evaluating Explanation Regularization Methods for NLP Models

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Abstract

Neural language models’ (NLMs’) reasoning processes are notoriously hard to explain. Recently, there has been much progress in automatically generating machine rationales of NLM behavior, but less in utilizing the rationales to improve NLM behavior. For the latter, explanation regularization (ER) aims to improve NLM generalization by pushing the machine rationales to align with human rationales. Whereas prior works primarily evaluate such ER models via in-distribution (ID) generalization, ER’s impact on out-of-distribution (OOD) is largely underexplored. Plus, little is understood about how ER model performance is affected by the choice of ER criteria or by the number/choice of training instances with human rationales. In light of this, we propose ER-TEST, a protocol for evaluating ER models’ OOD generalization along three dimensions: (1) unseen datasets, (2) contrast set tests, and (3) functional tests. Using ER-TEST, we study three key questions: (A) Which ER criteria are most effective for the given OOD setting? (B) How is ER affected by the number/choice of training instances with human rationales? (C) Is ER effective with distantly supervised human rationales? ER-TEST enables comprehensive analysis of these questions by considering a diverse range of tasks and datasets. Through ER-TEST, we show that ER has little impact on ID performance, but can yield large gains on OOD performance w.r.t. (1)-(3). Also, we find that the best ER criterion is task-dependent, while ER can improve OOD performance even with limited and distantly-supervised human rationales.

1 Introduction

Neural language models (NLMs) have achieved state-of-the-art performance on a broad array of natural language processing (NLP) tasks (Devlin et al., 2018; Liu et al., 2019). Even so, NLMs’ reasoning processes are notoriously opaque (Rudin, 2019; Doshi-Velez and Kim, 2017; Lipton, 2018), which has spurred significant interest in designing algorithms to automatically explain NLM behavior (Denil et al., 2014; Sundararajan et al., 2017; Camburu et al., 2018; Rajani et al., 2019; Luo et al., 2021). The majority of this work has focused on rationale extraction, which explains a NLM’s output on a given task instance by highlighting the input tokens that most influenced the output (Denil et al., 2014; Sundararajan et al., 2017; Li et al., 2016; Jin et al., 2019; Lundberg and Lee, 2017).

Recently, a number of works have investigated how machine rationales produced by rationale extraction algorithms can be operationalized to improve NLM decision-making (Hase and Bansal, 2021) (See Figure 1). Almost all prior works are based on explanation regularization (ER), which aims to improve NLM generalization by regularizing the NLM to yield machine rationales that align with human rationales (Ross et al., 2017; Huang et al., 2021; Ghaeini et al., 2019; Zaidan and Eis-
ner, 2008; Kennedy et al., 2020; Rieger et al., 2020; Liu and Avci, 2019). Human rationales can be created by annotating each training instance individually (Lin et al., 2020; Camburu et al., 2018; Rajani et al., 2019) or by applying task-level human priors across all training instances (Kennedy et al., 2020; Rieger et al., 2020; Ross et al., 2017; Liu and Avci, 2019).

Although prior works primarily evaluate such ER models via in-distribution (ID) generalization (Zaidan and Eisner, 2008; Lin et al., 2020; Huang et al., 2021), out-of-distribution (OOD) generalization is more crucial in many real-world settings (Chrysostomou and Aletras, 2022; Ruder, 2021), yet ER’s impact on OOD generalization is largely underexplored (Ross et al., 2017; Kennedy et al., 2020). Plus, despite them being major factors in ER, little is understood about how ER model performance is affected by the choice of ER criterion or by the number/choice of training instances with human rationale supervision. In light of this, we propose ER-TEST, a protocol for evaluating ER models’ OOD generalization along three dimensions: (1) unseen datasets, (2) contrast set tests, and (3) functional tests. For (1), ER-TEST assesses ER models’ task performance on datasets beyond their training distribution. For (2), ER-TEST assesses ER models’ sensitivity to counterfactual instances created by perturbing existing datasets. For (3), ER-TEST assesses ER models’ basic linguistic capabilities (e.g., perception of word/phrase sentiment, robustness to typos) expected for the given task.

Using ER-TEST, we study three key questions: (A) Which ER criterion are most effective for the given OOD setting? (B) How is ER affected by the number/choice of training instances with human rationales? (C) Is ER effective with distantly supervised human rationales? ER-TEST enables comprehensive analysis of these questions by considering a diverse range of text classification tasks and datasets. Through ER-TEST, we show that ER has little impact on ID performance (Sec. 5.3.1, 5.4.1), but can yield large gains on OOD performance (Sec. 5.3.2, 5.4.2) w.r.t. (1)-(3). Also, we find that the best ER criterion is task-dependent (Sec. 5.3), while ER can improve OOD performance even with limited human rationale supervision (Sec. 5.4). Furthermore, we show that ER can improve OOD performance using distantly supervised human rationales (Sec. 5.5).

2 Background

Text Classification Let \( F \) be a NLM task model for \( M \)-class text classification. In modern NLP systems, \( F \) usually has a BERT-style architecture (Devlin et al., 2018), consisting of a Transformer encoder (Vaswani et al., 2017) followed by a linear layer with softmax classifier. Let \( x_i = [x_i^1, \ldots, x_i^n] \) be the \( n \)-token input sequence (e.g., a sentence) for task instance \( i \). For sequence classification, \( F \) predicts a class for sequence \( x_i \), so let \( F(x_i) \in \mathbb{R}^M \) be the logits for \( x_i \). Let \( y_i = \arg \max_c F(x_i)_c \), denote \( F \)'s predicted class for \( x_i \). For token classification, \( F \) predicts a class for each token \( x_i^t \), so let \( F(x_i^t) \in \mathbb{R}^{n \times M} \) be the logits for the \( n \) tokens in \( x_i \). Let \( y_{i,t} = \arg \max_c F(x_i^t)_c \) denote \( F \)'s predicted class for \( x_i^t \). Let \( y_{i} = [y_{i,t}]_{t=1}^n \) collectively denote all of \( F \)'s predicted token classes for \( x_i \).

Rationale Extraction Given \( F, x_i, \) and \( y_i \), the goal of rationale extraction is to output machine rationale \( r_i = [r_i^t]_{t=1}^n \), such that each \( r_i^t \in \{0, 1\} \) is an importance score indicating how strongly token \( x_i^t \) influenced \( F \) to predict class \( y_i \). Let \( \mathcal{G} \) denote a rationale extractor, such that \( r_i = \mathcal{G}(F, x_i, y_i) \). \( \mathcal{G} \) first computes raw importance scores \( s_t \in \mathbb{R}^n \), then normalizes \( s_t \) as probabilities \( r_t \) using the sigmoid function. In general, \( \mathcal{G} \) can be a heuristic or learned function, but we focus on heuristic \( \mathcal{G} \) in this work, since they are more common (Luo et al., 2021). Broadly, heuristic \( \mathcal{G} \)'s can either be a gradient-based, that assign importance scores based on gradient changes in \( F \) (Sundararajan et al., 2017; Sanyal and Ren, 2021; Shrikumar et al., 2017), sampling-based, that assign important scores based on the neighbours/context of a given token (Zeiler and Fergus, 2013; Jin et al., 2019), or attention-based, that use the attention-scores or a function of them to assign importance scores. (Ding and Koehn, 2021)

Explanation Regularization (ER) However, \( \mathcal{G} \) can also be used to compute machine rationales w.r.t. other classes besides \( y_i \), e.g., target class \( \hat{y}_i \). Let \( \hat{r}_i \) denote the machine rationale for \( x_i \) w.r.t. \( \hat{y}_i \). Given \( \hat{r}_i \) obtained via \( \mathcal{G} \) and \( F \), many works have explored ER, in which \( F \) is regularized such that \( \hat{r}_i \) aligns with human rationale \( \hat{r}_i \) (Zaidan and Eisner, 2008; Lin et al., 2020; Rieger et al., 2020; Ross et al., 2017). Typically, \( \hat{r}_i \) is a binary vector, where ones and zeros indicate positive (important) and negative (unimportant) tokens, respectively. ER’s inductive bias pushes \( F \) to solve the task in a way
that follows the human reasoning process given by \( \hat{r}_i \), which ideally provides denser learning signal for improving \( F \)’s generalization.

