

Table 1: Analysis of Spearman correlations in Korean corpora.

		n-gram	Dependency parsing			Phrase structure parsing			POS tagging		
			BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE
Weather	Non-pretrained BERT	n=1	0.973	0.972	1.0	0.611	0.617	0.548	0.945	0.945	1.0
		n=2	0.900	0.900		0.620	0.618		0.864	0.863	
		n=3	0.845	0.845		0.622	0.621		1.0	1.0	
		n=4	0.682	0.691		0.625	0.626		0.882	0.882	
	Pretrained BERT	n=1	1.0	1.0	1.0	0.651	0.652	0.597	1.0	1.0	1.0
		n=2	0.991	0.991		0.662	0.659		1.0	1.0	
		n=3	0.982	0.982		0.663	0.662		1.0	1.0	
		n=4	0.810	0.819		0.666	0.667		0.836	0.900	
	Pretrained BERT for syntax sentence	n=1	0.973	0.972	1.0	0.664	0.667	0.590	-	-	-
		n=2	0.964	0.964		0.671	0.670		-	-	
		n=3	0.982	0.982		0.672	0.672		-	-	
		n=4	0.936	0.936		0.675	0.677		-	-	
Navi	Non-pretrained BERT	n=1	0.863	0.864	0.991	0.508	0.508	0.504	0.973	0.973	0.745
		n=2	0.736	0.718		0.515	0.515		0.801	0.864	
		n=3	0.610	0.545		0.517	0.516		0.855	0.855	
		n=4	0.791	0.755		0.521	0.519		0.791	0.723	
	Pretrained BERT	n=1	0.827	0.827	0.991	0.447	0.448	0.392	0.945	0.945	0.910
		n=2	0.845	0.864		0.450	0.450		0.810	0.864	
		n=3	0.573	0.582		0.448	0.450		0.673	0.745	
		n=4	0.573	0.545		0.448	0.451		0.718	0.718	
	Pretrained BERT for syntax sentence	n=1	1.0	1.0	1.0	0.474	0.479	0.417	-	-	-
		n=2	0.754	0.754		0.482	0.481		-	-	
		n=3	0.527	0.527		0.483	0.483		-	-	
		n=4	0.245	0.245		0.483	0.484		-	-	
Rest	Non-pretrained BERT	n=1	1.0	1.0	0.827	0.649	0.648	0.691	0.841	0.848	0.809
		n=2	0.763	0.865		0.662	0.658		0.845	0.848	
		n=3	0.811	0.861		0.669	0.663		0.810	0.823	
		n=4	0.803	0.858		0.676	0.669		0.733	0.761	
	Pretrained BERT	n=1	0.700	0.700	0.719	0.700	0.695	0.739	0.857	0.857	0.855
		n=2	0.609	0.597		0.709	0.709		0.859	0.863	
		n=3	0.290	0.305		0.714	0.712		0.826	0.839	
		n=4	0.092	0.116		0.718	0.715		0.740	0.769	
	Pretrained BERT for syntax sentence	n=1	0.701	0.790	0.696	0.732	0.732	0.752	-	-	-
		n=2	0.614	0.606		0.744	0.741		-	-	
		n=3	0.305	0.322		0.747	0.744		-	-	
		n=4	0.094	0.123		0.750	0.748		-	-	

Table 2: Analysis of Spearman correlations for joint modeling in the Korean corpora.

		n-gram	Dependency parsing			Phrase structure parsing			POS tagging		
			BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE
Weather	Non-pretrained BERT	n=1	1.0	1.0	1.0	1.0	1.0	0.472	1.0	1.0	1.0
		n=2	0.991	0.991		0.659	0.864		1.0	1.0	
		n=3	0.991	0.991		0.487	0.827		0.991	0.991	
		n=4	0.991	0.991		0.410	0.814		0.991	0.991	
	Pretrained BERT	n=1	1.0	1.0	1.0	0.631	0.632	0.540	1.0	1.0	1.0
		n=2	0.991	0.991		0.637	0.636		1.0	1.0	
		n=3	0.991	0.991		0.634	0.637		1.0	1.0	
		n=4	0.973	0.982		0.633	0.638		0.991	0.991	
Navi	Non-pretrained BERT	n=1	0.964	0.966	1.0	0.908	1.0	0.780	0.973	0.977	1.0
		n=2	0.800	0.673		0.908	0.969		0.536	0.527	
		n=3	0.818	0.791		0.799	0.935		0.536	0.400	
		n=4	0.691	0.736		0.655	0.851		0.445	0.418	
	Pretrained BERT	n=1	0.973	0.977	1.0	0.541	0.547	0.487	0.991	0.991	1.0
		n=2	0.655	0.600		0.548	0.547		0.882	0.900	
		n=3	0.782	0.709		0.547	0.547		0.809	0.773	
		n=4	0.891	0.891		0.547	0.548		0.764	0.764	
Rest	Non-pretrained BERT	n=1	0.683	0.687	0.628	0.486	0.488	0.546	0.747	0.774	0.732
		n=2	0.556	0.563		0.534	0.512		0.749	0.755	
		n=3	0.289	0.346		0.565	0.524		0.716	0.730	
		n=4	0.187	0.264		0.586	0.551		0.600	0.651	
	Pretrained BERT	n=1	0.691	0.697	0.674	0.503	0.527	0.602	0.748	0.776	0.774
		n=2	0.563	0.567		0.554	0.531		0.756	0.760	
		n=3	0.282	0.325		0.587	0.545		0.727	0.738	
		n=4	0.187	0.220		0.607	0.571		0.613	0.662	

