### Appendix A. Further Alignments With DBpedia

<table>
<thead>
<tr>
<th>Open relation</th>
<th>Frequency in OPIEC-Clean</th>
<th>Frequency in OPIEC-Link</th>
<th># KB hits</th>
<th># distinct KB rels.</th>
<th>Top-3 aligned DBpedia rel. and hit frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>“leave”</td>
<td>130,515</td>
<td>1,356</td>
<td>347 (25.6%)</td>
<td>54</td>
<td>associatedBand 70, associatedMusicalArtist 70, formerBandMember 35</td>
</tr>
<tr>
<td>“take”</td>
<td>127,757</td>
<td>660</td>
<td>49 (7.4%)</td>
<td>26</td>
<td>writer 4, previousWork 4, artist 3</td>
</tr>
<tr>
<td>“use”</td>
<td>127,537</td>
<td>2,951</td>
<td>123 (4.2%)</td>
<td>53</td>
<td>currency 9, affiliation 8, timeZone 7</td>
</tr>
<tr>
<td>“receive”</td>
<td>118,429</td>
<td>2,133</td>
<td>268 (12.6%)</td>
<td>19</td>
<td>award 236, team 4, debutTeam 4</td>
</tr>
<tr>
<td>“make”</td>
<td>116,688</td>
<td>1,063</td>
<td>140 (13.2%)</td>
<td>39</td>
<td>director 39, writer 25, producer 12</td>
</tr>
<tr>
<td>“be member of”</td>
<td>104,680</td>
<td>11,480</td>
<td>3,361 (29.3%)</td>
<td>80</td>
<td>associatedBand 740, associatedMusicalArtist 740, party 584</td>
</tr>
<tr>
<td>“return to”</td>
<td>104,392</td>
<td>482</td>
<td>117 (24.3%)</td>
<td>35</td>
<td>team 44, league 9, associatedBand 7</td>
</tr>
<tr>
<td>“be at”</td>
<td>102,844</td>
<td>20,328</td>
<td>8,314 (40.9%)</td>
<td>78</td>
<td>ground 1,887, city 1,759, location 1,109</td>
</tr>
<tr>
<td>“be species of”</td>
<td>101,846</td>
<td>54,269</td>
<td>13,639 (25.1%)</td>
<td>9</td>
<td>order 5,196, family 4,269, kingdom 2,826</td>
</tr>
<tr>
<td>“move to”</td>
<td>100,226</td>
<td>1,409</td>
<td>316 (22.4%)</td>
<td>43</td>
<td>team 124, managerClub 35, ground 16</td>
</tr>
<tr>
<td>“be write by”</td>
<td>96,790</td>
<td>6,340</td>
<td>1,956 (30.9%)</td>
<td>50</td>
<td>author 571, writer 457, notableWork 120</td>
</tr>
<tr>
<td>“be found in”</td>
<td>95,163</td>
<td>836</td>
<td>110 (13.2%)</td>
<td>17</td>
<td>location 21, city 19, headquarter 17</td>
</tr>
</tbody>
</table>

Table 6: The most frequent open relations in OPIEC-Clean, along with DBpedia alignment information from OPIEC-Link (continuation of Tab. 5)
## Appendix B. Complete List of OPIEC Meta-Data

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article ID</td>
<td>Wikipedia article ID</td>
</tr>
<tr>
<td>Sentence</td>
<td>Sentence from which the triple was extracted, including annotations: 1) <em>Sentence number</em> within the Wikipedia page; 2) <em>Span</em> of the sentence within the Wikipedia page; 2) <em>Dependency parse</em>; 4) <em>Token</em> information. For each token, OPIEC provides POS tag, NER type, span, the original word found in the sentence, lemma, position of the token within the sentence, and the WikiLink object (contains offset begin/end index of the link within the article, the original phrase of the link, and the link itself).</td>
</tr>
<tr>
<td>Polarity</td>
<td>The polarity of the triple (either <em>positive</em> or <em>negative</em>)</td>
</tr>
<tr>
<td>Negative words</td>
<td>Words indicating negative polarity</td>
</tr>
<tr>
<td>Modality</td>
<td>The modality of the triple (either <em>possibility</em> or <em>certainty</em>)</td>
</tr>
<tr>
<td>CT/PS words</td>
<td>Words indicating the detected modality</td>
</tr>
<tr>
<td>Attribution</td>
<td>Attribution of the triple (if found) including attribution phrase, predicate, factuality, space and time</td>
</tr>
<tr>
<td>Quantities</td>
<td>Quantities in the triple (if found)</td>
</tr>
<tr>
<td>Triple</td>
<td>Lists of tokens with linguistic annotations for subject, predicate, and object of the triple</td>
</tr>
<tr>
<td>Dropped words</td>
<td>To minimize the triple and make it more compact, MinIE sometimes drops words considered to be semantically redundant words (e.g., determiners). All dropped words are stored here.</td>
</tr>
<tr>
<td>Time</td>
<td>Temporal annotations, containing information about TIMEX3 type, TIMEX3 xml, disambiguated temporal expression, original core words of the temporal expression, pre-modifiers/post-modifiers of the core words and temporal predicate</td>
</tr>
<tr>
<td>Space</td>
<td>Spatial annotations, containing information about the original spatial words, the pre/post-modifiers and the spatial predicate</td>
</tr>
<tr>
<td>Time/Space for phrases</td>
<td>Information about the temporal annotation on phrases. This annotation contains: 1) modified word: head word of the constituent being modified, and 2) temporal/spatial words modifying the phrase</td>
</tr>
<tr>
<td>Confidence score</td>
<td>The confidence score of the triple.</td>
</tr>
<tr>
<td>Canonical links</td>
<td>Canonical links for all links within the triple (follows redirections)</td>
</tr>
<tr>
<td>Extraction type</td>
<td>Either one of the clause types listed in ClausIE [Del Corro and Gemulla, 2013] (SVO, SVA, . . . ), or one of the implicit extractions proposed in MinIE [Gashteovski et al., 2017] (Hearst patterns, noun phrases modifying persons, . . . )</td>
</tr>
</tbody>
</table>
Appendix C. Spatio-Temporal Annotations