We formalize the ER loss as: 
\[
L_{ER} = \Phi(\hat{r}_i, \tilde{r}_i),
\]
where \( \Phi \) is an ER criterion measuring the alignment between \( \hat{r}_i \) and \( \tilde{r}_i \). Thus, the full learning objective is: 
\[
\hat{L} = L_{\text{task}} + \lambda_{ER} L_{ER},
\]
where \( L_{\text{task}} \) is the task loss (e.g., cross-entropy loss) \( \lambda_{ER} \in \mathbb{R} \) is the ER strength (i.e., loss weight) for \( L_{ER} \). Let \( \gamma_{ER} > 0 \) be the rationale scaling factor, used to scale \( \hat{s}_i \) prior to sigmoid normalization. If the magnitudes of the \( \hat{s}_i \) scores are lower, then the \( \hat{r}_i \) scores will be closer to 0.5 (i.e., lower confidence). However, scaling \( \hat{s}_i \) by \( \gamma_{ER} > 1 \) will increase the magnitude of \( \hat{s}_i \), yielding \( \hat{r}_i \) scores closer to 0 or 1 (i.e., higher confidence). Though there are many possible choices for \( \Phi \), it is presently unclear how different \( \Phi \) impact training and when certain \( \Phi \) should be preferred. This limits our ability to use ER in real-world settings.

3 ER-TEST

Existing works primarily evaluate ER models via ID generalization (Zaidan and Eisner, 2008; Lin et al., 2020; Huang et al., 2021), though a small number of works have done auxiliary evaluations of OOD generalization (Ross et al., 2017; Kennedy et al., 2020; Rieger et al., 2020). However, these OOD evaluations have been relatively small-scale, only covering a narrow range of OOD generalization aspects, ER criteria, training settings, tasks, and datasets. As a result, little is understood about ER’s impact on OOD generalization. To address this gap, we propose ER-TEST, a unified benchmark for evaluating ER models’ OOD generalization along three dimensions: (1) unseen datasets; (2) contrast set tests; and (3) functional tests.

3.1 ID Generalization

While ER-TEST’s main focus is on evaluating OOD generalization, ER-TEST also considers ID generalization as a baseline evaluation. Let \( D = \{ \mathcal{X}, \mathcal{Y} \}_{i=1}^N \) be a \( M \)-class text classification dataset, where \( \mathcal{X} = \{ x_i \}_{i=1}^N \) are the text inputs, \( \mathcal{Y} = \{ y_i \}_{i=1}^N \) are the target classes, and \( N \) is the number of instances \( (x_i, y_i) \) in \( D \). We call \( D \) the ID dataset. Assume \( D \) can be partitioned into train set \( D_{\text{train}} \), dev set \( D_{\text{dev}} \), and test set \( D_{\text{test}} \), where \( D_{\text{test}} \) is an ID test set for \( D \). After using ER to train \( F \) on \( D_{\text{train}} \), we measure \( F \)’s task performance on the ID test set \( D_{\text{test}} \). Note that this is a standard protocol used by existing works to evaluate ER models (Zaidan and Eisner, 2008; Rieger et al., 2020; Liu and Avci, 2019; Ross et al., 2017; Huang et al., 2021; Ghaeini et al., 2019; Kennedy et al., 2020).

3.2 OOD Generalization

To assess \( F \)’s generalization ability when using ER, we consider various OOD settings. Given \( D \), let \( \tilde{D}_{\text{test}} \) denote an OOD test set, with a different distribution from \( D \). While \( F \) is expected to perform well on \( D_{\text{test}} \) (ID), \( F \) should also perform well on \( \tilde{D}_{\text{test}} \) (OOD). For each dimension of OOD generalization, we obtain \( \tilde{D}_{\text{test}} \) in a different manner.

3.2.1 Unseen Datasets

First, we evaluate OOD generalization w.r.t. unseen datasets. Besides \( D \), suppose we also have a set of datasets \( \{ \tilde{D}^{(1)}, \tilde{D}^{(2)}, \ldots \} \) of the same task as \( D \). Each of these datasets \( \tilde{D}^{(i)} \) has its own train/dev/test sets and a distribution shift from \( D \). After using ER to train \( F \) on \( D_{\text{train}} \), we measure
F’s task performance on each OOD test set \( \tilde{D}_{\text{test}}^{(i)} \). In other words, \( \tilde{D}_{\text{test}}^{(i)} \) is obtained by simply taking the test set of existing OOD dataset \( D_{\text{test}}^{(i)} \). This evaluation is designed to assess whether ER helps F learn general (i.e., task-level) knowledge representations that can (zero-shot) transfer across datasets.

### 3.2.2 Contrast Set Tests

Second, we evaluate OOD generalization under meaningful dataset perturbations. Annotation artifacts (Gururangan et al., 2018) are gaps present in a dataset that can lead to misleading interpretations of a model’s performance on that dataset. To mitigate this, we evaluate F on contrast sets (Gardner et al., 2020), which are (mostly) label-changing small perturbations on instances to understand the true local boundary of the dataset. Essentially, they help us understand if F has learnt any dataset-specific shortcuts.

Given \( D_{\text{test}}^{(i)}(j) \) (a \( j^{th} \) instance belonging to an OOD test set \( D_{\text{test}}^{(i)} \)), a perturbation function \( \phi_p \) is applied to that instance, where \( p \) denotes the kind of perturbation taking effect, and it often changes the target label for that instance. For example, \( p \) can signify semantic (e.g., changing tall to short), numeral (e.g., changing one dog to three dogs), or entities (e.g., changing dogs to cats). Each perturbation type is specific to the dataset it is being created for, so that instance labels are changed in a meaningful manner. The resulting set of instances \( \mathcal{C}^{(i)}(j) = \phi_p(D_{\text{test}}^{(i)}(j)) \forall j, p \) are termed as a contrast set for that dataset. Based on the way they are created, contrast sets are a property of the dataset, and are not created to explicitly challenge F (unlike adversarial examples (Gao and Oates, 2019)).

### 3.2.3 Functional Tests

Third, we evaluate OOD generalization w.r.t. functional tests (Ribeiro et al., 2020; Li et al., 2020). Unlike contrast sets which are designed to test artifacts present in a dataset, functional tests are used to provide ‘zoomed-in’ insights about specific linguistic capabilities (like changes in the vocabulary, adding negations to instances, etc). Furthermore, contrast sets are created by perturbing a reference real-world dataset, whereas, functional tests evaluate specific capabilities with the help of template-generated synthetic instances.

If ER consistently improves F’s performance on such tests, then we can have higher confidence that ER is a useful inductive bias for OOD generalization for that given capability. Across all tasks, ER-TEST considers four categories of stress tests, which are adopted from CheckList (Ribeiro et al., 2020). Each test is described below.

**Vocabulary Tests** Vocabulary tests are used to evaluate F’s capability to address changes in the vocabulary of the text, and is particularly diverse w.r.t the parts-of-speech it caters to. For example, certain vocabulary tests evaluate the relationship (taxonomy) between different nouns in a sentence, whereas some swap the modifiers or the verbs present in a sentence in a meaningful manner based on the task at hand, to capture F’s targeted performance towards such changes (Ribeiro et al., 2020).