Table 3: Analysis of Spearman correlations in English corpora.

			Dependency parsing			Phrase structure parsing			POS tagging		
			n-gram	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU
ATIS	Non-pretrained BERT	n=1	0.945	0.954	0.982	0.973	0.973	0.227	0.991	0.991	0.582
		n=2	1.0	1.0		0.973	0.973		1.0	1.0	
		n=3	0.991	1.0		0.991	0.973		1.0	1.0	
		n=4	0.991	0.991		0.991	0.991		0.991	0.991	
	Pretrained BERT	n=1	0.982	0.982	0.991	0.591	0.591	0.454	0.991	0.991	0.923
		n=2	0.982	0.982		0.591	0.591		0.991	0.982	
		n=3	0.945	0.964		0.591	0.591		0.991	0.991	
		n=4	0.973	0.964		0.591	0.591		0.991	0.991	
	Pretrained BERT for syntax sentence	n=1	0.991	0.991	1.0	0.501	0.502	0.477	-	-	-
		n=2	0.991	0.991		0.575	0.545		-	-	
		n=3	0.991	0.991		0.626	0.574		-	-	
		n=4	0.982	0.982		0.658	0.608		-	-	
SNIPS	Non-pretrained BERT	n=1	0.910	0.909	0.991	1.0	1.0	0.991	1.0	1.0	1.0
		n=2	0.991	0.991		1.0	1.0		1.0	1.0	
		n=3	0.900	0.800		1.0	1.0		0.991	0.991	
		n=4	0.982	0.954		1.0	1.0		0.964	0.945	
	Pretrained BERT	n=1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.991
		n=2	0.945	0.910		0.973	0.973		1.0	1.0	
		n=3	0.982	0.945		0.973	0.991		1.0	1.0	
		n=4	0.982	0.991		0.910	0.973		0.964	0.982	
	Pretrained BERT for syntax sentence	n=1	0.991	0.991	0.991	0.657	0.658	0.634	-	-	-
		n=2	1.0	1.0		0.718	0.697		-	-	
		n=3	0.982	0.964		0.740	0.717		-	-	
		n=4	0.918	0.918		0.749	0.734		-	-	
Sim-M	Non-pretrained BERT	n=1	0.991	0.991	0.127	1.0	1.0	0.464	0.855	0.854	0.127
		n=2	0.918	0.910		0.991	1.0		0.855	0.891	
		n=3	0.964	0.945		0.991	0.991		0.991	0.991	
		n=4	0.927	0.973		0.991	0.991		1.0	1.0	
	Pretrained BERT	n=1	0.754	0.754	0.991	0.910	0.910	-0.082	1.0	1.0	0.618
		n=2	0.754	0.754		0.910	0.910		1.0	1.0	
		n=3	1.0	0.991		0.910	0.910		0.991	0.991	
		n=4	0.827	0.827		0.945	0.945		0.991	0.991	
	Pretrained BERT for syntax sentence	n=1	0.654	0.655	0.800	0.827	0.877	0.799	-	-	-
		n=2	0.327	0.391		0.853	0.844		-	-	
		n=3	0.636	0.636		0.864	0.852		-	-	
		n=4	0.718	0.718		0.868	0.860		-	-	
Sim-R	Non-pretrained BERT	n=1	0.991	0.991	1.0	0.982	0.982	0.300	0.991	0.991	0.910
		n=2	1.0	1.0		0.991	0.991		1.0	1.0	
		n=3	0.991	0.991		1.0	0.982		0.982	0.991	
		n=4	0.973	0.982		1.0	1.0		0.964	0.964	
	Pretrained BERT	n=1	0.991	0.991	0.973	0.973	0.973	0.009	1.0	1.0	0.518
		n=2	0.991	0.973		0.964	0.973		1.0	1.0	
		n=3	0.900	0.882		0.973	0.964		0.991	0.991	
		n=4	0.800	0.791		0.973	0.964		0.991	0.991	
	Pretrained BERT for syntax sentence	n=1	0.810	0.809	0.991	0.828	0.828	0.787	-	-	-
		n=2	0.645	0.618		0.857	0.846		-	-	
		n=3	0.610	0.609		0.869	0.854		-	-	
		n=4	0.600	0.609		0.875	0.865		-	-	
NLUE	Non-pretrained BERT	n=1	1.0	1.0	0.661	1.0	1.0	0.591	0.927	0.927	1.0
		n=2	0.624	0.633		1.0	1.0		1.0	0.918	
		n=3	0.596	0.624		1.0	1.0		0.945	0.936	
		n=4	0.400	0.367		1.0	1.0		0.964	0.954	
	Pretrained BERT	n=1	1.0	1.0	1.0	1.0	1.0	0.591	1.0	1.0	1.0
		n=2	1.0	1.0		1.0	1.0		0.991	0.991	
		n=3	1.0	1.0		1.0	1.0		1.0	0.991	
		n=4	0.955	0.954		1.0	1.0		0.936	0.936	
	Pretrained BERT for syntax sentence	n=1	0.910	0.909	0.973	0.679	0.675	0.640	-	-	-
		n=2	0.982	0.982		0.712	0.701		-	-	
		n=3	0.927	0.909		0.723	0.710		-	-	
		n=4	0.955	0.973		0.730	0.710		-	-	

