Learning Negation in Multimodal Models via Task Augmentation

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Abstract

Multimodal learning can benefit from the representation power of pretrained Large Language Models (LLMs). However, state-of-the-art transformer based LLMs often ignore negations in natural language and there is no existing benchmark to quantitatively evaluate whether multimodal transformers inherit this weakness. In this study, we present a new multimodal question answering (QA) benchmark adapted from labeled music videos in AudioSet (Gemmeke et al., 2017) with the goal of systematically evaluating if multimodal transformers can perform complex reasoning to recognize new concepts as negation of previously learned concepts. We show that with standard fine-tuning approach multimodal transformers are still incapable of correctly interpreting negation irrespective of model size. However, our experiments demonstrate that augmenting the original training task distributions with negated QA examples allow the model to reliably reason with negation. To do this, we describe a novel data generation procedure that prompts the 540B-parameter PaLM model to automatically generate negated QA examples as compositions of easily accessible video tags. The generated examples contain more natural linguistic patterns and the gains compared to template-based task augmentation approach are significant.

1 Introduction

Large language models (LLMs) have difficulty understanding negation in natural language. Pretrained LLMs often ignore negation in cloze questions and give same prediction for negated ("Birds cannot [MASK]") and non-negated ("Birds can [MASK]") queries (Kassner and Schütze, 2019; Hosseini et al., 2021). Hossain et al. (2022) analyzed the training corpora of state-of-the-art LLMs and found that negation is rarely present, leading to the poor handling of negation at inference time.

State-of-the-art multimodal learning leverages pretrained LLMs for fusing different modalities (Jia et al., 2021; Radford et al., 2021; Oncescu et al., 2021; Kilgour et al., 2022; Nagrani et al., 2022). Will the fine-tuned LLMs intended for multimodal applications inherit the negation problem? Huang et al. (2022) showed that the zero-shot performance on the text query based audio retrieval task degrades when the text query includes negation cues, e.g., "no vocals". Yu et al. (2022) showed that the text-to-image model generates items that are mentioned in the text prompt, even when the prompt suggests the absence of the item. However, there is no benchmark for quantitatively evaluation of how well negation patterns in the text are handled in such multimodal settings.

In this study, we created MAQA, a binary music audio question answering benchmark, to evaluate how well the multimodal transformers understand negation in music related questions. This benchmark is created from labeled videos in the music-related portion of AudioSet (Gemmeke et al., 2017). While the original benchmarks focus on probing the musical knowledge of an audio model and only contains a handful of examples including negation, the proposed benchmark MAQA features a significant portion of negated questions that are generated programmatically from the original audio labels. Our goal is to evaluate if multimodal transformer can be fine-tuned to understand new concepts, e.g., “no vocals” as negation of the previously learned concept, e.g., “vocals” through compositional generalization.

The main contributions of the paper are: (1) A compositional generalization experiment that demonstrates standard fine-tuning prevents our baseline model, a multimodal transformer modified from the multilingual T5 (MT5) (Raffel et al., 2019; Xue et al., 2021) from generalizing to new concepts that are negation of learned concepts. (2) A PaLM-based data generation approach that au-

tomatically generate negated QA examples from easily access video tags. (3) Two task augmentation strategies that lead to a significant boost of the model performance on portion of MAQA with text negation.

The rest of this paper is organized as follows. Section 2 provides relevant background and related work on negation, compositional generalization and multimodal learning. Section 3 provides an overview of the MAQA dataset and its statistics. Section 4 details how we create the benchmark through data generation. Section 5 describes the experiment design to measure compositional generalization. The models and experiment results are presented in Section 6 and 7. The paper closes with a discussion on the limitations, implications of our results and future work.

2 Related Works

Negation. Despite improvements of LLMs in many NLP tasks such as natural language understanding, reading comprehension, zero-shot text generation, negation remains a challenge for pre-trained LLMs (Kassner and Schütze, 2019; Hosseini et al., 2021). Data augmentation has been used to tackle negation in the NLP literature. For example, modification of the natural language understanding corpora by adding negation to the verb or adjective and reversing the labels was proposed in (Hossain et al., 2020), and an unlikelihood loss for the span corruption pre-training tasks was proposed in (Hosseini et al., 2021). Negation is also addressed in the meta-learning literature (Murty et al., 2021), where it is treated as one of the reasoning categories that requires additional few-shot classification tasks to augment the original task distribution.

