Edge-labelled graphs and property graphs

- to the user, more similar than different

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Knowledge graphs

Two paradigms

- Edge-labelled graphs
  - based on concept of triple
  - standardized by W3C (RDF and SPARQL)
  - considerable theoretical understanding
- Property graphs
  - edges and nodes can have properties with literal values
  - originating from proprietary standards
    - now openCypher and draft GQL standard
  - widely used in commercial applications

An empirical study

- Objectives
  - compare ease of use
  - identify modelling preferences
    - and whether these differed between paradigms
  - understand difficulties in querying
- Using
  - RDF-star and SPARQL-star (Blazegraph implementation)
    - extensions to RDF and SPARQL to facilitate reification
  - Cypher (Neo4J)

Overview of study

- Between-participants
  - RDF*/SPARQL* N = 26
  - Cypher N = 18
- RDF*/SPARQL* participants more relevant experience than Cypher participants
  - controlled for in statistical analysis
- Modelling questions
  - asked participants to rank models
- Querying questions
  - asked participants to identify whether queries were correct or incorrect
- Five sections
  - modelling question followed by querying questions

Nodes versus literals

Sophie works for CreativeCo, which is located in London. Brian works for BigCo, which is located in York. Diane works for AcmeCo, which is located in York.

Required queries: Where is the company located for which Brian works?
Who works for a company located in the same town as Brian's company?

Cypher models

```
(1) CREATE ({name: 'Sophie'})   –[:worksFor]->   ({name: 'CreativeCo', located: 'London'}),
           ({name: 'Brian'})    –[:worksFor]->   ({name: 'BigCo', located: 'York'}),
           ({name: 'Diane'})    –[:worksFor]->   ({name: 'AcmeCo', located: 'York'})
```

literal ✓

```
(2) CREATE ({name: 'Sophie'})   –[:worksFor]-> ({name: 'CreativeCo'}) –[:located]–> ({name: 'London'}),
           ({name: 'Brian'})    –[:worksFor]-> ({name: 'BigCo'})      –[:located]–> (a {name: 'York'}),
           ({name: 'Diane'})    –[:worksFor]-> ({name: 'AcmeCo'})     –[:located]–> (a)
```

node ✓

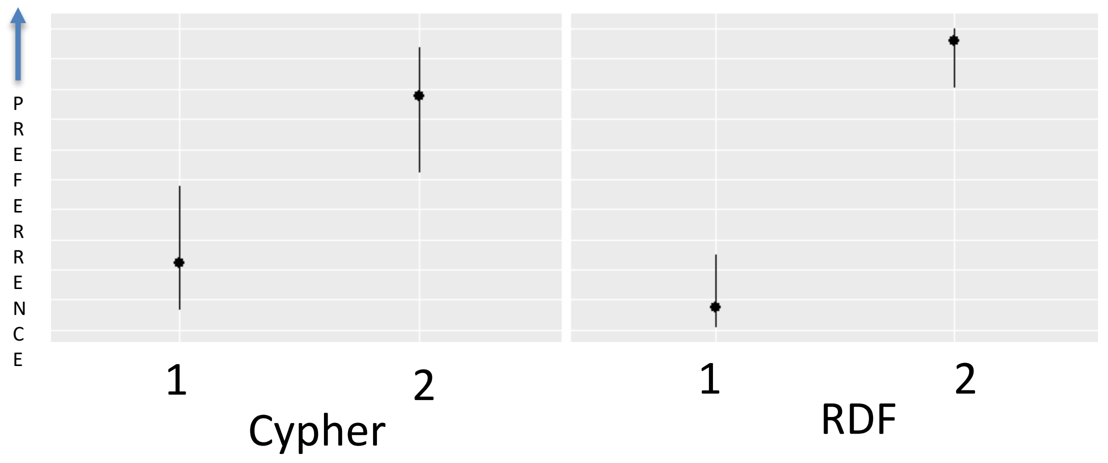
RDF models

```
(1)   :Sophie       :worksFor     :CreativeCo .
      :CreativeCo   :located      'London' .
      :Brian        :worksFor     :BigCo .
      :BigCo        :located      'York' .
      :Diane        :worksFor     :AcmeCo .
      :AcmeCo       :located      'York' .
```

literal ✓

```
(2)   :Sophie       :worksFor     :CreativeCo .
      :CreativeCo   :located      :London .
      :Brian        :worksFor     :BigCo .
      :BigCo        :located      :York .
      :Diane        :worksFor     :AcmeCo .
      :AcmeCo       :located      :York .
```

node ✓



N.B. lines represent 95% confidence intervals

Preference to represent cities as nodes
- but significantly less for Cypher than RDF