**Robustness Tests** Robustness tests evaluate F’s behavior under character-level edits to words in a sentence, keeping the rest of the context same so as to not change the overall prediction. They include testing against typos as well as contractions in words, as well as addition of tokens that are irrelevant for the downstream task (like URLs or gibberish like Twitter handles). (Jones et al., 2020; Wang et al., 2020)

**Logic Tests** Testing F’s reasoning capabilities towards logical changes in a sentence is also important to evaluate its reliance on shortcut-patterns. These tests perturb sentences in a logical manner (by adding or removing negations, or purposefully inducing contradictions) that also change the target label in the same manner. (Talman and Chatzikyriakidis, 2018; McCoy et al., 2019)

**Entity Tests** For certain tasks, named entities like numbers, locations, and proper nouns are not relevant for predicted a target label, and are often a source of gender or demographic biases (Mishra et al.; Mehrabi et al., 2020). Entity tests measure F’s sensitivity towards changed in named entities such that the overall context as well as the task label remains the same (Ribeiro et al., 2020).

### 3.3 Tasks and Datasets

To evaluate ER models, ER-TEST considers a diverse set of sequence and token classification tasks. For each task, ER-TEST provides one ID dataset (annotated with human rationales) and multiple OOD datasets. Compared to prior works, ER-TEST’s task/dataset diversity enables more extensive analysis of ER model generalization.

First, we have sentiment analysis, using SST (movie reviews) (Socher et al., 2013; Carton et al.,
Figure 3: **Analysis Setup**: We use ER-TEST to answer three RQs in this work - RQ1 addresses which ER criteria work for which task, and evaluates their improvements, RQ2 evaluates whether a particular method of selecting a fixed budget of samples for annotating human rationales yields performance improvements, and RQ3 studies ER w.r.t. another dimension of resource constraints, where we can only provide distant supervision to generate human rationales. We lay out more details in Section 4.

Typically, human rationales are created by annotating each training instance individually (Lin et al., 2020; Camburu et al., 2018; Rajani et al., 2019). For each training instance, humans are asked to mark tokens that support the gold label as positive, while the remaining tokens are marked as negative. Here, each human rationale is specifically conditioned on the input and gold label for the given instance. However, such *instance-level* human rationales are very expensive to obtain, given the high manual effort per instance.

Alternatively, some works have constructed distantly supervised human rationales by applying *task-level* human priors across all training instances (Kennedy et al., 2020; Rieger et al., 2020; Ross et al., 2017; Liu and Avci, 2019). For example, Kennedy et al. (2020) used a “blacklist” lexicon to distantly supervise human rationales for the hate speech detection task. In the past, hate speech detection models were largely oversensitive to certain group identifier words (e.g., “black”, “Muslim”, “gay”), almost always predicting hate speech for text containing these words. To address this, they first manually annotated a lexicon of group identifiers that should be ignored for hate speech detection. Then, for all training instances, they automatically marked only tokens belonging to the lexicon as negative (and the rest as positive). By using these human rationales for ER, they trained the NLM to be less biased w.r.t. these group identifiers. For the purpose of our study, we use the lexicons as used by (Jin et al., 2021) to generate

3.4 **Distantly Supervised Human Rationales**

Second, we have natural language inference (NLI), using e-SNLI (Camburu et al., 2018; DeYoung et al., 2019) as the ID dataset. For the OOD dataset, we use MNLI (Williams et al., 2017). e-SNLI contains only image captions, while MNLI contains both written and spoken text, covering various topics, styles, and formality levels. For NLI, we also use an OOD contrast set created for the MNLI dataset (Li et al., 2020). Functional tests for NLI are generated from the AllenNLP test suite (Gardner et al., 2017) for textual entailment.

Third, we have named entity recognition (NER), using CoNLL-2003 (Sang and De Meulder, 2003; Lin et al., 2020) as the ID dataset. For the OOD dataset, we use OntoNotes v5.0 (Pradhan et al., 2013). CoNLL-2003 contains only Reuters news stories, while OntoNotes v5.0 contains text from newswires, magazines, telephone conversations, websites, and other sources.

For contrast set tests, we use an OOD contrast set for MNLI (Li et al., 2020). Functional tests for NLI are generated from the AllenNLP test suite (Gardner et al., 2017) for textual entailment.

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4 Analysis Setup

After introducing the ER-TEST framework, we conduct a systematic study of ER through three primary research questions (described below) using ER-TEST (Figure 3). First, we aim to study which ER criteria are effective for a given task at hand (Section 4.1). Second, we study ER from a resource constraint perspective, where only a handful of instances can have human rationales annotated. What is key here is to define how to select these instances for rationale annotation (Section 4.2). Lastly, we look at human rationales that are distantly-supervised and how ER can help improve performance when dense, instance-level human rationale annotations are not available (Section 4.3).

4.1 RQ1: Which ER criteria are most effective?

Compared to existing works, ER-TEST uses a wider range of ER criteria to evaluate ER model generalization. This provides a more comprehensive picture of ER’s impact on both ID and OOD generalization. Also, this can help us understand why certain criteria work well and under what settings they work best. To demonstrate the utility of ER-TEST, we consider five representative ER criteria (i.e., choices of $\Phi$).

**Mean Squared Error (MSE)** MSE is used in Liu and Avci (2019), Kennedy et al. (2020), and Ross et al. (2017).

$$\Phi_{\text{MSE}}(\hat{r}_i, \hat{r}_i) = ||\hat{r}_i - \hat{r}_i||^2_2$$

**Mean Absolute Error (MAE)** MAE is used in Rieger et al. (2020).

$$\Phi_{\text{MAE}}(\hat{r}_i, \hat{r}_i) = |\hat{r}_i - \hat{r}_i|$$

**Binary Cross Entropy (BCE)** BCE loss is used in Chan et al. (2021).

$$\Phi_{\text{BCE}}(\hat{r}_i, \hat{r}_i) = -\sum_{t=1}^{n} \hat{r}_i^t \log(\hat{r}_i^t)$$

**Huber Loss** Huber loss (Huber, 1992) is a hybrid of MSE and MAE.

$$\Phi_{\text{Huber}}(\hat{r}_i, \hat{r}_i) = \begin{cases} \frac{1}{2} \Phi_{\text{MSE}}(\hat{r}_i, \hat{r}_i), & \Phi_{\text{MAE}}(\hat{r}_i, \hat{r}_i) < \delta \\ \delta (\Phi_{\text{MAE}}(\hat{r}_i, \hat{r}_i) - \frac{1}{2} \delta), & \text{otherwise} \end{cases}$$

**Order Loss** Recall that the human rationale $\hat{r}_i$ labels each token as positive (one) or negative (zero). Whereas other criteria generally push positive/negative tokens’ importance scores to be as high/low as possible, order loss (Huang et al., 2021) relaxes MSE to merely enforce that all positive tokens’ importance scores are higher than all negative tokens’ importance scores. This is especially useful if $\hat{r}_i$ is somewhat noisy, e.g., some positively-labeled tokens should not really be positive.

$$\Phi_{\text{Order}}(\hat{r}_i, \hat{r}_i) = \sum_{\hat{r}_i^t=1} \left( \min \left( \frac{\hat{r}_i^t}{\max \hat{r}_i^t} - 1, 0 \right) \right)^2$$

4.2 RQ2: How is ER affected by the number/choice of train instances with human rationales?

In real-world applications, it is infeasible to obtain human rationales $\hat{r}_i$ for all of the instances in the training set, as $\hat{r}_i$ requires dense annotation (Chiang and Lee, 2022; Kaushik et al., 2019).

Let $S$ be a subset of train instances for which we have human rationale annotations, $\hat{r}_i^S$. Therefore, the ER loss $L_{\text{ER}}^S = \Phi(\hat{r}_i^S, \hat{r}_i)$ and the full learning objective $\mathcal{L} = \mathcal{L}_{\text{task}} + \lambda_{\text{ER}} L_{\text{ER}}^S$, where $\mathcal{L}_{\text{task}}$ is computed on the full dataset as it would normally.