Compositional Generalization. Compositional Generalization refers to the ability to understand novel concept as compositions of previously learned concept or *atoms*. Negation can be thought as a form of composition. In the field of semantic parsing, several benchmarks have been proposed to evaluate compositional generalization (Lake and Baroni, 2018; Keysers et al., 2020; Kim and Linzen, 2020), which have encouraged development of techniques and architectures to make LLMs better at solving compositional tasks (Furrer et al., 2020; Ontanon et al., 2022; Csordás et al., 2021; Qiu et al., 2022). Several multimodal benchmarks have shown visually grounded LLMs often struggle with compositional generalization in visual reasoning tasks (Johnson et al., 2017), visual grounded command following tasks (Ruis et al., 2020), text-to-image matching (Zhang et al., 2021), etc. Our study focus on evaluating audio grounded LLMs on compositional tasks involves negation.

Multimodal QA. Multimodal question answering benchmarks are used to probe the multimodal models to evaluate their perception and reasoning capability on different modalities. Visual Question Answering benchmarks (Zhang et al., 2015; Agrawal et al., 2015) commonly consist of triplets of (image, a natural language question about the image, answer), and the task is to answer the question based on the visual cue in the image. In the field of audio perception, audio QA benchmarks (Fayek and Johnson, 2020) are less common than audio classification benchmarks (Gemmeke et al., 2017). In the music domain, most benchmarks are music information retrieval tasks (Law and Von Ahn, 2009), where the text labels are usually in the format of short form music tags.

Multimodal Transformers. A series of Transformer-based multimodal models (Sun et al., 2019; Tan and Bansal, 2019; Lu et al., 2019), referred to as "Multimodal Transformers" in this study, explored using Transformer encoder as a join encoder for multimodal fusion achieve state-of-the-art results on a range of multimodal QA tasks. Changpinyo et al. (2022) proposed a multimodal version of T5 (Raffel et al., 2019). Given the image and the question in a VQA example, the multimodal T5 takes the global and regional image features generated by a pre-trained visual encoder and text tokens of the question as inputs, and solves a classification problem with pre-defined classes of answers for the VQA task. The parameters of the visual encoder are frozen during T5 fine-tuning. We follow the same approach but use pre-trained audio encoders (Gemmeke et al., 2017; Huang et al., 2022) to extract global representation of the music audio. A detailed survey of audio representation can be found in Huang et al. (2022).

3 Music Audio Question Answering (MAQA)

To evaluate the ability of multimodal models to reason with negation, we create a music audio QA benchmark (MAQA) which emphasizes on correct understanding of text negation. The music audio QA pairs are generated programmatically from the

music related portion of AudioSet (Gemmeke et al., 2017), which contains music audio clips annotated with music attributes and an ontology describing their relationship. There are $388,262$ and $4,497$ unique music audio clips in the train and evaluation split, respectively. Each clip is labeled with one or more music tags out of the 141 unique music attributes covering music genres, music roles, music instruments and music moods.

Table 1 presents an example in MAQA, which consists of four QA pairs generated from an example of music attribute labeled audio clip in AudioSet. Q1 and Q2 are questions generated from the same seed attribute, and essentially probe about the same musical skill, i.e., listen to a music audio and try to identify if a bass guitar is played. Q2 is a negated form of Q1. If a model answer Q1 correctly and fail on its negated counterpart Q2, it suggests that the model does not understand the negation logic in the question and unable to perform compositional generalization.

MAQA contains two evaluation sets ASBaseEval and ASNegationEval and two training sets ASBaseTrain and ASNegationTrain as shown in Table 2 with balanced binary label distribution. ASBaseTrain / ASBaseEval contains non-negated QA pairs about music audio recordings. ASNegationTrain / ASNegationEval is a superset of ASBaseTrain / ASBaseEval, and it also includes their negated counterparts of the QA pairs. A multimodal model with strong music audio understanding capabilities should score high on ASBaseEval. Moreover, to demonstrate its ability of reasoning about negation logic, it has to also score high on ASNegationEval.

