

# VATEX: A Large-Scale, High-Quality Multilingual Dataset for Video-and-Language Research

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## Abstract

We present a new large-scale multilingual video description dataset, VATEX<sup>1</sup>, which contains over 41,250 videos and 825,000 captions in both English and Chinese. Among the captions, there are over 206,000 English-Chinese parallel translation pairs. Compared to the widely-used MSRVTT dataset [63], VATEX is multilingual, larger, linguistically complex, and more diverse in terms of both video and natural language descriptions. We also introduce two tasks for video-and-language research based on VATEX: (1) Multilingual Video Captioning, aimed at describing a video in various languages with a compact unified captioning model, and (2) Video-guided Machine Translation, to translate a source language description into the target language using the video information as additional spatiotemporal context. Extensive experiments on the VATEX dataset show that, first, the unified multilingual model can not only produce both English and Chinese descriptions for a video more efficiently, but also offer improved performance over the monolingual models. Furthermore, we demonstrate that the spatiotemporal video context can be effectively utilized to align source and target languages and thus assist machine translation. In the end, we discuss the potentials of using VATEX for other video-and-language research.

## 1. Introduction

Recently, researchers in both computer vision and natural language processing communities are striving to bridge videos and natural language. For a deeper understanding of the activities, the task of video captioning/description aims at describing the video content with natural language. A few datasets have been introduced for this task and cover a variety of domains, such as cooking [16, 68], movie [46],

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<sup>1</sup>VATEX stands for Video And TEXt, where X also represents various languages.

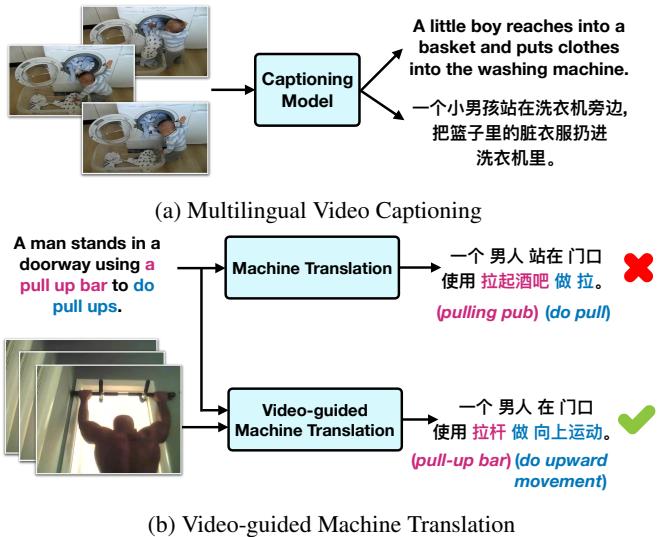


Figure 1: Demonstration of the VATEX tasks. (a) A compact unified video captioning model is required to accurately describe the video content in both English and Chinese. (b) The machine translation model mistakenly interprets “pull up bar” as “pulling pub” and “do pull ups” as “do pull” (two verbs), which are meaningless. While with the relevant video context, the English sentence is precisely translated into Chinese.

human actions [14, 63], and social media [22]. Despite the variants of this task, the fundamental challenge is to accurately depict the important activities in a video clip, which requires high-quality, diverse captions that describe a wide variety of videos at scale. Moreover, existing large-scale video captioning datasets are mostly monolingual (English only) and thus the development of video captioning models is restricted to English corpora. However, the study of multilingual video captioning is essential for a large population on the planet who cannot speak English.

To this end, we collect a new and largest multilingual dataset for video-and-language research, VATEX, that contains over 41,250 unique videos and 825,000 high-quality captions. It covers 600 human activities and a variety of



#### 10 English Descriptions:

- A person wearing a bear costume is inside an inflatable play area as they lose their balance and fall over.
- A person in a bear costumer stands in a bounce house and falls down as people talk in the background.
- A person dressed in a cartoon bear costume attempts to walk in a bounce house.
- A person in a mascot uniform trying to maneuver a bouncy house.
- A person in a comic bear suit falls and rolls around in a moonbounce.
- A person dressed as a teddy bear stands in a bouncy house and then falls over.
- Someone dressed in a bear costume falling over in a bouncy castle.
- A person dressed up as a bear is standing in a bouncy castle and falls down.
- A man in a bear costume is balancing in a bouncy castle before they tumble to the floor.
- A man in costume was trying to stand straight on a bouncy castle but fell.

#### 10 Chinese Descriptions:

- 一个人穿着熊的布偶外套倒在了蹦床上。
- 一个人穿着一套小熊服装在充气蹦蹦床上摔倒了。
- 一个穿着熊外衣的人在充气垫子上摔倒了。
- 一个穿着深色衣服的人正在蹦蹦床上。
- 在一个充气大型玩具里,有一个人穿着熊的衣服站了一下之后就摔倒了。
- 一个打扮成泰迪熊的人站在充气房上,然后摔倒了。
- 有个穿着熊装的人在充气城堡摔倒了。
- 一个装扮成熊的人站在充气蹦床里,然后摔倒了。
- 一个穿着熊服装的人在一个有弹性的城堡里平衡,然后他们就倒在了地板上。
- 一个穿着布偶熊的人试图站在一个充气城堡上,但却摔倒了。

Figure 2: A sample of our VATEX dataset. The video has 10 English and 10 Chinese descriptions. All depicts the same video and thus are distantly parallel to each other, while the last five are the paired translations to each other.

video content. Each video is paired with 10 English and 10 Chinese diverse captions from 20 individual human annotators. Figure 2 illustrates a sample of our VATEX dataset. Compared to the most popular large-scale video description dataset MSR-VTT [63], VATEX is characterized by the following major unique properties. First, it contains both English and Chinese descriptions at scale, which can support many multilingual studies that are constrained by monolingual datasets. Secondly, VATEX has the largest number of clip-sentence pairs with each video clip annotated with multiple unique sentences, and every caption is unique in the whole corpus. Thirdly, VATEX contains more comprehensive yet representative video content, covering 600 human activities in total. Furthermore, both the English and Chinese corpora in VATEX are lexically richer and thus can empower more natural and diverse caption generation.

With the capabilities of the VATEX dataset, we introduce the task of multilingual video captioning (see Figure 1a), which is to train a unified model to generate video descriptions in multiple languages (*e.g.*, English and Chinese). However, *would the multilingual knowledge further reinforce video understanding?* We examine different multilingual models where different portions of the architectures are shared for multiple languages. Experiments show that a compact unified multilingual captioning model is not only more efficient but also more effective than monolingual models.