In designing such a system, one needs to carefully select $S$ that leads to highest performance gains, meanwhile maintaining resource constraints. To select relevant samples to annotate, existing methods use to active-learning based approaches (Schröder and Niekler, 2020). We use ER-TEST to compare three such approaches to select $S$:

**Random Sampling** Given a $k$, we uniformly select $k\%$ of samples from $\mathcal{D}$ to construct $S$.

**Lower Confidence (LC) Sampling** Given a $k$, we select top $k\%$ of samples ordered on the basis
We can then study the effectiveness of ER methods. We sample the top \( k \) \( k \) words, these are the top \( (\text{Zaheer et al., 2020}) \), in order to handle input sequences of up to 4096 tokens. For all results, we report the mean over three seeds, as well as the standard deviation. By default, we use a learning rate of \( 2e-5 \) and effective batch size of 32. For \( \text{ER} \), there are many possible choices of rationale extractor \( \mathcal{G} \), but evaluating all of these choices would be prohibitive. Also, evaluating \( \mathcal{G} \) is orthogonal to \( \text{ER-Test} \)’s goal of evaluating \( \text{ER} \) criteria \( \Phi \). Thus, as a proof of concept, we use the Input\^Grad algorithm (\text{Denil et al., 2014}) as \( \mathcal{G} \) in all experiments, given its popularity and computational efficiency (\text{Bastings and Filippova, 2020; Luo et al., 2021}). We leave investigation of other \( \mathcal{G} \) for future work.

5.2 Intrinsic Evaluation of ER

ER in general is sensitive to certain hyperparameters for yielding meaningful training curves and actually attaining alignment between machine and human rationales. Due to a large set of tunable hyperparameters, running all configurations of \( \text{ER} \) are not feasible. Therefore, we intrinsically evaluate hyperparameter configurations by assessing the loss curves (which model alignment between machine and human rationales) w.r.t different hyperparameters values. We observe that the acceptable band of learning rates for \( \text{ER} \) is very narrow, and we use \( 2e-5 \) in all of our experiments. Furthermore, we also observe that setting \( \lambda_{\text{ER}} = 1 \) and \( \gamma_{\text{ER}} = 100 \) yields the most drop in the loss curves while training, so we use these hyperparameters for the rest of our experiments. We detail these experiments in Appendix A.1.

5.3 RQ1: Which \( \text{ER} \) criteria are most effective?

5.3.1 ID Generalization

In Table 1 (In-Distribution), we display the ID task performance results for sentiment analysis (SST), NLI (e-SNLI), and NER (OntoNotes-2003). For SST, we find that all of the \( \text{ER} \) criteria yield about the same task performance as the None baseline, whereas, all \( \text{ER} \) criteria also perform similarly for NLI (yielding higher performance than None). For NER, we see more variance in task performance among \( \text{ER} \) criteria, although the variance is still quite small among the best methods (MSE, MAE, Huber). Here, MAE yields the highest task performance, while BCE yields the lowest by far. Overall, using ID task performance, it is difficult to distinguish between \( \text{ER} \) criteria and underplays its overall benefits. This motivates us to consider other evaluation metrics.

5.3.2 OOD Generalization

Unseen Datasets In Table 1 (Out-of-Distribution), we display the OOD task performance results for sentiment analysis (Amazon, Yelp, Movies), NLI (MNLI), and NER (OntoNotes v5.0). For sentiment analysis, MAE yields significant gains over all other \( \text{ER} \) criteria.
Meanwhile, despite performing best on SST, Order performs much worse than all other ER criteria here. For NER, MAE still performs best, while MSE and Huber are competitive. Overall, OOD task performance is much better than ID at distinguishing between ER criteria, especially showing ER’s improvement over None.

**Contrast Set Tests** In Table 2 (Contrast Set Analysis), we observe the drop in performance (denoted by $\Delta$) for sentiment analysis (Movies) and NLI (MNLI) when using a contrast set designed for the given dataset. We observe that for both of the tasks, MAE leads to the least drop in performance.

All of the methods apart from Order yield lower drops than None. All of them also have a higher performance on the original and contrast sets. For sentiment analysis, we observe that Order has the highest variance, and for NLI, it has the highest drop in performance. We believe that some of it can be attributed to the soft-ranking that is imposed by Order, which may be indifferent towards minor label-changing edits, that is observed by the contrast sets.

**Functional Tests** Figure 4 demonstrates the failure rates on functional tests (as listed in Section 3.2.3) of our ID models trained on the sentiment analysis and NLI tasks. We also present the overall aggregated (over each individual tests within the categories mentioned) failure rates.

We observe that apart from the entity-based tests, ER criteria generally have a lower failure rate than None for all of the other tests. For entity-based tests, ER criteria either perform comparably (sentiment analysis) or worse (NLI) than None. Generally, all methods perform well on robustness-based tests, as they have lower failure rates, with order loss having the least. What is important to note is the significant improvement by order loss in vocabulary-based tests than None, even though all of the methods are exposed to the same training set instances. We hypothesize that the biases induced by ER alleviates the shortcuts learnt by None. This is also validated by the overall performance on all of these stress tests, where all of the ER criteria (apart from Huber in sentiment analysis) have lower failure rates than None.

### 5.4 RQ2: How is ER affected by the number/choice of train instances with human rationales?

Table 3 displays the results for our experiments on varying the amount of human rationales available, selected using different sampling methods. For these experiments, we refer to the same training and inference setup we have in Table 1 on sentiment analysis. Furthermore, all hyperparameters are same as that detailed in Section 5.2. We also choose the best performing ER criterion for sentiment analysis from Table 1 (MAE) and base the following results on the same criterion.

#### 5.4.1 ID Generalization

Consistent with the results we observed in Table 1, Table 3 shows us that there are little to no improvements in ID performance with prioritisation methods, however performance for all of them (except LC) is maintained at par with that of None and 100% sampling. This shows that doing ER on selective samples does not degrade ID performance.

#### 5.4.2 OOD Generalization (Unseen Datasets)

Interestingly, we observe distinctions within various prioritisation methods as we look at OOD evaluations in Table 3. In lower-resource scenarios (selecting only 5% samples for ER), all of the methods yield similar performance with each other, and
Table 2: Contrast Set Tests: Each ER criteria ($F$) are trained on their ID datasets from Table 1 and evaluated on the OOD original and contrast sets. $\Delta$ is the difference in performance of $F$ between the contrast and original set, and lower the value, better the generalization power of $F$. A value farther from 0 suggests that $F$ has learnt shortcuts specific a dataset, which are not generalizable to task that the dataset captures as a whole.

Table 4 lists the FPRD values of all the ER criteria in ID and OOD datasets. While all other crite-

outperform None. This implies that doing ER on a smaller subset of instances would instantly yield small improvements over None. As we increase the annotation budget, we observe that model performance declines as we select lower confidence samples, but is maintained or even improves over random while selecting instances with greater confidence. It is important to reiterate here, that samples are prioritized based on the confidence yielded by the None model. This implies that models in general require inductive biases on samples they are already confident on, vs. samples they are less confident on to avoid confusion. We plan to study this phenomenon in more detail for other tasks and more constrained annotation budgets as a part of our Future Work (as detailed in Section 6).

5.5 RQ3: Is ER effective with distantly supervised human rationales?

5.5.1 ID Generalization

For the task of hate speech detection, we train $F$ with the Stf dataset. We report all accuracies in Table 4. As it was observed in Section 5.3.1, ER does not lead to a significant improvement in performance for the Stf test set. However, it is important to note that “blacklisting” group identifier lexicons does not lead to a drop in ID performance either. Benefits of “blacklisting” are then observed in OOD generalization.

5.5.2 OOD Generalization

Unseen Datasets We evaluate $F$ on two OOD datasets, HatEval and GHC. Table 4 shows that while the improvements in HatEval are not significant, there are significant accuracy improvements for the GHC test set, which are due to the Order ER criterion.