4 Data Generation

Since music descriptive text that involves negation rarely occur in the standard text corpora (Hossain et al., 2022), we propose the following 3-step approach to programmatically generate binary audio QA pairs that involve text negation: 1. For each music audio-attribute pair in the original dataset, we sample a negative attribute that is not associated with the audio clip. 2. Convert the positive and the negative audio-attribute pair into a binary AQA example in the format of a triplet (audio clip, question on the attribute, *True* / *False* label). 3. Perform a text negation on the question and flip the binary label simultaneously to create *negated* audio QA pairs. As a first attempt we curate MAQA from AudioSet with this method, however it can be applied to other datasets containing annotated music audios. Next, we discuss the details of how we followed the 3 steps to create MAQA from AudioSet.

Negative Attribute Sampling. We adopt negative sampling to create a balanced binary label distribution. In particular, we sample hard negative attributes using sibling nodes in the ontology tree and assign *False* label to the derived audio QA pair. Consider the example in Table 1, the audio clip is tagged with *Bass guitar* and *Acoustic guitar*, which are both under the parent node *Guitar*. We sample hard negative attributes *steel guitar* and *slide guitar* from the sibling nodes, to create a negative audio-attribute pair. This hard negative sampling approach encourages the model to differentiate related but different music concepts.

Question Generation. We explore the following two approaches to generate questions from the audio-attribute pair sampled from the first step, which help us to create the base QA dataset, i.e., ASBaseEval and ASBaseTrain. The first approach is template based, and it takes advantage of the AudioSet ontology, where each music attribute is associated with one of the four attribute types: genres, roles, instruments, and moods. We use type-specific templates to convert attributes into a true-or-false question, e.g., "The [*Attribute Type*] of the song is [*Attribute Value*].". For example, the attribute *Bass Guitar* is a type of musical instrument according to the AudioSet ontology. The question generated by the template-based approach is "The [*musical instrument*] of the song is [*Bass Guitar*].".

The second approach leverages the few-shot text generation capability of PaLM (Chowdhery et al., 2022) to improve the diversity of generated questions. Similar to GPT-3 (Brown et al., 2020), when prompted with an instruction, e.g., "Generate a sentence about music given the music attribute", PaLM learns from a few demonstrations and generates questions on unseen attributes. Example questions generated by PaLM are shown in Table 1. We explored different combinations of text prompts and model hyper-parameters (e.g., temperature) to control the diversity of generated texts.

Task Augmentation with Negation. For each QA pair generated from the last step, we negate the question and reverse its binary answer to create a negated audio QA pair. By augmenting the ASBaseEval and ASBaseTrain with their negated counterparts, we create ASNegationEval and AS-

NegationTrain. If this negation augmentation step is applied to the training data then we refer to it as *Task Augmentation*. Again we explore both template-based and PaLM-based approaches for text negation.

The template-based approach convert a question to the negation form by inserting a modifier *not* before the noun, i.e., "The [*Attribute Type*] of the song is *not* [*Attribute Value*]." and the binary label is flipped. One of the limitation of this approach is that it is attribute type specific and only modifies nouns. PaLM based method overcomes such limitation with few shot text generation, which allows the model to generate different negation patterns by modifying both nouns and verbs. For example, the negation patterns associated with the instrument attribute "guitar" include "no guitar", "guitar is not played", and "the song does not feature guitar". For each music attribute, we use PaLM to generate a few question candidates and manually pick the best one. Row 2 and 4 in Table 1 are example questions generated in this way. The text prompts to PaLM can be found in Appendix C.

5 Compositionality Experiment Design

To evaluate model's ability to generalize compositionally so that it can understand composed music concepts like "no vocals" that involve negation, we split the data into train and test sets following the design recommended by (Keysers et al., 2020). In our setup, music attributes are the the basic knowledge structures or *atoms*, and all the generated music-related questions or the *compounds* are the results of applying compositional rules, e.g., negation to these basic building blocks. The Template-based and Model-based data generation procedures detailed in Section 4 can be thought of different ways to compose music atoms into QA compounds.