Video captioning is designed to push forward video understanding with natural language descriptions, but *can video information help natural language tasks like machine translation in return?* To answer this question, we collect around 206K English-Chinese parallel sentences among all the captions and introduce a new task, video-guided machine translation (VMT), to translate a source language description into the target language using the video information as additional spatiotemporal context. We assume that

the spatiotemporal context would reduce the ambiguity of languages (especially for verbs and nouns) and hence promote the alignment between language pairs. So we further conduct extensive experiments and verify the effectiveness of VMT. In Figure 1b, we demonstrate an example where video information can play a crucial role in translating essential information.

In summary, our contributions are mainly three-fold:

- We collect a new large-scale and high-quality multilingual video description dataset for the advance of the video-and-language research, and conduct in-depth comparisons among MSR-VTT, VATEX English corpus, and VATEX Chinese corpus.
- We introduce the task of multilingual video captioning and validate its efficiency and effectiveness of generating video descriptions in both English and Chinese with a compact, unified model.
- We are the first to propose the task of video-guided machine translation and examine the effectiveness of incorporating spatiotemporal context to improve the performance of machine translation.

## 2. Related Work

**Video Description Datasets.** Various datasets for video description/captioning have been introduced to empower different ways to describe the video content, covering a wide range of domains, such as cooking [16, 68, 44, 45], movie [54, 46, 47], social media [22], and human activities [14, 50, 63, 30]. In Table 1, we summarize existing video description datasets [1] and briefly compare their major statistics. Generally, video description tasks can mainly be divided into two families, single-sentence generation (*e.g.*, [14, 63]) and multi-sentence generation (*e.g.*, [30]),

Dataset	MLingual	Domain	#classes	#videos:clips	#sent	#sent/clip
TACoS[44]	-	cooking	26	127:3.5k	11.8k	-
TACoS-MLevel[45]	-	cooking	67	185:25k	75k	3
Youcook[16]	-	cooking	6	88:-	2.7k	-
Youcook II[68]	-	cooking	89	2k:15.4k	15.4k	1
MPII MD[46]	-	movie	-	94:68k	68.3k	1
M-VAD[54]	-	movie	-	92:46k	55.9k	-
LSMDC[47]	-	movie	-	200:128k	128k	1
Charades[50]	-	indoor	157	10k:10k	27.8k	2-3
VideoStory[22]	-	social media	-	20k:123k	123k	1
ActyNet-Cap[30]	-	open	200	20k:100k	100k	1
MSVD[14]	✓	open	-	2k:2k	70k	35
VTW[66]	-	open	-	18k:18k	18k	1
MSR-VTT[63]	-	open	257	7k:10k	200k	20
VATEX (ours)	✓	open	600	41.3k:41.3k	826k	20

Table 1: Comparison of the video description datasets.

though they may appear as different variants due to the difference of the corpora, *e.g.*, video title generation [66] and video story generation [22]. In this work, we present a large-scale, high-quality multilingual benchmark for single-sentence generation, aiming at encouraging fundamental approaches towards a more in-depth understanding of human actions. As shown in Table 1, our VATEX dataset is the largest benchmark in terms of video coverage and the language corpora; it also provides 20 captions for each video clip to take into consideration human variance when describing the same video and hence supports more human-consistent evaluations. Moreover, our VATEX dataset contains both English and Chinese descriptions at scale, which is an order of magnitude larger than MSVD [14]. Besides, MSVD does not have any translation pairs as VATEX does. Therefore, VATEX can empower many multilingual, multimodal research that requires the large-scale training.

**Multilingual Visual Understanding.** Numerous tasks have been proposed to combine vision and language to enhance the understanding of either or both, such as video/image captioning [18, 58, 2], visual question answering (VQA) [4], and natural language moment retrieval [25], etc. Multilingual studies are rarely explored in the vision and language domain. Gao *et al.* [21] introduce a multilingual image question answering dataset, and Shimizu *et al.* [49] propose a cross-lingual method for making use of English annotations to improve a Japanese VQA system. Pappas *et al.* [41] propose multilingual visual concept clustering to study the commonalities and differences among different languages. Meanwhile, multilingual image captioning is introduced to describe the content of an image with multiple languages [32, 55, 33]. However, none of them study the interaction between videos and multilingual knowledge. Therefore, we collect a multilingual dataset for video-and-language research and introduce the task of multilingual video captioning to facilitate multilingual understanding of the video dynamics.

**Multimodal Machine Translation.** The multimodal machine translation task aims at generating a better target sentence by supplementing the source sentence with extra in-

Split	train	validation	public test	secret test
#videos	25,991	3,000	6,000	6,278
action label	✓	✓	-	-

Table 2: The splits of the VATEX dataset (✓ indicates the videos have publicly accessible action labels). For the secret test set, we holdout the human-annotated captions for challenge use.

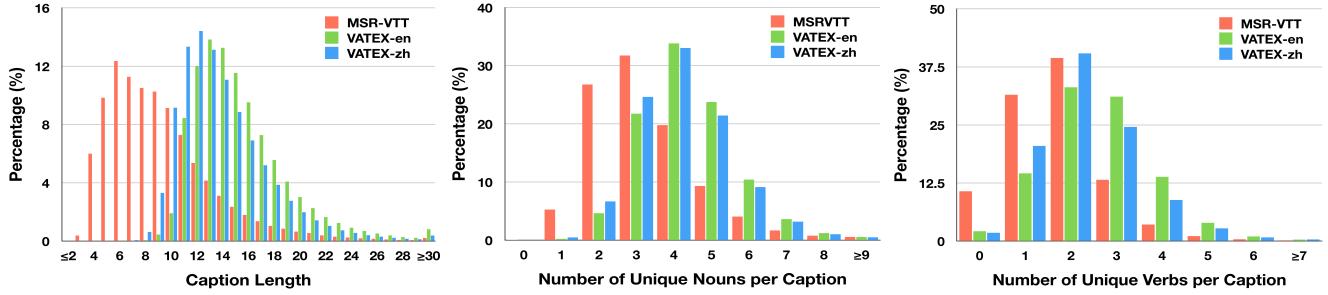
formation gleaned from other modalities. Previous studies mainly focus on using images as the visual modality to help machine translation [52, 19, 6]. The Multi30K dataset [20], which is annotated based on the image captioning dataset Flickr30K [43], is commonly used in this direction. For instance, [27, 23] consider the object features of the images, and [10, 34] import convolutional image features into machine translation. Additionally, other studies [38, 12, 39, 9] explore the cross-modal feature fusion of images and sentences. In this work, we are the first to consider videos as the spatiotemporal context for machine translation and introduce a new task—video-guided machine translation. Compared with images, videos provide richer visual information like actions and temporal transitions, which can better assist models in understanding and aligning the words/phrases between the source and target languages. Moreover, the parallel captions in VATEX go beyond of spatial relations and are more linguistically complex than Multi30K, *e.g.*, a series of actions. Last but not least, our VATEX dataset contains over 206K English-Chinese sentence pairs (5 per video), which is approximately seven times larger than Multi30K.