C.1 Temporal Annotations on Triples

To provide temporal annotations, we use as raw input the input sentence, its corresponding dependency parse tree, the \textit{n}-ary extraction by ClausIE \cite{DelCorro2013}, and the triple generated by MinIE \cite{Gashteovski2017}. We run the SUTime temporal tagger \cite{Chang2012} to obtain a list of temporal expressions from the input sentence. Next, we look at the head word $h$ of the triple’s relation and its descendants.

If $h$ has children in the dependency parse graph with typed dependency \textit{tmod} or \textit{advmod}, then we check for each child $c$ if it is contained in the list of temporal expressions. If so, we create a temporal annotation for the triple with $c$ and all the descendants $c^+$ of $c$ in the dependency parse.\footnote{We exclude descendants containing the typed dependencies \textit{rcmod}, \textit{punct}, \textit{appos}, \textit{dep}, \textit{cc}, \textit{conj} and \textit{vmod}.}

If $c$ is modified by the head word $h$ of the relation with a typed dependency \textit{prep}, then we check if the child of $c$ is a temporal expression. If so, we note the temporal annotation of the triple with $c^+$ and its descendants, and $c$ becomes the \textit{lexicalized temporal predicate} (Figure 5).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure4.png}
\caption{Example of temporal annotation on triple with \textit{tmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure5.png}
\caption{Example of temporal annotation on triple with \textit{prep}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure6.png}
\caption{Example of temporal annotation on triple with \textit{xcomp}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure7.png}
\caption{Example of temporal annotation on triple with \textit{vmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure8.png}
\caption{Example of temporal annotation on triple with \textit{nn}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure9.png}
\caption{Example of temporal annotation on triple with \textit{nsubj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure10.png}
\caption{Example of temporal annotation on triple with \textit{dobj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure11.png}
\caption{Example of temporal annotation on triple with \textit{amod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure12.png}
\caption{Example of temporal annotation on triple with \textit{tmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure13.png}
\caption{Example of temporal annotation on triple with \textit{advmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure14.png}
\caption{Example of temporal annotation on triple with \textit{prep}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure15.png}
\caption{Example of temporal annotation on triple with \textit{xcomp}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure16.png}
\caption{Example of temporal annotation on triple with \textit{vmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure17.png}
\caption{Example of temporal annotation on triple with \textit{nn}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure18.png}
\caption{Example of temporal annotation on triple with \textit{nsubj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure19.png}
\caption{Example of temporal annotation on triple with \textit{dobj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure20.png}
\caption{Example of temporal annotation on triple with \textit{amod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure21.png}
\caption{Example of temporal annotation on triple with \textit{tmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure22.png}
\caption{Example of temporal annotation on triple with \textit{advmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure23.png}
\caption{Example of temporal annotation on triple with \textit{prep}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure24.png}
\caption{Example of temporal annotation on triple with \textit{xcomp}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure25.png}
\caption{Example of temporal annotation on triple with \textit{vmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure26.png}
\caption{Example of temporal annotation on triple with \textit{nn}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure27.png}
\caption{Example of temporal annotation on triple with \textit{nsubj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure28.png}
\caption{Example of temporal annotation on triple with \textit{dobj}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure29.png}
\caption{Example of temporal annotation on triple with \textit{amod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure30.png}
\caption{Example of temporal annotation on triple with \textit{tmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure31.png}
\caption{Example of temporal annotation on triple with \textit{advmod}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure32.png}
\caption{Example of temporal annotation on triple with \textit{prep}}
\end{figure}
n-ary extraction: (“Elon Musk”; “decided”; “to go to Washington yesterday”)
Final extraction: (“Elon Musk”; “decided to go to”; “Washington”) T: (yesterday)

Figure 6: Example of temporal annotation on triple with xcomp

head word itself, so we also check if $c^+$’s children obey the same rules as for tmod, advmod, prep (Fig. 6).