Consider using the question "The song is played with a banjo" composed by PaLM as testing examples and "The [musical instrument] of the song is [banjo]" composed by templates as training examples. Both questions are composed from the atom "banjo" so they evaluate the same music knowledge, but the resulted compounds are different as the combinations of the atoms are different. To prove a model is capable of compositional generalization, the train and test split should have similar *atoms* distributions and different *compounds* distributions (Keysers et al., 2020). Therefore, by design the music attributes are similarly represented in the train and test sets (Table 2), while the test set contains novel combinations of the atoms that are not seen in the train set.

Compound Divergence is used to measure quantitatively how different is the compound distributions in the train and test split (Keysers et al., 2020). Here we use Compound Divergence (CD) as a qualitative measure of how much a train-test split measures the compositional generalization ability of the multimodal models. As shown in Table 3, we define five train-test split scenarios labeled by the CD type. The scenario with highest CD is the most challenging case for compositional generalization. Below we list the research questions we try to answer with these experiments and analyze the results in details in Section 7:

1. Can multimodal transformers be fine-tuned to solve QA tasks with in-domain music concepts? (Section 7.1)

2. Does the standard multimodal fine-tuning allow the multimodal transformer to generalize to QAs composed from in-domain concepts via negation? (Section 7.2)

3. Will task augmentation help with QA tasks that require reasoning with negation? (Section 7.3 and 7.4)

6 Multimodal Modeling

Following the VQA literature (Changpinyo et al., 2022; Zhang et al., 2015), we treat the audio QA as a binary classification task. We adopt a multimodal T5 architecture similar to that in Changpinyo et al. (2022) to fuse the audio and text inputs, and we replace T5 with its multilingual version MT5 (Xue et al., 2021). Each music audio clip input is represented as a 128-dimensional embedding obtained either from VGGish (Gemmeke et al., 2017)[1], which uses a VGG ConvNet architecture, or the transformer based MuLan model (Huang et al., 2022). The audio embedding and text tokens are fed into the pre-trained multi-layer MT5 (Xue et al., 2021) encoder as a sequence of vectors and the final multimodal representation is classified into the binary classes. The audio embeddings are projected to the text token embedding space through a linear projection layer, which is initialized randomly at the beginning of finetuning. The model is

[1] https://github.com/tensorflow/models/tree/master/research/audioset/vggish

Sampled Attributes	Question	Answer	Negated
Bass guitar (+)	Q1)The musical instrument played in the song is **Bass guitar**	TRUE	No
Bass guitar (+)	Q2)**Bass guitar** is not played in the song	FALSE	Yes
steel guitar, slide guitar (−)	Q3)The song has **steel guitar** or **slide guitar**	FALSE	No
steel guitar, slide guitar (−)	Q4)The song does not have **slide guitar** or **steel guitar**	TRUE	Yes

Table 1: Examples of generated Binary Audio QA Pairs in MAQA. The original AudioSet example is a music audio clip associated with the following tags: *Bass guitar, Guitar, Acoustic guitar and Strum*. Questions and their negated counterpart are generated from the sampled attributes with the PaLM based approach. Negative attributes *steel guitar, slide guitar* are sampled from the sibling nodes in the AudioSet ontology.

Data Version	QA Type	Label Stats		# of QA Pairs		# of mentions			
		True	Negated	Non-negated	Negated	Genre	Mood	Instrument	Role
ASBaseEval	PALM	50%	0%	17,028	0	5574	730	9740	984
ASNegationEval	PALM	50%	50%	17,028	17,028	(32.7%)	(4.3%)	(57.2%)	(5.8%)
ASBaseTrain	TEMP/PALM	50%	0%	1,263,004	0	439,904	28,634	740,126	54,340
ASNegationTrain	TEMP/PALM	50%	50%	1,263,004	1,263,004	(34.8%)	(2.3%)	(58.6%)	(4.3%)

Table 2: Statistics on Music Audio QA (MAQA) Benchmark. Both evaluation sets ASBaseEval and ASNegationEval are generated by PaLM. Each training set has a template-generated and a PaLM-generated version. All the datasets have balanced binary label distributions. ASNegationEval contains ASBaseEval and its negated counterparts. The music attributes have a simialr distribution in training and evaluation split.

warm started from the MT5 checkpoints[2] without pre-training on other multimodal data. The multimodal code is based on the Flaxformer framework[3]. Training details can be found in Appendix A.