### 3. VATEX Dataset

#### 3.1. Data Collection

For a wide coverage of human activities, we reuse a subset of the videos from the Kinetics-600 dataset [28], the largest and widely-used benchmark for action classification. Kinetics-600 contains 600 human action classes and around half a million video clips. To collect those videos, Kay *et al.* [28] first built an action list by combining previous video datasets [24, 31, 51, 3, 60], and then searched the videos from YouTube for candidates, which eventually were filtered by Amazon Mechanical Turkers. Each clip lasts around 10 seconds and is taken from a unique YouTube video. The VATEX dataset connects videos to natural language descriptions rather than coarse action labels. Notably, we collect the English and Chinese descriptions of 41,269 valid video clips from the Kinetics-600 validation and hold-out test sets, costing approximately \$51,000 in total. The data collection window is around two months. We have obtained approvals from the institutional reviewing agency to conduct human subject crowdsourcing experiments, and our payment rate is reasonably high (the estimated hourly rate is higher than the minimum wage required by law).

We split those videos into four sets as shown in Table 2.



(a) Distributions of caption lengths. (b) Distributions of unique nouns per caption. (c) Distributions of unique verbs per caption.

Figure 3: Statistical histogram distributions on MSR-VTT, VATEX-en, and VATEX-zh. Compared to MSR-VTT, the VATEX dataset contains longer captions, each with more unique nouns and verbs.

Note that the train and validation sets are split from the Kinetics-600 validation set, and the test sets are from the Kinetics-600 holdout test set. Below we detail the collection process of both English and Chinese descriptions.

### 3.1.1 English Description Collection

Towards large-scale and diverse human-annotated video descriptions, we build upon Amazon Mechanical Turk (AMT)<sup>2</sup> and collect 10 English captions for every video clip in VATEX, where each caption from an individual worker. Specifically, the workers are required to watch the video clips and describe the corresponding captions in English. In each assignment, the workers are required to describe 5 videos. We show the instructions that the workers should describe all the important people and actions in the video clips with the word count in each caption no less than 10. The AMT interface can be found in the supplementary material, which contains more details.

To ensure the quality of the collected captions, we employ only workers from the English-speaking countries, including Australia, Canada, Ireland, New Zealand, UK, and US. The workers are also required to complete a minimum of 1K previous tasks on AMT with at least a 95% approval rate. Furthermore, we daily spot-check the captions written by each worker to see if they are relevant to the corresponding videos. Meanwhile, we run scripts to check the captions according to the following rules: (1) whether the captions are shorter than 8 words; (2) whether there are repeated captions; (3) whether the captions contain sensitive words; and (4) whether the captions are not written in English. We reject all the captions that do not achieve the requirements and block the workers consistently providing low-quality annotations. The rejected captions are re-collected until all captions strictly follow the requirements. In preliminary experiments, we find that the workers may struggle to write good captions with only the instructions. Hence, we further provide some accepted good examples and rejected bad ex-

amples (both are unrelated to the current video clips) for workers’ reference. We observe that this additional information brings in evident quality improvement on the collected captions. Overall, 2,159 qualified workers annotate 412,690 valid English captions.

### 3.1.2 Chinese Description Collection

Similar to the English corpus, we collect 10 Chinese descriptions for each video. But to support the video-guided machine translation task, we split these 10 descriptions into two parts, five directly describing the video content and the other five are the paired translations of 5 English descriptions for the same video. All annotations are conducted on the Bytedance Crowdsourcing platform<sup>3</sup>. All workers are native Chinese speakers and have a good education background to guarantee that the video content can be correctly understood and the corresponding descriptions can be accurately written.

For the first part that directly describes the video content, we follow the same annotation rules as in the collection process of the English captions, except that each Chinese caption must contain at least 15 Chinese characters.

As for the second part, we aim to collect 5 English-Chinese parallel pairs for each video to enable the VMT task. However, the direct translation by professional translators is costly and time-consuming. Thus, following previous methods [8, 65] on collecting parallel pairs, we choose the post-editing annotation strategy. Particularly, for each video, we randomly sample 5 captions from the annotated 10 English captions and use multiple translation systems to translate them into Chinese reference sentences. Then the annotation task is, given the video and the references, the workers are required to post-edit the references and write the parallel Chinese sentence following two rules: (1) the original sentence structure and semantics need be maintained to guarantee the alignment to the corresponding English sentence, and (2) lost or wrong entities and actions

<sup>2</sup><https://www.mturk.com>

<sup>3</sup>A public Chinese crowdsourcing platform: <https://zc/bytedance.com>

Dataset	sent length	duplicated sent rate		#unique n-grams				#unique POS tags			
		intra-video	inter-video	1-gram	2-gram	3-gram	4-gram	verb	noun	adjective	adverb
MSR-VTT	9.28	66.0%	16.5%	29,004	274,000	614,449	811,903	8,862	19,703	7,329	1,195
VATEX-en	15.23	0	0	35,589	538,517	1,660,015	2,773,211	12,796	23,288	10,639	1,924
VATEX-zh	13.95	0	0	47,065	626,031	1,752,085	2,687,166	20,299	30,797	4,703	3,086

Table 3: We demonstrate the average sentence length, the duplicated sentence rate within a video (intra-video) and within the whole corpus (inter-video), the numbers of unique  $n$ -grams and POS tags. Our VATEX dataset is lexically richer than MSR-VTT in general. Note that the Chinese POS tagging rules follow the Penn Chinese Treebank standard [62], which is different from English due to different morphemes. For instance, VATEX-zh has more nouns and verbs but fewer adjectives than VATEX-en, because the semantics of many Chinese adjectives are included in nouns or verbs [67]<sup>4</sup>.

could be corrected based on the video content to eliminate the errors from the translation systems. To further reduce the annotation bias towards one specific translation system, here we use three advanced English→Chinese translation systems (Google, Microsoft, and self-developed translation systems) to provide the workers with machine-translated sentences as references for each English caption.