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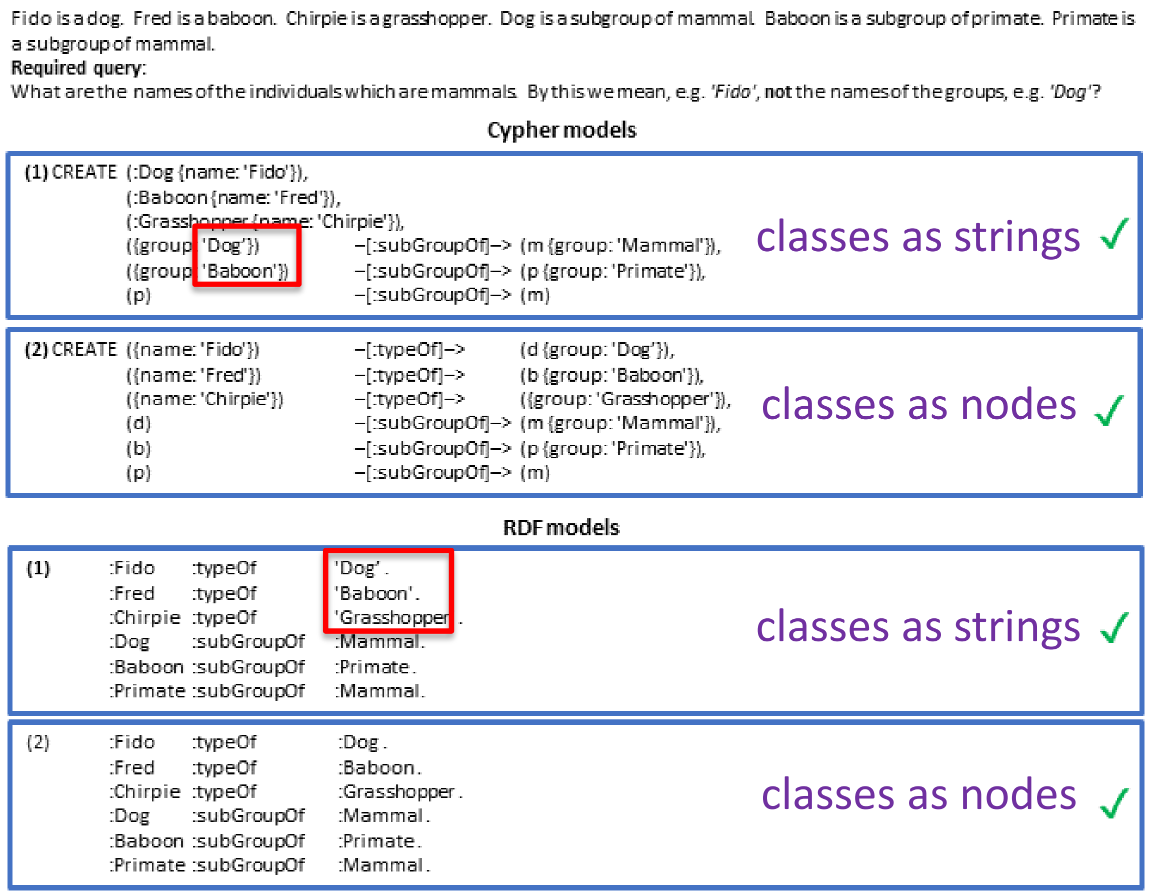
Class hierarchies



Fido is a dog. Fred is a baboon. Chirpie is a grasshopper. Dog is a subgroup of mammal. Baboon is a subgroup of primate. Primate is a subgroup of mammal.
Required query:
What are the names of the individuals which are mammals. By this we mean, e.g. *'Fido'*, not the names of the groups, e.g. *'Dog'*?