7 Results and Analysis

We report experiment results on the ASBaseEval and ASNegationEval evaluation benchmark in Table 4 and Table 5 respectively. The Audio QA task is formulated as a binary classification problem, and we report the best AUC-ROC score and the corresponding accuracy in the positive class. For each split scenario, we compare the performance of fine-tuned multimodal transformer with different audio feature extractors, as well as with different sized pre-trained MT5 model. Furthermore, we vary the types of QA pairs (template-based or PaLM-based) used in training and study how compound divergence affects learning negation.

7.1 Music Understanding

Table 4(a) shows the result for the first split scenario in Table 3 where the model is trained and evaluated on non-negated QA pairs generated by PaLM. This Low CD experiment establish a fine-tuning baseline on basic music concepts. The fine-tuned multimodal MT5 score over 90% AUC-ROC on the ASBaseEval benchmark that features Audio QA tasks on music styles, moods, genres, instruments, etc. Recall the random baseline is 50% for balanced binary classification tasks, this suggests multimodal transformer learn to efficiently fuse audio and text signals through fine-tuning, even it is warm started from a text-only checkpoint. Probing the model on different music attributes suggests that music concepts like "Scary music", "Children music" and popular percussion instruments like "Cowbell" are easy for the fine-tuned model to pick up, while the model has a harder time to understand electronic music genres such as "Drum and bass", "Trance music".

We further replace the training examples generated by PaLM with the template-generated QA examples for the second split senario, resulting in a Medium CD setting (Table 3). The model scores around 6% lower in the Medium CD setting (Table 4(b)) compared to the Low CD setting. This suggest the model can still transfer most of the music knowledge learned in a different linguistic context via compositional generalization. For both split scenarios the best multimodal model is the MT5-XL with Mulan embedding as audio features.

7.2 Reasoning with Negation

For the third split scenario we apply the same fine-tuning setup as in Table 4(a) but evaluate on ASNegationEval, where the non-negated half is from ASBaseEval and the other half contains their negation counterparts. As shown in Table 5(a), the mul-

[2]https://github.com/google-research/multilingual-t5
[3]https://github.com/google/flaxformer

Attribute	Train Examples	Test Examples	CD Type	Eval Set
(a) Without Task Augmentation (ASBaseTrain)				
Banjo	The song is played with a **banjo**. (PaLM)	The song is played with a banjo. (PaLM)	Low CD	ASBaseEval
Blues	The [genre] of the song is [**blues**]. (Temp)	The song is a blues song. (PaLM)	Med CD	ASBaseEval
Scary	The music is **scary**.(PaLM)	The music is **scary**.(PaLM) The music is not **scary**.(PaLM)	High CD	ASNegationEval
(b) With Task Augmentation (ASNegationTrain)				
Chant	The music is a **Chant**.(PaLM) The music is not a **Chant**.(PaLM)	The music is a **Chant**.(PaLM) The music is not a **Chant**.(PaLM)	Low CD	ASNegationEval
Dance music	The [music role] of the song is [**Dance music**].(Temp) The [music role] of the song is not [**Dance music**].(Temp)	The music is suitable for **dancing**. (PaLM) The music is not suitable for **dancing**. (PaLM)	Med CD	ASNegationEval

Table 3: The train and test split design of MAQA. For each of the 5 split scenarios we list a few example questions included in the train and test split. All the QA examples or *compounds* are composed from the seed music attributes or *atoms* via Template-based (Temp) or PaLM-based (PaLM) approach. Compound Divergence (CD) Type is used to measure the difference between the train and test compound distribution. Task Augmentation is applied during training for the ASNegationEval-LowCD and ASNegationEval-MedCD split scenario.

timodal MT5 fine-tuned on non-negated audio QA pairs (ASBaseTrain) scores only 50% on the ASNegationEval benchmark in this High CD setting. Although the model still scores around 80% on the non-negated QAs (comparable to the accuracy on ASBaseEval in Table 4), it scores only around 20% on their negated counterparts. The model does worse than the 50% random guess baseline on these negated questions after fine-tuning. This shows that while the model is trained to answer the non-negated questions correctly, they also learn to "ignore" the negation cue in the negated questions. We also show that increasing the model size does not improve the AUC-ROC score, suggesting that even larger model fail to generalize compositionally using the standard fine-tuning approach.