In order to ensure the quality of the Chinese captions, we conduct a strict two-stage verification: every collected description must be reviewed and approved by another independent worker. Workers with less than 90% approval rate are blocked. The interfaces for Chinese caption collection can be found in the supplementary material. Eventually, 450 Chinese workers participate in these two tasks and write 412,690 valid Chinese captions. Half of the captions are English-Chinese parallel sentences, so we have 206,345 translation pairs in total.

### 3.2. Dataset Analysis

In Table 1, we briefly compare the overall statistics of the existing video description datasets. In this section, we conduct comprehensive analysis between our VATEX dataset and the MSR-VTT dataset [63], which is the widely-used benchmark for video captioning and the closest to VATEX in terms of domain and scale. Since MSR-VTT only has English corpus, we split VATEX into the English corpus (VATEX-en) and the Chinese corpus (VATEX-zh) for comparison. VATEX contains 413k English and 413k Chinese captions depicting 41.3k unique videos from 600 activities, while MSR-VTT has 200k captions describing 7k videos from 257 activities. In addition to the larger scale, the captions in both VATEX-en and VATEX-zh are longer and more detailed than those in MSR-VTT (see Figure 3). The average caption lengths of VATEX-en, VATEX-zh, and MSR-VTT are 15.23, 13.95, and 9.28.

To assess the linguistic complexity, we compare the unique  $n$ -grams and part-of-speech (POS) tags (*e.g.*, verb, noun, adverb etc.) among MSR-VTT, VATEX-en and VA-

<sup>4</sup>For example, the segmented Chinese word 长发 (“long hair”) is labeled as one noun in Chinese, but an adjective (“long”) and a noun (“hair”) in English.

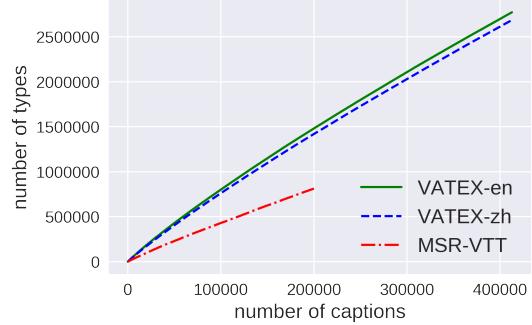


Figure 4: Type-caption curves. Type: unique 4-gram. VATEX has more lexical styles and caption diversity than MSR-VTT.

TEX-zh (see Table 3), which illustrates the improvement of VATEX over MSR-VTT and the difference between the English and Chinese corpora. Evidently, our VATEX datasets represent a wider variety of caption styles and cover a broader range of actions, objects, and visual scenes.

We also perform in-depth comparisons of caption diversity. First, as seen in Table 3, MSR-VTT faces a severe duplication issue in that 66.0% of the videos contains some exactly same captions, while our VATEX datasets are free of this problem and guarantee that the captions within the same video are unique. Not only within videos, but the captions in our VATEX datasets are also much more diverse even within the whole corpus, which indicates that our VATEX can also be a high-quality benchmark for video retrieval.

For a more intuitive measure of the lexical richness and caption diversity, we then propose the *Type-Caption Curve*, which is adapted from the type-token vocabulary curve [64] but specially designed for the caption corpora here. The total number of captions and the number of distinct vocabulary words (types) are computed for each corpus. So we plot the number of types against the number of captions for MSR-VTT, VATEX-en, and VATEX-zh (see Figure 4 where we choose 4-grams as the types). From these type-caption curves, inferences are drawn about lexical style or caption diversity (vocabulary use), as well as lexical competence (vocabulary size), so our VATEX datasets are shown to be more linguistically complex and diverse.

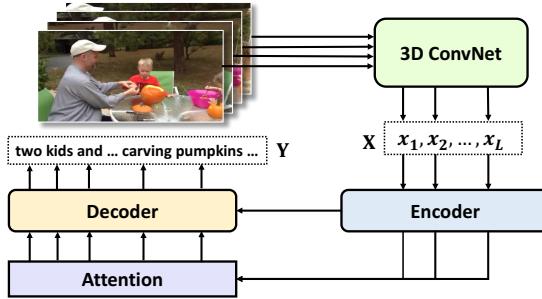


Figure 5: Monolingual video captioning model.

## 4. VATEX Tasks

### 4.1. Multilingual Video Captioning

Multilingual video captioning is the task of describing the content of a video using more than one language such as English and Chinese. Below we first introduce a baseline model for monolingual video captioning and then present three different models for multilingual video captioning.

#### 4.1.1 Models

We begin with the well-known attention-based encoder-decoder model for video captioning. As illustrated in Figure 5, there are three main modules to this architecture:

- A 3D convolutional neural network (3D ConvNet) that learns the spatiotemporal features of the video and outputs a sequence of segment-level features  $X = \{x_1, x_2, \dots, x_L\}$ .
- A video encoder module  $f_{enc}$  that encodes  $X$  into video-level features  $V = \{v_1, v_2, \dots, v_L\}$  by modeling long-range temporal contexts.
- An attention-based language decoder module  $f_{dec}$  that produces a word  $y_t$  at every time step  $t$  by considering the word at previous step  $y_{t-1}$ , the visual context vector  $c_t$  learned from the attention mechanism.

We instantiate the captioning model by adapting the model architectures from the state-of-the-art video captioning methods [42, 59]. We employ the pretrained I3D model [13] for action recognition as the 3D ConvNet to obtain the visual features  $X$ , Bidirectional LSTM [48] (bi-LSTM) as the video encoder  $f_{enc}$ , and LSTM [26] as the language decoder  $f_{dec}$ . We also adopt the dot-product attention, so at the decoding step  $t$ , we have

$$y_t, h_t = f_{dec}([y_{t-1}, c_t], h_{t-1}), \quad (1)$$

where  $h_t$  is the hidden state of the decoder at step  $t$  and

$$c_t = \text{softmax}(h_{t-1} W V^T) V, \quad (2)$$

where  $W$  is a learnable projection matrix.