Finally, MinIE-SpaTe tries to reason about how to construct the triples in a more compact manner. First, we utilize ClausIE’s n-ary extractions, and then see if $n > 3$. If so, we check if the whole temporal extraction is one phrase, and if it is, then we drop it from the original triple, and proceed with the triples’ structuring algorithm in MinIE (Figure 4).

C.2 Temporal Annotations on Arguments

Sometimes the arguments themselves contain some temporal information that is about the phrase itself, but not for the whole triple. Consider the sentence: “Isabella II opened the 17th-century Parque del Retiro in 1868.”. MinIE would extract the following triple: (“Isabella II”; “opened the 17th-century Parque del Retiro in”; “1868”). This triple contains two pieces of temporal information: “1868” and “17th-century”. MinIE-SpaTe rewrites this as: (“Isabella II”; “opened”; “Parque del Retiro”) T: (in, 1868); Object → T: 17th-century

Distinguishing these types of temporal information is important, because the correct temporal information should be attached to the correct place. In this example, we should not attach “17th century” as a temporal annotation to the whole triple (because the park was not opened in 17th century by Isabella II), but just to the object (the park itself is from 17th century).

To obtain such annotations, we search for a noun or an adjective in a phrase (word $w$), and check if it is modified by one the following dependencies: amod, acmop, advmod, nn, num, number, tmod. If so, we consider the children of $w$. If a child of $w$ is a temporal word, we include it in the temporal annotation and drop it from the triple.\(^5\)

C.3 Spatial Annotations

For spatial annotations, we follow a similar approach as for temporal annotations. The main differences are (1) instead of getting a list of annotated temporal expressions, we get a list of locations from Stanford NER [Finkel et al., 2005], and (2) we use the similar rules as for temporal annotations for prep, but not for xcomp, tmod, and advmod dependencies.

\(^5\) We ignore the children derived from the following dependencies: rcmob, punct, appos, cc, conj
C.4 Precision of Spatio-Temporal Annotations

We performed an experimental study to assess the precision of the spatio-temporal annotations. We used the sample of 10k random sentences drawn from the New York Times corpus by Gashteovski et al. [2017]. We ran MinIE-SpaTe on these sentences and created four sets of extractions: triples containing temporal annotations on (1a) the triple level and (1b) the argument level, and triples containing spatial annotations on (2a) the triple level and (2b) the argument level. From each subset, we selected 200 random triples and labeled whether the corresponding MinIE extraction (which does not provide spatio-temporal annotations) was correctly extracted. We construct our final evaluations sets by including 100 random but correctly extracted triples. In each subset, a human labeler then assessed whether the spatial and/or temporal annotations provided by MinIE-SpaTe were correct as well.

For the triple-level temporal annotations, 91/100 extractions were labeled as correctly annotated; for the argument-level temporal annotations, 80/100 were correctly annotated. Similar precision was measured for the spatial annotations: 91/100 on the triple-level and 82/100 on the argument level. We performed an error analysis and found that common errors stem from incorrect spatio-temporal tags (e.g., the argument “Summer Olympics” gets reduced to “Olympics” with temporal annotation “Summer”) or incorrect dependency parses.

Appendix D. Confidence Score Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (sentence / extraction)</td>
<td>int / int</td>
</tr>
<tr>
<td>Clause type</td>
<td>SVA, SVO, ...</td>
</tr>
<tr>
<td>Dropped all optional adverbials / prep.</td>
<td>bool / bool</td>
</tr>
<tr>
<td>Relation as whole string in sentence</td>
<td>bool</td>
</tr>
<tr>
<td>Comparison of POS Tags</td>
<td>bool</td>
</tr>
<tr>
<td>Comparison of conjunction words in subject</td>
<td>bool</td>
</tr>
<tr>
<td>Contains possessive relation / gerund</td>
<td>bool / bool</td>
</tr>
<tr>
<td>Contains infinitive verb in subj / rel</td>
<td>bool / bool</td>
</tr>
<tr>
<td>Order of words in the extraction</td>
<td>bool</td>
</tr>
<tr>
<td>Extraction contains dep</td>
<td>bool</td>
</tr>
<tr>
<td>Processed conjunction subj/rel/obj</td>
<td>bool / bool</td>
</tr>
<tr>
<td>Object before subject in sentence</td>
<td>bool</td>
</tr>
<tr>
<td>Triple occurs in MinIE-D / MinIE-A</td>
<td>bool / bool</td>
</tr>
<tr>
<td>Is the relation frequent?</td>
<td>bool</td>
</tr>
<tr>
<td>Extracts quantity / time / space</td>
<td>bool / bool</td>
</tr>
</tbody>
</table>

6. minimum support: 100 K