7.3 Task Augmentation

We then apply task augmentation during training by augmenting ASBaseTrain with negated QA example generated by PaLM (AsNegationTrain-PaLM), which lower the compound divergence. The task augmentation proves to be an effective strategy for tackling negation. As shown in Table 5(b), multimodal MT5 fined-tuned with task augmentation improves the baseline on ASNegationEval as shown in Table 5(a) by nearly 40%, while obtaining similar performance on the non-negated QA pairs (ASBaseEval). The AUC-ROC score and accuracy is on par with the scores on the non-negated Audio QA pairs (ASBaseEval), suggesting that task augmentation can indeed help the model to learn to answer the questions with negation correctly. The best result on ASNegationEval is obtained by fine-tuned MT5-XL with MuLan audio embedding.

7.4 Template versus PaLM

We further explore how different task augmentation strategy affects the learning outcome. As shown in Table 5(c), we use template-based approach for composing QA pairs and task augmentation, and compare with the fine-tuning results with PaLM-generated QA pairs. The Template-based fine-tuning scores around 10% lower in AUC score compared to PaLM-based fine-tuning. The observed gap can be explained by the increased compound divergence between the training data and the evaluation data. The accuracy difference on the non-negated split is around 7% while the difference on the negated split is around 10% to 12%. Recall that the template-based approach only modifies the noun for negation while Palm-based approach incorporates more variations, which can explain why the template-based fine-tuning performs worse on the negated split. This experiment has highlighted the importance of composing augmented tasks with natural linguistic variations that match human language used in production environment. However, even Template-based task augmentation can improve negation understanding significantly, on average 30% higher than training without task augmentation (Table 5(a)).

	Finetuning Details		ASBaseEval		
	Model	**Train Data - QA Type**	**CD Type**	AUC	Acc
a)	MT5-Base+VGGish	ASBaseTrain-PaLM	Low CD	0.905	0.821
	MT5-XL+VGGish	ASBaseTrain-PaLM	Low CD	0.911	0.827
	MT5-Base+MuLan	ASBaseTrain-PaLM	Low CD	0.913	0.828
	MT5-XL+MuLan	ASBaseTrain-PaLM	Low CD	**0.918**	**0.832**
b)	MT5-Base+VGGish	ASBaseTrain-Temp	Med CD	0.847	0.771
	MT5-XL+VGGish	ASBaseTrain-Temp	Med CD	0.850	0.765
	MT5-Base+MuLan	ASBaseTrain-Temp	Med CD	0.845	0.766
	MT5-XL+MuLan	ASBaseTrain-Temp	Med CD	**0.851**	**0.767**

Table 4: Accuracy on ASBaseEval for two different Compound Divergence (CD) settings.

	Finetuning Details		ASNegationEval				
					Acc		
	Model	**Train Data - QA Type**	**CD Type**	AUC	Avg	Negated	Non-negated
a)	MT5-Base+VGGish	ASBaseTrain-PaLM	High CD	0.524	0.513	0.218	0.803
	MT5-XL+VGGish	ASBaseTrain-PaLM	High CD	0.525	0.525	0.247	0.802
	MT5-Base+MuLan	ASBaseTrain-PaLM	High CD	**0.553**	**0.541**	**0.273**	**0.802**
	MT5-XL+MuLan	ASBaseTrain-PaLM	High CD	0.528	0.520	0.220	0.819
b)	MT5-Base+VGGish	ASNegationTrain-PaLM	Low CD	0.896	0.814	0.814	0.813
	MT5-XL+VGGish	ASNegationTrain-PaLM	Low CD	0.903	0.821	0.821	0.821
	MT5-Base+MuLan	ASNegationTrain-PaLM	Low CD	0.905	0.821	0.821	0.822
	MT5-XL+MuLan	ASNegationTrain-PaLM	Low CD	**0.907**	**0.825**	**0.825**	**0.825**
c)	MT5-Base+VGGish	ASNegationTrain-Temp	Med CD	0.784	0.715	0.690	0.741
	MT5-XL+VGGish	ASNegationTrain-Temp	Med CD	0.823	0.743	0.724	0.763
	MT5-Base+MuLan	ASNegationTrain-Temp	Med CD	0.805	0.739	0.723	0.755
	MT5-XL+MuLan	ASNegationTrain-Temp	Med CD	**0.828**	**0.750**	**0.740**	**0.759**

Table 5: Accuracy on ASNegationEval for three different Compound Divergence (CD) settings.