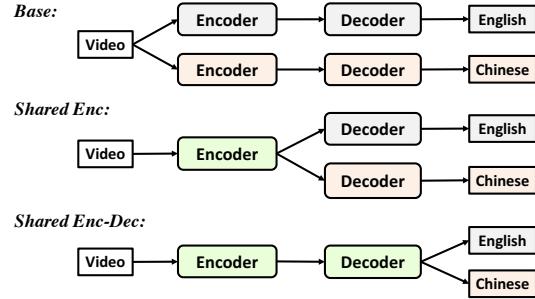


Figure 6: Multilingual video captioning models.

To enable multilingual video captioning, we examine three methods (see Figure 6): (1) Two **Base** models, which are two monolingual encoder-decoder models (as described in Figure 5) trained separately for either English or Chinese; (2) A **Shared Enc** model, which has a shared video encoder but two language decoders to generate English and Chinese; (3) A **Shared Enc-Dec** model, where there are just one encoder and one decoder, both shared by English and Chinese, and the only difference is that the word embedding weight matrices are different for different languages.

#### 4.1.2 Experimental Setup

**Data Preprocessing.** We train the models on the VATEX dataset following the splits in Table 2. To preprocess the videos, we sample each video at  $25\text{fps}$  and extract the I3D features [13] from these sampled frames. The I3D model is pretrained on the original Kinetics training dataset [28] and used here without fine-tuning. Both the English and Chinese captions are truncated to a maximum of 30 words. Note that we use the segmented Chinese words<sup>5</sup> rather than raw Chinese characters. The vocabularies are built with a minimum word count 5, resulting in around 11,000 English words and about 14,000 Chinese words.

**Implementation Details.** All the hyperparameters are tuned on the validation sets and same for both English and Chinese caption training. The video encoder is a bi-LSTM of size 512 and the decoder LSTM is of size 1024. The dimensions of the word embedding layers are 512. All models are trained using MLE loss and optimized using Adam optimizer [29] with a batch size 512. We adopt Dropout for regularization. The learning rate is initially set as 0.001 and then halted when the current CIDEr score does not surpass the previous best for 4 epochs. Schedule sampling [7] is employed to train the models. At test time, we use beam search of size 5 to report the final results.

**Evaluation Metrics.** We adopt four diverse automatic evaluation metrics: BLEU [40], Meteor [17], Rouge-L [35], and CIDEr [56]. We use the standard evaluation code from MS-COCO server [15] to obtain the results.

<sup>5</sup>We use the open source tool Jieba for Chinese word segmentation: <https://github.com/fxsjy/jieba>

Model	#Params	English						Chinese							
		B-1	B-2	B-3	B-4	Meteor	Rouge	CIDEr	B-1	B-2	B-3	B-4	Meteor	Rouge	CIDEr
Base w/o WT	52.5M	70.8	52.7	38.9	27.8	21.7	46.7	45.4	74.3	53.6	36.6	25.2	29.8	51.8	35.7
Base	39.7M	71.1	53.2	39.3	28.2	21.7	46.9	45.7	74.2	53.6	36.8	25.2	29.7	51.7	36.3
Shared Enc	34.9M	<b>72.0</b>	<b>53.9</b>	<b>40.0</b>	<b>28.9</b>	<b>21.9</b>	<b>47.4</b>	<b>46.8</b>	<b>75.5</b>	<b>54.9</b>	<b>38.1</b>	<b>26.3</b>	<b>29.9</b>	<b>52.2</b>	<b>36.7</b>
Shared Enc-Dec	26.3M	71.7	53.8	39.9	28.7	<b>21.9</b>	47.2	45.6	<b>75.5</b>	<b>55.2</b>	<b>38.1</b>	25.9	<b>29.9</b>	<b>52.5</b>	<b>36.9</b>

Table 4: Multilingual video captioning. We report the results of the baseline models in terms of BLEU (B), Meteor, and Rouge-L, and CIDEr scores. WT: weight tying, which means the input word embedding layer and the softmax layer share the same weight matrix.

#### 4.1.3 Results and Analysis

Table 4 shows the results of the three baseline models on both English and Chinese test sets. The performances of the multilingual models (*Shared Enc* and *Shared Enc-Dec*) are consistently (though not significantly) improved over the monolingual model (*Base*). It indicates that multilingual learning indeed helps video understanding by sharing the video encoder, as the *Shared Enc* performs the best. More importantly, the parameters of the *Shared Enc* and *Shared Enc-Dec* are significantly reduced by 4.7M and 13.4M over the *Base* models. These observations validate that a compact unified model is able to produce captions in multiple languages and visual understanding can benefit from multilingual knowledge learning. We also believe that specialized multilingual model design would further improve the understanding of the videos and lead to better results.

### 4.2. Video-guided Machine Translation

In this section, we discuss the enabled new task, Video-guided Machine Translation (VMT), to translate a source language sentence into the target language using the video information as additional spatiotemporal context. This task has various potential real-world applications, e.g., translating posts with the video content in social media.

#### 4.2.1 Method

In VMT, the translation system takes a source sentence and the corresponding video as the input, and generates the translated target sentence. To effectively utilize the two modalities, text and video, we design a multimodal sequence-to-sequence model [53, 57] with the attention mechanism [5, 37] for VMT. The overview of our model is shown in Figure 7, which mainly consists of the following three modules.

**Source Encoder.** For each source sentence represented as a sequence of  $N$  word embeddings  $S = \{s_1, s_2, \dots, s_N\}$ , the source encoder  $f_{enc}^{src}$  transforms it into the sentence features  $U = \{u_1, u_2, \dots, u_N\}$ .

**Video Encoder.** Similar in Section 4.1, we use a 3D ConvNet to convert each video into a sequence of segment-level features  $X$ . Then we employ a video encoder  $f_{enc}^{vi}$  to transform  $X$  into the video features  $V = \{v_1, v_2, \dots, v_L\}$ .

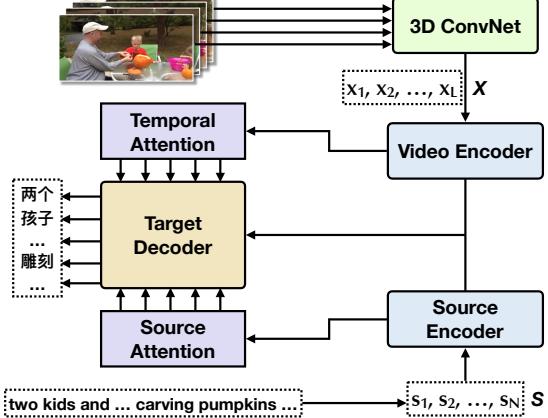


Figure 7: Video-guided machine translation model.