Table 4: Analysis of Spearman correlations for joint modeling in English corpora.

			Dependency parsing			Phrase structure parsing			POS tagging		
			n-gram	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU	ROUGE	BLEU	Weighted BLEU
ATIS	Non-pretrained BERT	n=1	1.0	1.0		1.0	1.0		1.0	1.0	
		n=2	1.0	1.0		1.0	1.0		1.0	1.0	
		n=3	1.0	0.991	1.0	1.0	1.0	0.991	1.0	1.0	1.0
		n=4	0.991	1.0		1.0	1.0		0.991	0.991	
	Pretrained BERT	n=1	1.0	1.0		1.0	1.0		1.0	1.0	
		n=2	0.973	0.991		1.0	1.0		0.973	1.0	
		n=3	0.991	0.973	0.991	1.0	1.0	1.0	0.973	0.973	0.945
		n=4	0.991	0.991		1.0	0.900		0.964	0.864	
SNIPS	Non-pretrained BERT	n=1	0.909	0.910		0.973	0.973		0.991	0.991	
		n=2	0.745	0.745		1.0	0.991		0.927	0.891	
		n=3	0.891	0.773	1.0	0.991	1.0	1.0	0.818	0.773	1.0
		n=4	0.991	1.0		0.991	0.991		0.955	0.955	
	Pretrained BERT	n=1	0.910	0.909		0.973	0.973		0.945	0.954	
		n=2	0.800	0.945		0.973	0.973		0.736	0.745	
		n=3	0.954	0.936	1.0	0.945	0.973	1.0	0.573	0.573	1.0
		n=4	0.927	0.836		0.910	0.945		0.482	0.482	
Sim-M	Non-pretrained BERT	n=1	0.910	0.909		0.655	0.655		0.573	0.566	
		n=2	0.745	0.745		0.573	0.655		0.536	0.536	
		n=3	0.891	0.773	1.0	0.573	0.573	0.910	0.564	0.563	0.973
		n=4	0.991	1.0		0.573	0.573		0.564	0.582	
	Pretrained BERT	n=1	0.910	0.909		0.800	0.800		0.800	0.800	
		n=2	0.782	0.782		0.900	0.845		0.736	0.745	
		n=3	0.982	0.982	0.945	0.900	0.845	0.982	0.982	0.891	.491
		n=4	0.991	0.991		0.936	0.900		0.800	0.982	
Sim-R	Non-pretrained BERT	n=1	1.0	1.0		0.991	0.991		0.973	0.973	
		n=2	0.982	0.982		0.991	0.991		0.964	0.964	
		n=3	0.973	0.964	1.0	0.991	0.991	1.0	0.982	0.945	0.991
		n=4	0.927	0.945		0.982	0.973		0.964	0.955	
	Pretrained BERT	n=1	0.991	0.991		1.0	1.0		0.991	0.991	
		n=2	0.973	0.973		0.991	0.991		0.973	0.973	
		n=3	0.964	0.927	0.973	0.991	0.991	0.991	0.973	0.955	0.936
		n=4	0.882	0.845		0.973	0.991		0.927	0.836	
NLUE	Non-pretrained BERT	n=1	1.0	1.0		1.0	1.0		1.0	1.0	
		n=2	0.973	0.900		1.0	1.0		1.0	0.991	
		n=3	0.900	0.654	1.0	1.0	1.0	1.0	0.973	0.973	1.0
		n=4	0.745	0.691		1.0	1.0		0.782	0.727	
	Pretrained BERT	n=1	1.0	1.0		1.0	1.0		1.0	1.0	
		n=2	1.0	1.0		1.0	1.0		1.0	1.0	
		n=3	0.945	0.864	1.0	1.0	1.0	1.0	0.973	0.991	1.0
		n=4	0.791	0.718		1.0	1.0		0.836	0.727	