8 Considerations and Limitations

While most PaLM-generated examples generated can be used without modifications, we still have to rely on human supervision to make judgement on some ambiguous examples, e.g., "The song has a Guitar solo", "There is a drum roll at the beginning of the song". These generated sentences are consistent with the music tag, but can be correct or incorrect depending on the specific music audio context. For our experiment the number of music tags are small (around 100) so human supervision is still affordable. For large number of tags we still need to develop programs to automatically filter irrelevant candidates. Furthermore, there is a trade-off between the diversity and reliability of the PaLM-generated output, which is mainly controlled via the prompts and hyper-parameters. We hope to see future studies on automatic prompts tuning so that we don't have to design task-specific prompts.

9 Conclusion

In this work, we propose a new Binary Audio QA benchmark MAQA in the music domain to probe the state-of-the-art multimodal models on understanding negation. MAQA fills in the gap of lacking negation-focused evaluation benchmark in the multimodal setting. Our experiments show that standard fine-tuning prevents the multimodal transformers from generalizing to new concepts that are negation of the learned concepts. While increasing the model size or adopting a better audio encoder doesn't help with negation, task augmentation allows the model to reason with negation by providing more fine-tuning examples that contain negation. And LLMs like PaLM can be used to generate negated examples with more natural linguistic variations, which have a significant effect on the learning outcome. With the MAQA benchmark, we hope to encourage multimodal research community to develop new modeling frameworks or algorithms to handle complex natural language instructions that involves negation. We plan to release the MAQA dataset on Github.

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Model	ASBaseEval-Temp		ASNegationEval-Temp	
	AUC	Acc	AUC	Acc
MT5-Base + VGGish	0.907	0.822	0.505	0.502
MT5-Base + MuLan	0.909	0.827	0.505	0.504
MT5-XL + VGGish	0.907	0.826	0.514	0.509
MT5-XL + MuLan	**0.916**	**0.833**	**0.515**	0.506

Table 6: Fine-tuned results on ASBaseTrain without Task Augmentation on template-generated QAs.

Model	ASBaseEval-Temp		ASNegationEval-Temp	
	AUC	Acc	AUC	Acc
MT5-Base + VGGish	0.893	0.804	0.877	0.800
MT5-Base + MuLan	0.905	0.825	0.901	0.820
MT5-XL + VGGish	0.903	0.818	0.903	0.820
MT5-XL + MuLan	**0.914**	**0.829**	**0.908**	**0.834**

Table 7: Fine-tuned results on ASNegationTrain, with Task Augmentation on template-generated QAs.

A Training Details

For the MT5-base encoder there are 12 Transformer encoder layers and the input embedding dimension is 768. For MT5-XL there are 24 Transformer encoder layers and the input embedding dimension is 2048. MT5-XL has 3.7 billion parameters and MT5-base has 580 million parameters. The batch size is 64 for MT5-base model and 128 for MT5-XL model. We use fixed a learning rate among $\{10^{-3}, 10^{-4}, 5^{-5}\}$ and observe 1×10^{-3} works best in general. The model outputs 2-dimensional logits as the Audio QA task is formulated as binary classification. We train all models with data parallelism using 16 Cloud TPU Pods. For all experiments we run for $50,000$ steps and reports the AUCROC and Accuracy based on the best checkpoint measured by AUCROC. For each experiment we pick the highest AUCROC of multiple runs. It takes around 1 hour for MT5-Base and around 4 hours for MT5-XL.

B Results with Template-generated QAs

Table 6 and Table 7 shows the results on template-generated QA evaluation set. The QA pairs in both train and evaluation set are generated using templates. The results further reinforce the findings based on PaLM-generated evaluation set (Table 4 and Table 5). Table 6 shows standard fine-tuning on audio QA pairs prevents multimodal transformers from learning negation, and Table 7 shows task augmentation help with negation by reducing the compound divergence.