**Target Decoder.** The sentence embedding from the source language encoder  $f_{enc}^{src}$  and the video embedding from the video encoder  $f_{enc}^{vi}$  are concatenated and fed into the target language decoder  $f_{dec}^{tgt}$ . To dynamically highlight the important words of the source sentence and the crucial spatiotemporal segments in the video, we equip the target decoder  $f_{dec}^{src}$  with two attention mechanisms. Thus, at each decoding step  $t$ , we have

$$y_t, h_t = f_{dec}^{tgt}([y_{t-1}, c_t^{src}, c_t^{vi}], h_{t-1}), \quad (3)$$

where  $h_t$  is the hidden state of the decoder at step  $t$ .  $c_t^{vi}$  is the video context vector that is computed with the temporal attention of the video segments (see Equation 2), and  $c_t^{src}$  is the source language context vector:

$$c_t^{src} = \text{softmax}(h_{t-1} W^{src} U^T) U, \quad (4)$$

where  $W^{src}$  is a learnable projection matrix.

#### 4.2.2 Experimental Setup

**Baselines.** We consider the following three baselines to compare: (1) *Base NMT Model*: We only consider the text information for machine translation and adopt the encoder-decoder model with the source attention mechanism. (2) *Average Video Features*: We average the segment-level features  $X$  of each video as  $\bar{x}$ . The average video feature  $\bar{x}$  is then concatenated with each word embedding  $s_t$  in  $S$ . The model structure is the same as the base NMT model. (3)

Model	English→Chinese	Chinese→English
Base NMT w/o VI	27.74	25.36
+ Average VI	27.82 (+0.08)	25.39 (+0.03)
+ LSTM VI w/o Attn	28.45 (+0.71)	25.61 (+0.25)
+ LSTM VI w/ Attn (VMT)	<b>30.20</b> (+2.46)	<b>27.18</b> (+1.82)

Table 5: Video-guided Machine Translation. We report the results of the baseline models in terms of the BLEU-4 score. VI: Video features from the pretrained I3D model. Attn: temporal attention mechanism.

*LSTM Video Features*: This is our VMT model without the temporal attention for videos in the decoder.

**Implementation Details.** The data prepossessing steps are the same as in the Section 4.1.2 except that we truncate the captions with maximum length 40 here. The baseline NMT is composed of a 2-layer bi-LSTM encoder of size 512 and a 2-layer LSTM decoder of size 1024. The dimensions of both English and Chinese word embeddings are 512. The video encoder is a bi-LSTM of size 512. MLE loss is implemented to train the model using Adam optimizer [29]. The batch size is 32 during training and early-stopping is used to choose the models. As for evaluation, we use beam search of size 5 to report the results on the BLEU-4 metric.

#### 4.2.3 Results and Analysis

**VMT.** We first show in Table 5 the results of four different models on *English→Chinese* and *Chinese→English* translations. The marginal improvements by the *Average video Features* and the *LSTM Video Features* reveal that, passively receiving and incorporating the video features is ineffective in helping align source and target languages. However, we can observe that the translation system achieves much better performance when using the *LSTM Video Features* with temporal attention (our full VMT model) to dynamically interact with the video features. It is because that with the attention mechanism, the language dynamics are used as a query to highlight the relevant spatiotemporal features in the video, and then the learned video context would assist the word mapping between source and target language spaces. This also validates that extra video information can be effectively utilized to boost machine translation systems.

**Masked VMT.** Videos contain rich information on subject nouns, object nouns, and action verbs. Therefore, we further conduct noun/verb masking experiments [11] to investigate to what extent the video information can help machine translation. We randomly replace 0%/25%/50%/75%/100% nouns or verbs of the English captions with a special token [M], and then train the NMT and VMT models on the *English→Chinese* translation task with different masking rates. This experimental design is to evaluate the capability of VMT in recovering the missing information of the source sentence with the help of the video context.

Rate	BLEU-4					Accuracy (%)				
	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%
Noun Masking										
NMT	27.7	21.5	14.3	9.4	4.7	70.8	55.4	36.1	17.5	11.6
VMT	30.2	25.6	19.8	17.6	15.6	78.6	68.2	52.9	46.4	41.3
Verb Masking										
NMT	27.7	23.9	16.4	12.5	8.7	66.4	58.0	42.8	34.7	21.5
VMT	30.2	28.8	23.7	20.8	18.6	71.5	65.3	56.1	50.2	42.6

Table 6: Video-guided machine translation on *English→Chinese* with different noun/verb masking rates. We evaluate the results using the BLEU-4 score and noun/verb recovery accuracy.

In addition to the BLEU-4 metric, we propose to use the noun/verb recovery accuracy, which is the percentages of the correctly translated nouns/verbs in the target sentences, to precisely evaluate the impact of additional video information on recovering nouns/verbs. The results with different masking rates are shown in Table 6. First, the VMT model consistently outperforms the NMT model with different masking rates on both metrics. Moreover, as the masking rate increases, the NMT model struggles to figure out the correct nouns/verbs because of the scarce parallel caption pairs; while the VMT model can rely on the video context to obtain more useful information for translation, and thus the performance gap on the recovery accuracy increases dramatically. It shows that in our VMT model, video information can play a crucial role in understanding subjects, objects, and actions, as well as their relations.

## 5. Discussion and Future Work

In this paper, we introduce a new large-scale multilingual dataset for video-and-language research. In addition to (multilingual) video captioning and video-guided machine translation, there are also some other potentials of this dataset. For example, since the natural language descriptions in VATEX are unique and each one corresponds to a video clip, one promising direction is to retrieve video clips using multilingual descriptions of our dataset as textual queries [36]. Meanwhile, VATEX has 600 fine-grained action labels, so we can further holdout certain action classes to evaluate the generalization of different video captioning models to support zero-/few-shot learning [61]. Furthermore, our dataset can possibly contribute to other research fields like Neuroscience. For instance, when describing the same videos, the focus points of people using different languages can be reflected by their written captions. By analyzing multilingual captions, one can likely infer the commonality and discrepancy on the brain attention of people with different cultural and linguistic backgrounds. In general, we hope the release of our VATEX dataset would facilitate the advance of video-and-language research.