Fairness Tests In addition to generic performance metrics like accuracy, we also measure group identifier bias (against the groups detailed by group identifier lexicons) by evaluating the False Positive Rate Difference (FPRD) as shown by (Jin et al., 2021). FPRD is computed as $\sum_{z} |\text{FPR}_z - \text{FPR}_{\text{overall}}|$, where $\text{FPR}_z$ is the false positive rate of all of the test instances mentioning group identifier $z$, and $\text{FPR}_{\text{overall}}$ is the false positive rate of all the test instance. Essentially, FPRD evaluates if $F$ is more biased against a given group identifier $z$, than all of the groups. A lower FPRD value indicates less biased against the listed group identifiers by $F$.

Figure 4: Functional Tests’ Failure Rates (lower the better): We plot the failure rates of the four functional tests (vocab., robust., logic, entity) as described in Section 3.2.3, as well as the overall failure rate on all of the tests combined (mean). Each of the values are out of 100, but plotted accordingly for visible comparison.
where Order criterion leads to improvements. Our comparison between the time taken to annotate ex-

| $k$ (in %) | Selection Method | In-Distribution | Out-of-Distribution | Sentiment Analysis |
|------------|------------------|-----------------|---------------------|-------------------|
|            |                  | SST             | Amazon              | Yelp              | Movies            |
| None       | -                | 94.22 (±0.77)   | 90.72 (±1.36)       | 92.07 (±2.66)     | 89.83 (±6.79)    |
| 100        | -                | 94.11 (±0.38)   | 92.02 (±0.25)       | 94.55 (±0.30)     | 95.50 (±1.32)*   |
| Random     |                  | 94.36 (±0.05)   | 91.57 (±0.10)       | 93.36 (±0.15)     | 92.39 (±2.50)    |
| 5          | LC               | 93.14 (±1.97)   | 90.72 (±0.43)       | 93.50 (±0.53)     | 93.17 (±1.26)    |
|            | HC               | 94.32 (±0.42)*  | 91.57 (±0.19)*      | 93.03 (±0.81)*    | 91.33 (±3.09)    |
| 15         | Random           | 94.46 (±0.21)   | 90.06 (±1.17)       | 90.81 (±2.63)     | 86.22 (±2.94)    |
|            | LC               | 93.48 (±0.80)   | 90.12 (±2.66)       | 90.90 (±5.50)     | 83.67 (±1.04)    |
|            | HC               | 94.39 (±0.27)*  | 90.38 (±1.12)*      | 93.48 (±0.64)*    | 91.33 (±5.11)*   |
| 50         | Random           | 93.47 (±0.02)   | 90.28 (±1.42)       | 91.85 (±2.11)     | 89.78 (±5.68)    |
|            | LC               | 89.92 (±1.90)   | 90.75 (±0.78)       | 93.05 (±0.14)     | 87.50 (±4.95)    |
|            | HC               | 92.93 (±0.17)   | 92.15 (±0.36)*      | 94.48 (±0.94)*    | 91.00 (±6.50)*   |

Table 3: Instance Prioritisation Methods (with ID/OOD Performance): All values are accuracy (higher the better) on sentiment analysis. None corresponds to models trained without ER, where $k = 100\%$ corresponds to no annotation budget. Each of the $k = [5, 15, 50]\%$ have 3 instance prioritisation methods. □ corresponds to cases where HC is significantly greater than Random and greater than LC. ◦ corresponds to cases where all the three methods are significantly similar and * corresponds to cases where the 100% ER setup is significantly similar and greater than None respectively. All tests are conducted with ($p < 0.05$).

| ER Criteria | In-Distribution | Out-of-Distribution | Hate Speech Detection |
|-------------|-----------------|---------------------|-----------------------|
|             | Stf              | HatEval             | GHC                   |
| Accuracy ↑  | FPRD ↓           | Accuracy ↑          | FPRD ↓                |
| None        | 89.50 (±0.20)    | 63.66 (±0.78)       | 1.64 (±0.66)          | 89.43 (±0.98)     | 1.09 (±0.12)     |
| MSE         | 89.46 (±0.21)    | 64.30 (±1.52)       | 1.99 (±0.26)          | 88.19 (±0.62)     | 1.50 (±0.10)     |
| MAE         | 89.59 (±0.06)    | 63.30 (±0.49)       | 1.80 (±0.59)          | 88.07 (±1.66)     | 1.43 (±0.24)     |
| BCE         | 89.42 (±0.71)    | 63.54 (±0.57)       | 1.87 (±0.45)          | 88.99 (±0.83)     | 1.36 (±0.58)     |
| Huber       | 89.50 (±0.51)    | 64.85 (±1.50)       | 2.11 (±0.27)          | 87.77 (±1.21)     | 1.84 (±0.34)     |
| Order       | 89.21 (±1.18)    | 64.46 (±1.18)       | 0.92 (±0.92)          | 92.84 (±0.46)     | 0.59 (±0.25)     |

Table 4: ID/OOD Task Performance (Distantly-supervised Human Rationales): Higher values for accuracy and lower values for FPRD are considered better. All models are displayed on the ID dataset (Stf) with distantly supervised rationales (for ER criteria) and no rationales (for None) and evaluated on ID and OOD test splits.

rations suffer with higher bias than None, we observe that Order criterion consistently leads to the least bias, both in-distribution and out-of-distribution. Furthermore, the reduction in bias is significant when compared to None. Interestingly, Order ER criterion was initially conceived for distantly-supervised rationales (Huang et al., 2021), and the authors of the original paper also demonstrated experiments with rationales generated from lexicons where Order criterion leads to improvements. Our observations are in-line with theirs, and we also show its benefit in reducing bias in $\mathcal{F}$.

### 6 Future Work

**Time-based Rationale Annotation Cost** Current experiments in selecting instances for ER detailed in Section 5.4 are based on the assumption that each instance takes the same amount of time to annotate. Furthermore, in order to effectively comment about the improvements made by ER under constrained scenarios, there needs to be a comparison between the time taken to annotate explanations (Yao et al., 2021) vs. the time taken to label new training instances, that we aim to evaluate using ER-TEST.

**Online ER and connections to human-in-the-loop learning** Fine-tuning strategies have shown to distort the underlying data distribution (Kumar et al., 2022), therefore, once $\mathcal{F}$ undergoes ER, its machine rationales differ from before. Currently, ER is being studied in an offline manner – once human rationales are collected, they are used to update model weights. However, what is more effective is to study the effect of ER when applied incrementally, thus improving rationale alignment.

### 7 Related Work

**ER criteria** ER criteria primarily differ in how they obtain human rationale $\hat{r}_i$ and how they compute machine-human rationale alignment $\Phi(\hat{r}_i, \hat{r}_j)$. First, $\Phi$ can be obtained by annotating each training instance individually (Zaidan and Eisner, 2008; Lin et al., 2020; Camburu et al., 2018; Rajani et al., 2020;...
The former approach is more expensive, while the latter approach has more limited applicability since it requires domain knowledge. Second, existing choices of $\Phi$ include MSE (Liu and Avci, 2019; Kennedy et al., 2020; Ross et al., 2017), MAE (Rieger et al., 2020), BCE (Chan et al., 2021), order loss (Huang et al., 2021), and KL divergence (Chan et al., 2021). Currently, there is little understanding about how these ER design choices impact OOD generalization, so ER-TEST aims to provide a testbed for conducting such analysis. Beyond ER, Hase and Bansal (2021) presents a more general study about how models can learn from explanations, claiming that explanations are best used as model inputs.

**Evaluating ER criteria** Existing works have primarily evaluated ER models via ID generalization (Zaidan and Eisner, 2008; Lin et al., 2020; Huang et al., 2021), which only captures one aspect of ER’s impact. Meanwhile, a few works have considered auxiliary evaluations — e.g., machine-human rationale alignment (Huang et al., 2021; Ghaeini et al., 2019), task performance on unseen datasets (Ross et al., 2017; Kennedy et al., 2020), social group fairness (Rieger et al., 2020; Liu and Avci, 2019). However, such evaluations are uncommon and relatively small-scale, only covering a narrow range of OOD generalization aspects, ER criteria, tasks, and datasets. These limitations make it difficult to thoroughly compare ER criteria, analyzing why they work and when they work best. To address these limitations, ER-TEST provides a unified benchmark for evaluating multiple aspects of OOD generalization, across a diverse range of ER criteria, tasks, and datasets.