C Text Prompts used for PaLM

After a few iterations, we've found the text prompts shown in Table 8 works best for generating negated and non-negated QA pairs. The one-line instruction at the beginning of the prompt is crucial to guide PaLM to generate desired sentences. Table 9 shows more PaLM-generated questions. The total number of seed attributes used for text generation are 130, and for each attribute we pick one non-negated and one negated question selected from the candidate questions generated from PaLM.

D Further Considerations

Risk The QA examples generated by PaLM are supervised by the authors to ensure there is no offensive content generated, hence the risk to open source the data is low.

Information that names or uniquely identifies individual people or offensive content Our data is derived from the music portion of Audio Set, which contains audio features and tags of 10s YouTube video clips rated by Human raters. No metadata or personal identifiable information on these YouTube videos have been exposed.

User Input (Music Tag): *Trumpet*

Model Input:

Generate a sentence about music and its negation given the music tag
music tag: drum
describe the music: The music is played with a drum
negate the description: drum is not played in the song
music tag: rock
describe the music: This is a rock song
negate the description: the genre for the song is not rock
music tag: happy
describe the music: The music makes one feel happy
negate the description: The mood of the song is not happy
music tag: Choir
describe the music: The song features a choir
negate the description: The song does not feature a choir
music tag: Tabla
describe the music: Tabla is played in the song
negate the description: Tabla is not played in the song
music tag: *Trumpet*
describe the music: <*extra_id_1*>
negate the description: <*extra_id_2*>

Model Output:

<*extra_id_1*>: A trumpet is played in this song
<*extra_id_2*>: A trumpet is not played in this song

Table 8: Text prompts used for PaLM to generate non-negated and negated sentences from a seed music attribute. Here we show a example output for the attribute *Trumpet*.

Intended uses. AudioSet is made available by Google Inc. under a Creative Commons Attribution 4.0 International (CC BY 4.0) license, while the ontology is available under a Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) license. As all the QA examples in MAQA benchmark are derived from AudioSet, it is subject to the same license as AudioSet. MAQA is intended to use for research-only purposes.

Seed Attribute	Generated Questions	Generated Negated Questions
A capella	The song is sung without any musical instruments	The song is not sung without any musical instruments
Accordion	The musical instrument of the song is accordion	accordion is not played in the song
Acoustic guitar	The song is played with an acoustic guitar	The song is not played with an acoustic guitar
Ambient music	The song is ambient music	The song is not ambient music
Angry music	The song makes one feel angry	The mood of the song is not angry
Background music	The song is background music	The song is not background music
Bagpipes	The musical instrument of the song is Bagpipes	Bagpipes is not played in the song
Banjo	The song is played with a banjo	The song is not played with a banjo
Bass drum	The musical instrument of the song is Bass drum	Bass drum is not played in the song
Bass guitar	The musical instrument of the song is Bass guitar	Bass guitar is not played in the song
Beatboxing	Beatboxing features in the song	Beatboxing does not feature in the song
Bell	The musical instrument of the song is bell	bell is not played in the song
Bluegrass	The genre of the song is bluegrass	bluegrass is not the genre of the song
Blues	The song is a blues song	the song is not a blues song
Bowed string instrument	The musical instrument of the song is a bowed string instrument	The music is not played with a bowed string instrument
Brass instrument	The musical instrument of the song is brass	brass is not played in the song
Carnatic music	The music is Carnatic	The music is not Carnatic
Cello	The musical instrument of the song is Cello	Cello is not played in the song
Chant	The music is a chant	The music is not a chant
Choir	The song features a choir	The song does not feature a choir
Christian music	It is Christian music	It is not Christian music
Christmas music	The music is Christmas music	The music is not Christmas music
Clarinet	The song is played by clarinet	clarinet is not played in the song
Classical music	The music is classical	The genre for the song is not classical
Country	The genre of the song is Country	This is not a Country song
Cowbell	The song has cowbell	The song does not have cowbell
Cymbal	The musical instrument of the song is Cymbal	Cymbal is not played in the song
Dance music	The music is suitable for dancing	The music is not suitable for dancing
Didgeridoo	The music is played on a didgeridoo	The music is not played on a didgeridoo
Disco	The song belongs to the disco genre	The song does not belong to the disco genre
Double bass	The musical instrument of the song is double bass	double bass is not played in the song
Drum and bass	The music is drum and bass	The song is not drum and bass

Table 9: More examples of PaLM-generated non-negated and negated questions.