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## Supplementary Material

The supplementary material is organized as follows:

- **Data collection interfaces:** We show the AMT interface for English caption collection in Figure 8. Since the Chinese captions are divided into two parts, we build two separate interfaces, one of which is to collect the captions that directly describe the video (Figure 9) and the other for collecting the Chinese translations parallel to the English captions (Figure 10).
- **More VATEX samples:** In addition to the example shown in the main paper, Figure 11 demonstrates more samples of our VATEX dataset.
- **Qualitative results of multilingual video captioning:** Figure 12 illustrates some qualitative examples of multilingual video captioning, where we compare both the English and Chinese results generated by the monolingual models (*Base*), the multilingual model that shares the video encoder for English & Chinese (*Shared Enc*), and the multilingual model that shares both the video encoder and the language decoder for English & Chinese (*Shared Enc-Dec*).
- **Qualitative results of video-guided machine translation (VMT):** In Figure 13, we showcase the advantages of the VMT model over the base neural machine translation (NMT) model. Moreover, we further conduct the masked machine translation experiments and qualitatively demonstrate the effectiveness of VMT in recovering nouns or verbs in Figure 14.

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## Describe the 10-second video in one sentence

<b>Instructions:</b>  <ul style="list-style-type: none"><li>• In each HIT you must describe 5 videos.</li><li>• Describe all the <b>important people and actions</b> of the video.</li><li>• The sentence should contain <b>at least 10 words</b>.</li><li>• Avoid making spelling errors in the description.</li><li>• Be objective. <b>Do not</b> involve your personal feelings. For example, avoid using "I" and "my".</li><li>• <b>Do not</b> start the sentences with "There is" or "There are".</li><li>• <b>Do not</b> write your descriptions as "A video containing", "A video of" or similar.</li><li>• <b>Do not</b> describe unimportant details.</li><li>• <b>Do not</b> describe things that might have happened in the future or past.</li><li>• <b>Do not</b> give people proper names.</li><li>• <b>Do not</b> use the text box to report an error.</li></ul>	<b>Video:</b>  
---	--

### Accepted Good Examples (unrelated to this video)

- In a studio two women are seated and having a conversation.
- A group of people look at sportcars, load one of them in a trailer, and then leave.
- A man is playing a guitar while another plays drums.

### Rejected Bad Examples (unrelated to this video)

- I enjoyed watching the video and learning how to use a knife.
- There are a group of people in the video.
- Playing the guitar.
- A video/clip/instruction of cooking.

Please summarize the video #5 with one sentence (no less than 10 words).

1 2 3 4 5

Figure 8: The AMT interface for collecting the English captions. In each assignment, the workers are required to annotate 5 video clips. The instructions are kept visible for each clip. We provide the workers with the accepted good examples and rejected bad examples to further improve the quality of annotations. Note that the given examples are unrelated to the current video clips.



Figure 9: The interface for collecting the Chinese captions by directly describing the video content. In each assignment, the workers are required to annotate 1 video clip. The instructions are kept visible for each clip. After the first-stage annotation, each Chinese caption must be reviewed and approved by another independent worker.



Figure 10: The interface for collecting the Chinese captions by post-editing the translated reference sentences and watching the video clips. In each assignment, the workers are required to annotate 1 video clip. The instructions are kept visible for each clip. We provide the workers with three reference sentences translated by Google, Microsoft and Self-developed translation systems. Note that the order of three reference sentences is randomly shuffled for each video clip to reduce the annotation bias towards one specific translation system. After the first-stage annotation, each Chinese caption must be reviewed and approved by another independent worker.



#### 10 English Descriptions:

- A person is parasailing above a body of water and landing on a beach.
- Someone is recording people who are parasailing and people who are watching too.
- A man is riding a parachute and a group of people are standing down and watching them.
- Someone parasailing over a lake with several men watching.
- A person is coming down from a sky riding on a balloon glide.
- Men on a beach prepare to assist an incoming parasailor.
- A person is landing with a parachute onto a beach while others are greeting him or her.
- Someone hanging from a parachute is being pulled on a line while people watch.
- Tied to the end of a long cable, someone is para sailing and comes for a landing on a sandy beach in front of others.
- A group of people help a person parasailing to the ground.

#### 10 Chinese Descriptions:

- 一群人看另一个人从降落伞上准备落下。
- 一群人看着一个人带着降落伞从空中落了下来。
- 一个女人在一个滑翔伞上滑翔，几个男的把她拽了下来。
- 一个人乘着降落伞即将降落到沙滩上，沙滩上的人们在对他挥手。
- 在一个晴朗的天气，有一个人飘在空中，旁边有一些人在看着。
- 在海滩上的人都在准备协助降落伞的掉落。
- 一个人带着降落伞降落在海滩上，而其他人正在围向他。
- 挂在降落伞上的人被人用绳子拉着，而人们则在旁边观看。
- 一个人绑在一条长长的电缆的末端并在别人面前降落在沙滩上。
- 在室外，有一群人正在帮助一个人跳伞到地面。



#### 10 English Descriptions:

- A person is walking around in an outdoor field with a can that is on fire.
- A man holds a beer bottle that is on fire and tries two times to blow on it to make the flame bigger.
- A man is holding a burning bottle and then he spits flames from it in the air.
- Man holding a flaming beer being coaxed by others to spit into the flame.
- Someone holds a bottle with a flame and blows on it to make the flame even larger.
- A man is cheered on by others as demonstrated fire spitting.
- A man is holding a torch with a fire and spitting a liquid on it.
- A man is holding something on fire as he blows in to it to make a large flame.
- A crowd cheers on "go go go" as a boy holds a bottle on fire and blows to make flames.
- A man holding a flame in his hands tries to unsuccessfully blow it out.

#### 10 Chinese Descriptions:

- 一个男人正在一片绿色的草地上玩喷火。
- 一个男人在草地上拿着点着的瓶子给周围人表演吹火。
- 一个人正在拿着火把进行杂技表演。
- 一个穿着短袖的人在户外草坪上玩火。
- 一个男人手中拿着燃烧着的燃烧瓶，并用嘴吹了第一下喷火了，吹第二下的时候没喷火。
- 一个男人在别人的鼓励下对着火把吐火。
- 一名男子手持火炬，然后在上面喷了一口液体，表演喷火。
- 当一个人在向它吹的时候，手里拿着东西着火了，形成了一个大的火焰。
- 当一个男孩拿着一个瓶子着火并吹起火焰时，一群人在欢呼。
- 一个人手里拿着一个带火焰的物体，他用嘴使劲吹，但是火焰变得更大了。



#### 10 English Descriptions:

- People are crossing the street and cars are turning at a busy intersection in a business district.
- Pedestrians attempt to cross a street at a busy intersection where construction is also taking place.
- Several people try to cross the street using a crosswalk as cars drive around a city.
- Several cars drive through an intersection as three people wait at the edge of the road to cross the street.
- People are crossing a busy street that is filled with traffic.
- Someone at a cross walk records vehicles as they drive by.
- People are standing and waiting to cross the street in a busy city.
- A busy street with car traffic and pedestrians walking at a crossing.
- A red color vehicle is taken reverse and a woman crosses the road swiftly.
- A group of people are attempting to cross a busy street.