8 Acknowledgements

This research is supported in part by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA), via Contract No. 2019-19051600007, NSF IIS 2048211, and gift awards from Google, Amazon, JP Morgan and Sony. We would like to thank all the collaborators in USC NLP Group, USC INK research lab and Meta AI for their constructive feedback on the work.

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A Appendix

A.1 Intrinsic Evaluation: evaluating ER’s sensitivity to hyperparameters

When using ER to train $\mathcal{F}$, it is important to assess whether ER exhibits expected training behavior, orthogonally to task performance. If ER improves task performance, this kind of analysis can help us better understand ER’s effectiveness. Conversely, if ER does not improve task performance, such analysis can help us identify the problem.

Motivated by this, ER-TEST’s intrinsic evaluation is based on machine-human rationale alignment, captured by the ER loss $L_{ER} = \Phi(\hat{r}_i, \hat{r}_i)$. When using ER, we should generally expect the ER loss to decrease as $\mathcal{F}$ is trained. In practice, this may not always be the case, even when ER leads to slightly higher task performance (which is likely a mirage caused by lucky random seeds)! That is, by definition, non-decreasing ER loss signals ineffective ER usage, since the machine rationales are not becoming more similar to the human rationales. This can stem from a number of issues: e.g., poor choice of ER criteria $\Phi$, improper ER strength $\lambda_{ER}$, improper rationale scaling factor $\gamma_{ER}$, noisy human rationale $\hat{r}_i$, insufficient $\mathcal{F}$ capacity. Thus, we measure machine-human rationale alignment as the first step in diagnosing such issues.

Let $ER$ loss curve denote a chart which plots $L_{ER}$ vs. the number of train epochs. For each combination of ER criteria $\Phi$ and some training configuration, we plot ER loss curves for the training set. Each component of our intrinsic evaluation varies a different hyperparameter in the training configuration: (A) ER strength $\lambda_{ER}$; (B) rationale scaling factor $\gamma_{ER}$; and (C) learning rate $\alpha$. In contrast, prior works do not explore the relationship between $L_{ER}$ and these training variables (Huang et al., 2021; Ghaeini et al., 2019).

For intrinsic evaluation, we use ER strength $\lambda_{ER} = 1$, rationale scaling factor $\gamma_{ER} = 1$, and learning rate $\alpha = 2e^{-5}$, unless otherwise specified. As a proof of concept, we focus on SST here, but plan to add other datasets in future work.

A.1.1 ER Strength

Fig. 6 displays the ER loss curves for different ER strengths $\lambda_{ER} = [0.5, 1, 10, 100, 300]$, on SST using MAE. Among the $\lambda_{ER}$ values, we see that $\lambda_{ER} = 1$ yields ER loss curves with the greatest decrease (Table 6), signaling good ER optimization.
Table 5: **Relative Decrease in ER Loss.** For various ER rationale scaling factors, we report the percentage decrease in ER train loss (on SST), from max point to min point.

| ER criteria | 1   | 10  | 100 | 1000 |
|-------------|-----|-----|-----|------|
| MSE         | 0.69| 4.60| 18.35| 11.41|
| MAE         | 0.04| 0.40| 1.29 | 1.17 |
| BCE         | 0.10| 0.34| 0.90 | 1.03 |
| Huber       | 0.10| 7.75| 16.67| 9.30 |
| Order       | 7.21| 9.38| 47.97| 1.89 |

Table 6: **Relative Decrease in ER Loss.** For various ER strengths, we report the percentage decrease in ER train loss (on SST), from max point to min point.

| ER criteria | 0.5 | 1   | 10  | 100 | 300 |
|-------------|-----|-----|-----|-----|-----|
| MSE         | 0.91| 1.52| 1.41| 1.29| 1.35|
| MAE         | 1.89| 2.01| 1.72| 1.80| 1.74|
| BCE         | 1.99| 2.17| 1.65| 1.65| 1.75|
| Huber       | 1.85| 2.09| 2.24| 2.27| 2.40|
| Order       | 2.15| 2.40| 1.60| 2.53| 1.89|

**A.1.2 Rationale Scaling Factor**

Fig. 5 displays the ER loss curves for different rationale scale factors \( \gamma_{ER} = \{1, 10, 100, 1000\} \), on SST. Among the four \( \gamma_{ER} \) values, we see that \( \gamma_{ER} = 100 \) yields ER loss curves with the greatest decrease (Table 5), signaling good ER optimization. Meanwhile, although ER works use \( \gamma_{ER} = 1 \) by default, we see that \( \gamma_{ER} = 1 \) yields nearly flat ER loss curves for all five \( \Phi \) choices. This suggests poor ER optimization. Based on these results, we fix \( \gamma_{ER} = 100 \) for all experiments (Sec. 5), thus greatly reducing the hyperparameter search space (Sec. A.3).

**A.1.3 Learning Rate**

Here, we obtain similar conclusions, with \( \alpha = 2e^{-5} \) yielding the best ER loss curves (Sec. A.1.4).

**A.1.4 Learning Rate**

Fig. 7 displays the ER loss curves for different learning rates \( \alpha = \{2e^{-6}, 2e^{-5}, 2e^{-4}\} \). Among the three learning rates, we see that \( \alpha = 2e^{-5} \) yields the most steadily decreasing ER loss curves.

**A.2 ER performance with different hyperparameters**

**ER Strength vs. Task Performance** To measure ER’s impact on task performance, we plot \( \mathcal{F} \)’s task performance as a function of ER strength \( \lambda_{ER} \). This is conducted for ID test sets.

**ER Loss vs. Task Performance** To measure ER’s impact on task performance, we plot \( \mathcal{F} \)’s task performance as a function of ER loss \( L_{ER} \). This is conducted for both ID and OOD test sets.

**Change in Target Class Confidence** Let \( \mathcal{F}_{No-ER} \) and \( \mathcal{F}_{ER} \) denote non-ER-trained (vanilla) and ER-trained NLMs, respectively. For each test instance, we plot \( \mathcal{F}_{No-ER} \)’s predicted target class confidence probability vs. \( \mathcal{F}_{ER} \)’s. Each point in the plot is color-coded by whether ER changes the prediction from correct to incorrect, changes the prediction from incorrect to correct, keeps the prediction as correct, or keeps the prediction as incorrect. The purpose of this plot is to visualize how individual instances’ predictions are affected by ER. We conduct this for ID dev sets.

**A.2.1 ER Strength vs. Task Performance**

For each sentiment analysis dataset, Fig. 8 shows task performance for ER strengths \( \lambda_{ER} = \{0, 0.5, 1, 10, 100, 300\} \), using MAE. Note that \( \lambda_{ER} = 0 \) is equivalent to training the NLM without ER (i.e., None in Table 1). For the ID dataset (SST), we see that all ER strengths yield very similar task performance, suggesting that ER has little effect on ID task performance. However, for the OOD datasets (Amazon, Yelp, Movies), task performance generally increases as \( \lambda_{ER} \) increases, showing ER’s positive impact on NLM generalization. Overall, based on OOD task performance, we find that \( \lambda_{ER} = [1, 100] \) are the best ER strengths. This aligns with the results of Sec. A.1.1.

