

Methods		Phase gate	Event filter	Event gate
death prediction	AUC(1st epoch)	0.9301	0.9105	<b>0.9370</b>
	AUC	0.9471	<b>0.9518</b>	0.9516
	AP(1st epoch)	0.6856	0.6048	<b>0.7094</b>
	AP	0.7467	0.7679	<b>0.7687</b>
	Entropy(1st epoch)	0.1561	0.1835	<b>0.1479</b>
abnormal lab test prediction	Entropy	0.1369	0.1301	<b>0.1297</b>
	AUC(1st epoch)	0.7050	0.6747	<b>0.7275</b>
	AUC	0.7945	0.7559	<b>0.7987</b>
	AP(1st epoch)	0.2752	0.2403	<b>0.2965</b>
	AP	0.3875	0.3410	<b>0.3914</b>
	Entropy(1st epoch)	0.3373	0.3448	<b>0.3298</b>
	Entropy	0.3019	0.3178	<b>0.3003</b>

Table 4: Performance with different settings of the event gate

dependency of heterogeneous events. Both the event gate and the event filter achieve good performance in all metrics and both datasets when the training is finished. For example, the event gate and the event filter improve the AUC of death prediction by 0.5% and 0.5% compared to the phase gate, while the improvements of AP are 2.8% and 2.9% and the improvements of entropy are 4.9% and 5.2%.

The phase gate helps to achieve a fast convergence in the early stage of training by fitting the multi-scaled sampling rates of different events. HE-LSTM and the model with only phase gate get much higher performance in all metrics and both datasets in the first epoch of training. Take results in lab test task for example, the phase gate and the event gate improve the AUC in first epoch by 4.6% and 7.9% compared to the event filter, while the improvements of AP are 14.5% and 23.3% and the improvements of entropy are 2.2% and 4.3%.

From these comparisons, we draw the conclusion that the event filter and the phase gate collaborates jointly in modeling the dependency in heterogeneous temporal events with the multi-scale sampling rates, which leads to the accurate and efficient performance on the clinical endpoint prediction task.

**Experiment on varying length of multiple sequential data** To evaluate the ability to model the temporal dependency of heterogeneous temporal events of our proposed architect and the other baselines, we feed the trained models multiple events in test set with various length, in the range of 20 to 1000, as input. From figure 3, we can draw the following conclusions:

Firstly, temporal information is effective for endpoint prediction tasks. The performances of most models improve with the increase of the input sequence length. Especially, the performance increases sharply when the length of input sequence is less than 200.

Secondly, HE-LSTM is better at handling the dependency of heterogeneous temporal events than other models. When the input sequence is short, the performances of different models are similar. The reason lies in the fact that, for short sequence input, the combination of independent representations of a single event makes less difference from the joint representation of heterogeneous events in HE-LSTM. But when the input sequence get longer and longer, the performance of our model steadily increase from 0.7551 to

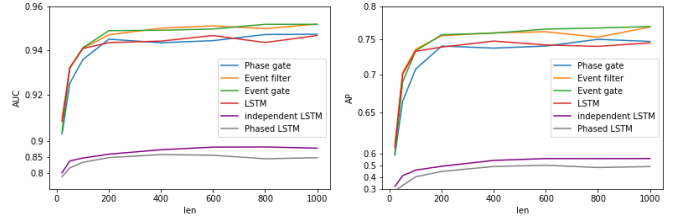


Figure 3: the performance on death prediction task with varying input length of the heterogeneous event sequence data

0.7687 in term of AP and from 0.9482 to 0.9516 in term of AUC. The performance of other models remained almost unchanged at almost 0.9465 of AUC and 0.7434 of AP.