Cypher models

```
(1) CREATE (:Dog {name: 'Fido'}),
           (:Baboon {name: 'Fred'}),
           (:Grasshopper {name: 'Chirpie'}),
           ({group: 'Dog'})      –[:subGroupOf]–> (m {group: 'Mammal'}),
           ({group: 'Baboon'})   –[:subGroupOf]–> (p {group: 'Primate'}),
           (p)                   –[:subGroupOf]–> (m)
```

classes as strings ✓

```
(2) CREATE ({name: 'Fido'})      –[:typeOf]–>     (d {group: 'Dog'}),
           ({name: 'Fred'})      –[:typeOf]–>     (b {group: 'Baboon'}),
           ({name: 'Chirpie'})   –[:typeOf]–>     ({group: 'Grasshopper'}),
           (d)                   –[:subGroupOf]–> (m {group: 'Mammal'}),
           (b)                   –[:subGroupOf]–> (p {group: 'Primate'}),
           (p)                   –[:subGroupOf]–> (m)
```

classes as nodes ✓

RDF models

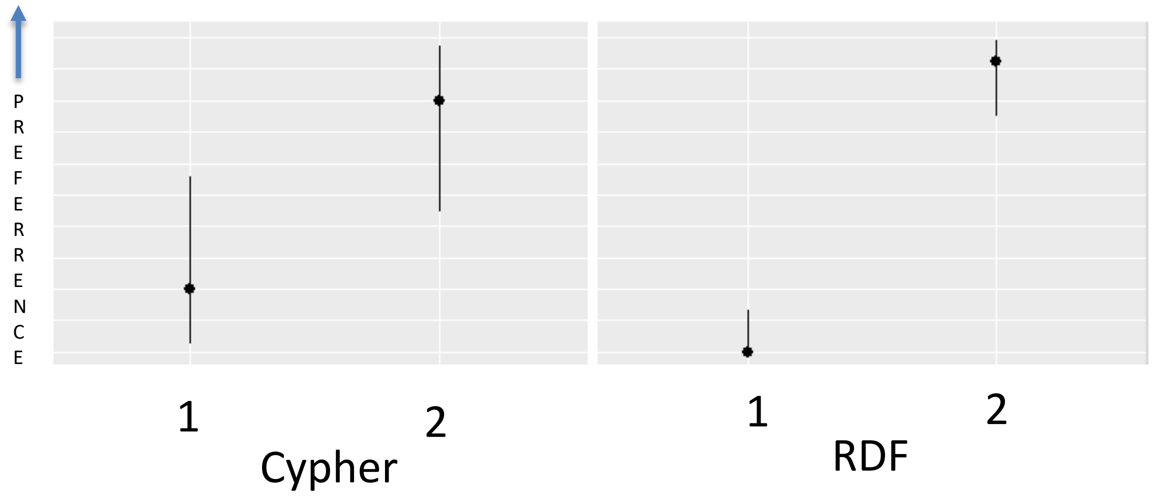
```
(1)   :Fido    :typeOf      'Dog' .
      :Fred    :typeOf      'Baboon' .
      :Chirpie :typeOf      'Grasshopper' .
      :Dog     :subGroupOf  :Mammal .
      :Baboon  :subGroupOf  :Primate .
      :Primate :subGroupOf  :Mammal .
```

classes as strings ✓

```
(2)   :Fido    :typeOf      :Dog .
      :Fred    :typeOf      :Baboon .
      :Chirpie :typeOf      :Grasshopper .
      :Dog     :subGroupOf  :Mammal .
      :Baboon  :subGroupOf  :Primate .
      :Primate :subGroupOf  :Mammal .
```

classes as nodes ✓

- Class hierarchies are straightforward in RDF
  - use predicate to represent subsumption
- In Cypher, labels used for classes
  - no natural way of creating hierarchies
  - need to represent labels as strings
- Compare classes as strings (e.g. Cypher labels) with classes as nodes



Preference to represent classes as nodes
- *even in Cypher (i.e. rather than labels)*
- *although significantly less for Cypher than RDF*

'Neo4j generally pushes for the use of labels as "types", but the path query for recursive subgroups is going to be akward …'

Querying class hierarchies

Query: What are the names of the individuals which are mammals?

classes as strings (models 1)

Cypher queries

```
(1) MATCH (x), (y)–[:subGroupOf *]–>({group: 'Mammal'})  WHERE y.group IN labels(x) RETURN x.name   ✓
```

```
(2) MATCH (x)–[:subGroupOf *]–>({group: 'Mammal'}) RETURN x.name   X
```

```
(3) MATCH (x)  WHERE 'Mammal' IN labels(x) RETURN x.name   X
```