#### 10 Chinese Descriptions:

- 一辆白色汽车在人来人往的马路上开动，三个人正在横过斑马线。
- 一辆白色长车开过，而后一辆小车也开过，三个人站在斑马线等着过马路。
- 白色的车辆从马路上驶过，人们快速走过斑马线。
- 一群人在人行横道上躲着车过马路。
- 一个个的行人正在急匆匆的穿过马路。
- 有人在交叉行走时记录了车辆经过的过程。
- 在一个繁忙的城市里，人们站着等着过马路。
- 一条繁忙的街道与汽车交通，一部分行人走在十字路口。
- 一辆红色的车在倒车，一名女子迅速的通过了马路。
- 一群人正试图穿过一条繁忙的街道。

Figure 11: More samples of our VATEX dataset. Each video has 10 English and 10 Chinese descriptions. All depicts the same video and thus are distantly parallel to each other, while the last five are the paired translations to each other.



### English Captions

#### Human:

a young man is getting set and then throws a frisbee across an open field .

#### Base:

a man is throwing a frisbee in a field .

#### Shared Enc:

a man is throwing a frisbee across a grassy field .

#### Shared Enc-Dec:

a man is standing in a field and throws a frisbee into the air .

### Chinese Captions

#### Human:

一个男人站在一个长满草的小丘上把飞盘扔出去了。

#### Base:

一个男人在草地上扔飞盘，然后把它扔了出去。

#### Shared Enc:

一个穿着黑色衣服的男人在草地上扔飞盘。

#### Shared Enc-Dec:

一个男人正在室外的空地上拿着飞盘扔了出去。

### English Captions

#### Human:

a boy is casting a fishing line into the river .

#### Base:

a man is standing in the water with a fishing pole .

#### Shared Enc:

a young boy is standing in the water and he is casting a fishing pole into the water .

#### Shared Enc-Dec:

a young boy is standing in the water and casting his fishing line into the water .

### Chinese Captions

#### Human:

一个穿着蓝色马甲的男孩在河边，把鱼竿甩出去。

#### Base:

一个男人站在河边，手里拿着鱼竿在钓鱼。

#### Shared Enc:

一个男人在河边拿着鱼竿在钓鱼。

#### Shared Enc-Dec:

一个穿着蓝色衣服的小男孩在河边拿着鱼竿钓鱼。

### English Captions

#### Human:

two teams of women play netball on an outdoor court in the evening .

#### Base:

a group of girls are playing a game of basketball on an outdoor court .

#### Shared Enc:

a group of women are playing a game of basketball on a court .

#### Shared Enc-Dec:

a group of people are playing a game of basketball on a basketball court .

### Chinese Captions

#### Human:

两队女子在室外篮球场进行篮球比赛。

#### Base:

一群人在室外的篮球场上进行着激烈的篮球比赛。

#### Shared Enc:

一群人在一个大的篮球场上打球。

#### Shared Enc-Dec:

一群人在篮球场上进行着激烈的篮球比赛。

Figure 12: Qualitative comparison among different methods of multilingual video captioning on the VATEX dataset. Both the English and Chinese results are shown. For each video sample, we list a human-annotated caption and the generated results by three models, *Base*, *Shared Enc*, and *Shared Enc-Dec*. The multilingual models (*Shared Enc* and *Shared Enc-Dec*) can generate more coherent and informative captions than the monolingual model (*Base*).



**English:**

a young girl does a cartwheel in her homes living room .

**Ground Truth:**

一个年轻女孩在她家的起居室里做侧手翻。

**NMT:**

一个年轻女孩在她的房间里做车轮。

**VMT:**

一个年轻女孩在她的房间里翻筋斗。

**English:**

a boy hits his head on a wall and knocks himself out .

**Ground Truth:**

一个男孩的头撞在墙上，把自己撞倒了。

**NMT:**

一个男孩撞他的头在墙上，然后敲自己出去。

**VMT:**

一个男孩他的头撞在墙上，然后自己撞倒了。

**English:**

a girl shows how to apply eyeliner, describing how to use strokes .

**Ground Truth:**

一个女孩展示了如何使用眼线笔，讲述如何画眉。

**NMT:**

一个女孩展示了如何使用眼线笔，描述了如何使用笔画。

**VMT:**

一个女孩展示了如何使用眼线笔，描述了如何画眼线。

Figure 13: Qualitative comparison between neural machine translation (NMT) and video-guided machine translation (VMT) on the VATEX dataset. For each video sample, we list the original English description and the translated sentences by the base NMT model and our VMT model. The NMT model mistakenly interprets some words and phrases, while the VMT model can generate more precise translation with the corresponding video context.



**English:**

a woman with blonde hair is giving a [M] a [M] .

[M]: dog, haircut.

**Ground Truth:**

一位金发女士正在用电剪刀给狗理发。

**NMT:**

一个金发女人正在给指示一个人。

**VMT:**

一个金发女人正在给一只狗理发。

**English:**

a [M] is putting on a [M] performance while using large string instruments .

[M]: band, rock.

**Ground Truth:**

一支乐队正在使用大型弦乐器表演摇滚乐。

**NMT:**

一个男人正在使用大型弦乐器表演。

**VMT:**

一支乐队正在使用大型弦乐器表演摇滚。

**English:**

a child, together with mom is [M] around as they [M] in the room .

[M]: playing, laugh.

**Ground Truth:**

一个孩子和妈妈在房间里玩的时候在笑。

**NMT:**

一个孩子和妈妈在房间里跳舞同时笑。

**VMT:**

一个孩子和妈妈在房间里正在玩同时笑。

Figure 14: Qualitative comparison between masked neural machine translation (NMT) and masked video-guided machine translation (VMT) on the VATEX dataset. The nouns/verbs in English captions are randomly replaced by a special token [M]. For each video sample, we list the original English description and the translated sentences by the base NMT model and our VMT model. The NMT model struggles to figure out the correct nouns/verbs because of the scarce parallel pairs, while the VMT model can rely on the video context to recover the masked nouns/verbs.