**A.2.2 ER Loss vs. Task Performance**

Fig. 9 displays the SST results for ID task performance (accuracy) vs. ER loss. For a given ER criterion, each point in the corresponding scatter plot represents the checkpoint at some train epoch of the
ER-trained model, evaluated on either the dev set or test set (yielding two point sets). Fitting each point set with linear regression, we find that there is an inverse relationship between task performance and ER loss. In other words, higher machine-human rationale alignment (i.e., low ER loss) corresponds to higher task performance, which validates the usage of ER to improve generalization. Table 7 displays the slopes and $R^2$ scores of the lines in Fig. 9. The slope indicates the strength of the relationship between machine-human rationale alignment and task performance (lower is better), while the $R^2$ score indicates how accurately each line fits its corresponding data points. Among the five ER criteria, across dev and test, we find that MAE has the lowest slopes and highest $R^2$ scores overall, suggesting that using ER with MAE is most effective.

### A.2.3 Change in Target Class Confidence

We consider ER with the MAE criterion, trained/evaluated on SST (via dev ID task performance). Fig. 10 visualizes how ER changes each dev instance’s target class confidence as a result of ER, color-coding each point w.r.t. how ER changes the model’s predicted class for this point. Among instances for which $\mathcal{F}_{\text{No-ER}}$’s target class confidence is low, there is a higher percentage of instances that are predicted incorrectly/correctly without/with ER. This suggests that instances with low target class confidence are more likely to benefit from ER. Also, based on the T-test, target class confidence scores are significantly higher ($p < 0.005$) with ER than without.

### A.2.4 ER Opportunity Cost

An ER-trained NLM $\mathcal{F}_{\text{task, ER}}$ and a non-ER-trained NLM $\mathcal{F}_{\text{task, No-ER}}$ are likely to yield different outputs given the same inputs. Let $D_{\text{ER}}^+ \subseteq \mathcal{D}$ and $D_{\text{No-ER}}^+ \subseteq \mathcal{D}$ denote the sets of instances predicted correctly by $\mathcal{F}_{\text{task, ER}}$ and $\mathcal{F}_{\text{task, No-ER}}$, respectively. Ideally, we would have $D_{\text{No-ER}}^+ \subseteq D_{\text{ER}}^+$. This means there is no opportunity cost in us-

![Figure 6: ER Loss Curves (ER Strength). Here, we use the MAE criterion.](image)

![Figure 7: ER Loss Curves (Learning Rate)](image)

![Figure 8: ER Strength vs. Task Performance. For various combinations of sentiment analysis dataset and ER strength, we plot task performance using MAE.](image)

Table 7: ER Loss vs. Task Performance. We summarize the line plots in Fig. 9 (ER Loss vs. Task Performance), using slope and $R^2$ score (Sec. A.2.2). Ideally, Fig. 9’s lines would have low slope and high $R^2$, indicating that ER helps improve task performance. We see that MAE yields the best ER results.

| ER criteria | Dev | Test |
|-------------|-----|------|
| MSE         | -7.48 | 0.050 |
| MAE         | -128.60 | 0.083 |
| BCE         | -17.48 | 0.003 |
| Huber       | -23.59 | 0.091 |
| Order       | -0.49 | **0.101** |

Table 8: Change in Target Class Confidence. For bins where $\mathcal{F}_{\text{No-ER}}$’s target class confidence is low, there is a higher percentage of instances that are predicted incorrectly/correctly without/with ER (i.e., incor $\rightarrow$ cor). This suggests that, for $\mathcal{F}_{\text{No-ER}}$, instances with low target class confidence are more likely to benefit from ER (Table 8). Also, based on the T-test, target class confidence scores are significantly higher ($p < 0.005$) with ER than without.
ing ER, as ER increases the number of correct instances without turning any previously-correct incorrect. However, this may not necessarily be the case, so we measure ER’s opportunity cost as follows. Let $n_{\text{ER}} = |D_{\text{ER}}^+ \cap D_{\text{No-ER}}^-|$ be the number of instances predicted correctly by $F_{\text{task}, \text{ER}}$, but not by $F_{\text{task}, \text{No-ER}}$. Let $n_{\text{No-ER}} = |D_{\text{No-ER}}^- \cap D_{\text{ER}}^+|$ be the number of instances predicted correctly by $F_{\text{task}, \text{No-ER}}$, but not by $F_{\text{task}, \text{ER}}$. Then, the opportunity cost of using ER is defined as:

$$o_{\text{ER}} = \frac{n_{\text{ER}} - n_{\text{No-ER}}}{|D|}$$  \hspace{1cm} (7)

In practice, instead of defining $o_{\text{ER}}$ for all of $D$, we only consider test sets $D_{\text{test}}$ and $\tilde{D}_{\text{test}}$.

Table 9 displays the opportunity cost results for sentiment analysis. Generally, the opportunity cost results mirror the task performance results in Table 1, such that the methods with highest task performance tend to have the lowest opportunity cost. However, using opportunity cost, the variance is very high for OOD datasets, making it difficult to compare methods. In future work, we plan to modify the opportunity cost metrics to better accommodate OOD settings.

### A.3 Efficient hyperparameter tuning with ER-TEST

In intrinsic evaluation (Sec. A.1), we used ER loss curves as priors for selecting three key ER hyperparameters (i.e., ER strength $\lambda_{\text{ER}}$, rationale scaling factor $\gamma_{\text{ER}}$, learning rate $\alpha$). In Sec. 5, we assumed a tuning budget that allows only one value for each of $\lambda_{\text{ER}}$, $\gamma_{\text{ER}}$, and $\alpha$. By not tuning these hyperparameters, we greatly reduced our hyperparameter search space. Since ER has little effect on ID task performance, tuning based on ID task performance is unlikely to have helped anyway. ER works better on OOD data, but it also does not make sense to tune based on OOD task performance (otherwise, it would not be OOD). Though the ER hyperparameters chosen via intrinsic evaluation generally improved OOD task performance, we seek to verify their effectiveness compared to other possible hyperparameter values.

In Table 10 (in the appendix), we report sentiment analysis OOD (Amazon, Yelp, Movies) task performance, while varying each of the three hyperparameters. We include a Mean column, which averages the Amazon/Yelp/Movies columns. Our hyperparameters chosen via ER loss curves are highlighted in blue. For $\lambda_{\text{ER}}$, 1 (ours) and 100 yield very similar Mean results, while considerably beating the other three values. For $\gamma_{\text{ER}}$, we see the same trend for 100 (ours) and 10. For $\alpha$, $2e-5$ (ours) vastly outperforms other values in all columns. These results validate the utility of ER-TEST’s intrinsic evaluation for low-resource ER hyperparameter tuning.

### A.4 Details for Functional Tests

In this section, we provide details for different functional tests listen in Section 3.2.3. We breakdown each subcategory of functional tests and show performances of different ER criteria on those individual tests. For functional tests on the sentiment
ER criteria & Sentiment Analysis (Out-of-Domain) 

| ER criteria | Amazon | Yelp | Movies | Mean |
|-------------|--------|------|--------|------|
| None & \(\lambda_{ER} = 0.5\) | 90.72 (±1.38) | 92.07 (±2.66) | 89.83 (±6.79) | XX.XX (±X.XX) |
| MAE (\(\lambda_{ER} = 0.5\)) | 92.02 (±0.25) | 94.55 (±0.30) | 95.50 (±1.32) | 94.02 (±2.15) |
| MAE (\(\lambda_{ER} = 1\)) | 92.53 (±0.28) | 94.92 (±1.58) | 95.50 (±0.30) | 94.25 (±1.89) |
| MAE (\(\lambda_{ER} = 10\)) | 93.35 (±0.42) | 95.97 (±1.28) | 95.50 (±0.30) | 95.00 (±1.74) |
| MAE (\(\gamma_{ER} = 1\)) | 90.63 (±1.88) | 92.32 (±2.23) | 86.47 (±4.25) | 90.54 (±2.22) |
| MAE (\(\gamma_{ER} = 10\)) | 92.30 (±2.11) | 93.91 (±2.14) | 96.83 (±1.04) | 94.07 (±3.89) |
| MAE (\(\gamma_{ER} = 100\)) | 92.92 (±0.25) | 94.55 (±0.30) | 95.50 (±1.32) | 94.02 (±2.15) |
| MAE (\(\gamma_{ER} = 1000\)) | 90.47 (±2.06) | 92.80 (±2.90) | 92.67 (±6.25) | 91.98 (±1.14) |

Table 10: Task Performance vs. \(\{\text{ER Strength (\(\lambda_{ER}\)), Rationale Scaling Factor (\(\gamma_{ER}\))}\}\). Higher values are better.