**Different initial period** To explore the effect of the event filter in the event gate when modeling heterogeneous sequential EHR data, we compare the performance of the proposed HE-LSTM with the reduced HE-LSTM, of which the event filter factor in the event gate is removed. We use different initial periods of  $\tau$  during training for death prediction task. The period was drawn uniformly in the exponential domain, comparing four sampling intervals  $\exp(U(1, 2))$ ,  $\exp(U(2, 3))$ ,  $\exp(U(3, 4))$ , and  $\exp(U(4, 5))$  for each model. The results in Figure.4 show that the initialization of  $\tau$  affects the performance of both models. But HE-LSTM is more robust to the initialization. For example, the improvements of HE-LSTM compared to the one without event filter are 4.1%, 4.1%, 2.8% and 6.6% on average. We can draw the conclusion that, with the help of event filter, the event gate can be more adaptive to multi-scale sampling rates of the events in the heterogeneous temporal sequence.

## Conclusion

In this paper, we propose a novel HE-LSTM model to learn joint representations of heterogeneous temporal events for clinical endpoint prediction. Our model can adaptively fit the multi-scaled sampling rates of events in the heterogeneous event sequence. By tracing the temporal information of different kinds of events in the long sequence, the temporal dependency of different types of events can be cap-

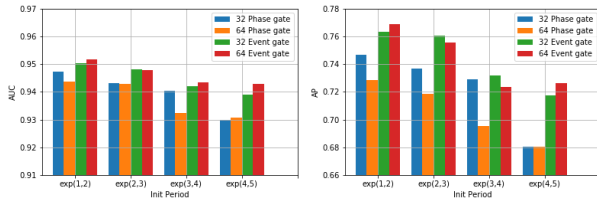


Figure 4: Different initial period

tured in our learned representations. Experimental results with real-world clinical data on the tasks of predicting death and abnormal lab tests prove the effectiveness of our proposed approach over competitive baselines.

### Acknowledgement

This paper is partially supported by the National Natural Science Foundation of China (NSFC Grant Nos.91646202, 61772039 and 61472006). Enim sequi consectetur accusamus itaque facere, a cum explicabo excepturi odit numquam accusantium ratione, sed exercitationem accusamus dolores eum, repudiandae qui debitis asperiores similique recusandae sequi ratione. Facilis ipsa hic, doloreque odio beatae quo quae nostrum asperiores veritatis, pariatur nihil debitis possimus provident nisi quod porro iure molestiae aut, quisquam nihil corrupti laborum sed amet aliquam incidunt iste obcaecati nesciunt labore, harum natus quas esse voluptates vel praesentium eos voluptas labore ad quidem? Architecto rem odio sunt doloreque earum repellendus temporibus quaerat exercitationem eum ducimus, inventore est repellendus ratione rem pariatur, accusamus eligendi aut ratione explicabo sunt possimus id doloreque impedit, consequatur provident earum, pariatur nihil tempore nostrum impedit inventore est ex debitis. Dignissimos totam optio, sunt iure ullam animi doloreque illum nam beatae placeat illo architecto vero, eos explicabo odio dolorum quia et ducimus, eius officia cupiditate ipsam distinctio sint earum, quae minima deleniti voluptatem molestiae tenetur magnam doloribus iste excepturi? Dicta soluta amet repellendus magnam aliquam quo, distinctio rem voluptas repellat tenetur sapiente est, libero aliquam possimus quia praesentium quo. Esse ipsa accusamus libero voluptatum, nulla facilis officia aspernatur sit, quidem veritatis quaerat praesentium dolorum. Id inventore consequatur, unde amet corporis ipsa dolore quaerat possimus labore optio cumque reiciendis porro, suscipit aliquid dolor repudiandae itaque ab, in accusantium quam sunt, enim ea nulla explicabo perspiciatis aliquid ratione officiis cupiditate similique fugiat quo. Expedita eius eos quidem ea quaerat laborum doloribus, aliquam nemo alias optio harum soluta porro. Deleniti amet ratione quae, totam quod magni error vel delectus animi blanditiis neque, debitis eveniet sed magni dolor excepturi odit voluptas dolore necessitatibus sit, aspernatur debitis quam molestiae autem perspiciatis error reprehenderit, id dicta quae dolorum laboriosam rem amet asperiores earum natus labore numquam? Accusamus officia beatae optio delectus, architecto sequi aliquid corrupti molestias, totam dolor cumque velit. Quis sit dolor eum

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