SPARQL queries

```
(1)     SELECT ?name
        WHERE { ?name :typeOf ?groupname .  ?group :subGroupOf+ :Mammal .  FILTER (CONTAINS(STR(?group), ?groupname)) ✓
```

```
(2)     SELECT ?name
        WHERE { ?name :subGroupOf+ :Mammal }   X
```

```
(3)     SELECT ?name
        WHERE { ?name :typeOf+ ?groupname .  FILTER (CONTAINS(STR(:Mammal), ?groupname)) }   X
```

classes as nodes (models 2)

Cypher queries

```
(1) MATCH (x)–[:subGroupOf *]–>({group:'Mammal'}) RETURN x.name   X
```

```
(2) MATCH (x)–[:typeOf *]–>({group:'Mammal'}) RETURN x.name   X
```

```
(3) MATCH (x) –[:typeOf]–>()–[:subGroupOf *]–>({group: 'Mammal'}) RETURN x.name   ✓
```

SPARQL queries

```
(1)     SELECT ?name
        WHERE { ?name :subGroupOf+  :Mammal }   X
```

```
(2)     SELECT ?name
        WHERE { ?name :typeOf+  :Mammal }   X
```

```
(3)     SELECT ?name
        WHERE { ?name :typeOf / :subGroupOf+  :Mammal }   ✓
```

mean accuracy	classes as strings (models 1)	classes as nodes (models 2)
mean accuracy	2.43 / 3	2.89 / 3

Querying question answered significantly more accuracy for model 2, representing classes as nodes, than model 1, using string labels

- *consistent with participants' preference for model 2*
- *no difference in performance between the paradigms*

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Reverse predicates

Adrian works as a lawyer for TransportCo. In addition, he works as an advisor for ArtsCo. Clare works as an accountant for TransportCo.
Query: For which companies does Adrian work and what role does he have in each company?

Cypher model

```
(1) CREATE  (a {name: 'Adrian'})      –[:worksFor {role: 'lawyer'}]->      (b {name: 'TransportCo'}),
            (a)                       –[:worksFor {role: 'advisor'}]->     ({name: 'ArtsCo'}),
            ({name: 'Clare'})         –[:worksFor {role: 'accountant'}]->  (b)
```
✓

query

```
(3) MATCH (n)<–[e:worksFor]–({name: 'Adrian'})          RETURN n.name, e.role
```
✓

RDF* model

```
(1)      <<:Adrian:worksFor       :TransportCo>>    :role 'lawyer' .
         <<:Adrian:worksFor       :ArtsCo>>         :role 'advisor' .
         <<:Clare  :worksFor      :TransportCo>>    :role 'accountant' .
```
✓

query

```
(3)      SELECT ?company ?role
         WHERE {
                  ?role ^:role <<:Adrian :worksFor ?company>>
               }
```
✓

Cypher question recognized as correct significantly more frequently than SPARQL query*

- *reverse arrow may be more intuitive than ^*
- *but this effect not observed in other, possibly less complex, queries*
- *needs more investigation*

Results

- Where models analogous, similar preferences in the two paradigms
  - – even where Cypher ‘style’ might encourage a different preference
- Preference for representing class hierarchies as connected nodes
  - – rather than labels needing string representation
  - – suggests extending Cypher to enable hierarchies of node labels; and edge types
    - to enable query-time processing (c.f. rdfs:subClassOf and rdfs:subPropertyOf
- Little difference in identifying correct / incorrect queries
  - – suggests interpretability of two paradigms similar
    - possibility of preference for Cypher **<-** over SPARQL **^**
  - – study with timing information might reveal differences

Conclusions

- Each paradigm can learn from the other
  - node and edge properties may enable rich structures to be created relatively easily
  - but edge-labelled graphs (RDF) enables query-time reasoning

- Consider how closely they can be brought together
  - see Hartig ‘Reconciliation of RDF* and property graphs’: https://arxiv.org/abs/1409.3288
  - Stardog offers Property Graph syntax to describe RDF* https://www.stardog.com/blog/property-graphs-meet-stardog/
    - enables property values to be nodes as well as literals