A.5 Details for Instance Prioritisation

Experiments

In this section, we provide further implementation details for confidence-based instance prioritisation experiments as described in Section 4.2.

Given that we have 3-seed runs for the None model in Table 1, we extract the confidence scores based on the given metric (LC or HC), and then average these confidence scores across the 3 seed runs to obtain a single score for every instance. This process is done for training set instances only. This is followed by ranking each instance by the aggregated confidence metric and selecting the top \(k\)% of samples from this ranking. For experiments with random sampling based prioritisation, we generate 3 random subsets selected in a uniform manner.

While training in this setting, we ensure that within each batch, certain (one third to be specific) set of instances have available rationales. For these instances, we calculate the ER loss \(L_{ER}\), whereas, for the rest of the instances in the batch, we compute the task loss \(L_{task}\). All prioritisation settings are trained with 3 different model seeds and the aggregated results for ID and OOD datasets are shown in Table 3.
### Table 11: Functional Tests: Sentiment Analysis

| Capability                          | Test Type                                      | ER criteria       |
|-------------------------------------|------------------------------------------------|-------------------|
|                                     |                                                | None  | MSE  | MAE  | BCE  | Huber | Order |
| **Vocabulary**                      |                                                | 1.20 (±0.74) | 0.60 (±0.16) | 1.27 (±0.84) | 1.00 (±0.86) | 1.13 (±0.50) | 0.80 (±0.28) |
| Sentiment-laden words in context    | Change Neutral words with BERT                 | 5.59 (±0.16) | 5.13 (±0.90) | 5.40 (±0.28) | 5.67 (±0.68) | 5.67 (±0.74) | 5.60 (±1.63) |
| Change Neutral words with BERT      | Intensifiers                                    | 2.13 (±1.63) | 1.80 (±0.16) | 1.40 (±0.16) | 2.67 (±0.77) | 2.67 (±0.96) | 1.60 (±0.65) |
|                                       | Reducers                                       | 23.85 (±7.18) | 35.00 (±46.01) | 27.38 (±5.95) | 25.00 (±25.00) | 17.46 (±13.65) | 0.77 (±0.43) |
|                                       | Add +ve phrases                                | 1.40 (±0.28) | 2.33 (±1.84) | 0.67 (±0.50) | 1.27 (±1.00) | 2.33 (±1.76) | 2.07 (±1.52) |
|                                       | Add -ve phrases                                | 22.86 (±7.43) | 14.80 (±1.40) | 20.67 (±4.07) | 17.40 (±3.64) | 20.67 (±3.35) | 16.93 (±1.91) |
|                                    | Adding Random URLs and Handles                 | 9.80 (±0.48) | 7.27 (±2.23) | 9.07 (±1.80) | 7.87 (±2.76) | 10.27 (±0.9) | 9.6 (±2.47) |
|                                    | Punctuations                                   | 3.93 (±0.89) | 1.93 (±0.41) | 3.00 (±1.02) | 2.87 (±0.19) | 3.80 (±0.28) | 2.67 (±0.34) |
|                                    | Typos                                          | 2.60 (±0.90) | 2.53 (±0.82) | 2.60 (±0.57) | 3.13 (±0.90) | 2.60 (±0.75) | 2.00 (±0.86) |
|                                    | 2 Typos                                        | 3.93 (±0.65) | 3.87 (±1.24) | 4.27 (±0.5) | 4.13 (±1.2) | 4.6 (±0.43) | 3.33 (±0.25) |
|                                    | Contractions                                    | 1.00 (±0.00) | 0.80 (±0.33) | 0.87 (±0.25) | 0.80 (±0.43) | 0.47 (±0.09) | 0.53 (±0.50) |
|                                    | Negatives                                      | 5.20 (±2.75) | 4.27 (±1.65) | 4.47 (±3.07) | 4.47 (±1.75) | 3.93 (±1.57) | 5.67 (±1.68) |
|                                    | Non-negatives                                   | 59.73 (±9.48) | 59.00 (±15.81) | 37.47 (±10.41) | 63.27 (±17.61) | 59.07 (±14.97) | 45.87 (±24.13) |
|                                    | Negation of positive with neutral stuff in the middle | 32.2 (±4.65) | 35.13 (±19.1) | 35.00 (±16.52) | 19.00 (±8.66) | 40.93 (±4.31) | 29.13 (±10.60) |
|                                    | Change Names                                   | 0.70 (±0.14) | 1.91 (±0.71) | 1.11 (±0.51) | 0.81 (±0.14) | 1.61 (±0.62) | 1.91 (±1.51) |
|                                    | Change Locations                               | 3.33 (±0.74) | 2.73 (±1.15) | 3.40 (±0.86) | 3.07 (±1.79) | 3.00 (±0.33) | 3.20 (±1.57) |
|                                    | Change Numbers                                 | 0.80 (±0.00) | 0.53 (±0.34) | 0.47 (±0.41) | 0.60 (±0.33) | 0.60 (±0.43) | 0.67 (±0.81) |

### Table 12: Functional Tests: NLI

| Capability                          | Test Type                                      | ER criteria       |
|-------------------------------------|------------------------------------------------|-------------------|
|                                     |                                                | None  | MSE  | MAE  | BCE  | Huber | Order |
| **Vocabulary**                      |                                                | 71.66 (±20.98) | 64.77 (±21.97) | 84.55 (±11.53) | 65.88 (±21.40) | 74.77 (±20.41) | 62.55 (±13.16) |
| Antonym in Hypothesis               | Synonym in Hypothesis                          | 32.61 (±7.41) | 24.11 (±7.62) | 30.11 (±6.42) | 25.88 (±6.86) | 30.77 (±7.07) | 29.27 (±6.95) |
| Supertype in Hypothesis             | 24.44 (±15.95)                                 | 11.00 (±6.62) | 13.77 (±6.71) | 9.31 (±5.90) | 8.77 (±8.06) | 13.55 (±7.10) | |
|                                    | Punctuation                                    | 14.55 (±4.13) | 9.44 (±2.79) | 11.33 (±1.63) | 8.11 (±1.19) | 10.00 (±2.58) | 9.88 (±2.51) |
|                                    | 2 Typos                                        | 15.88 (±3.44) | 10.22 (±3.04) | 12.33 (±1.63) | 9.66 (±2.01) | 10.88 (±2.68) | 10.77 (±2.52) |
|                                    | Contractions                                    | 15.33 (±3.68) | 9.77 (±1.81) | 12.00 (±1.76) | 9.44 (±2.31) | 11.11 (±2.99) | 10.00 (±2.66) |
|                                    | Negation in the Hypothesis                      | 50.88 (±32.25) | 27.77 (±37.24) | 9.77 (±15.66) | 41.33 (±41.54) | 15.22 (±28.77) | 18.44 (±23.21) |
|                                    | Induce Contradiction                            | 99.88 (±0.31) | 98.54 (±3.78) | 91.69 (±20.37) | 98.65 (±2.56) | 98.42 (±4.44) | 99.88 (±0.31) |
|                                    | Same Premise and Hypothesis                     | 14.22 (±8.63) | 14.33 (±10.14) | 19.44 (±12.12) | 18.16 (±12.69) | 14.38 (±9.23) | 17.38 (±10.16) |
|                                    | Switch one Entity in the Hypothesis             | 77.21 (±39.57) | 88.88 (±24.11) | 79.91 (±22.20) | 85.18 (±30.04) | 83.83 (±24.25) | 96.40 (±4.85) |