Scope of Real Beliefs in Belief Revision

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Belief Revision involves changing a previously held belief in light of new, assumed true information.

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It is known by numerous terms: *knowledge updating, belief change, or belief-revision*.

What all these terms have in common is that the reasoner has a commitment to an epistemic set of assertions,

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which must be revised because the beliefs are challenged by an **incontrovertible assumption** (e.g., Revlin, Cate, & Rouss. 2001; Hasson & Johnson-Laird, 2003).

In true belief revision, **principles of logic can inform us that there are inconsistencies** that must be reconciled.

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For example, the assumption and (1a) jointly contradict (1b). Alternatively, the assumption and (1b) jointly contradict (1a).

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Logic points out the contradictions, but logic fails to prescribe which way the inconsistency should be reconciled.

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Relevant to the present research, **under some conditions, people are consistent** in how they approach belief-revision and how they resolve the inconsistencies. **We'll have more to say about this in a moment**.

Some tasks have used artificial content, with no relational structure among the beliefs (e.g., Byrne & Walsh, 2001; Revlis, & Hayes, 1972). **In others, the artificial beliefs have been**

part of simple assertions or immersed in stories (e.g., Revlin, Calvillo & Ballard, 2005; Van Hoeck, Revlin, Dieussaert, & Schaeken, 2012).

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In cases where **presumed beliefs have been used, they are often not verified**. The **present study created belief revision conditions where the meaning of the statements and the degree to which they could be interpreted as scientific laws—their *Scope***—have been independently verified along with reasoners' commitment to them. Let me explain…

Scope

The **scope of a quantified statement specifies the instances of the rule that are subsumed with it across time and space**. Consider two statements: *All coins in my pocket are silver* and *All whales are mammals*. Both of these statements are universally quantified generalities.

The first is an accidental generality, and its Scope is quite small—the type and number of coins in your pocket at a moment in time—while the second is a scientific law, whose Scope is large and holds across past, present, and future. **We propose that Scope is a proxy for knowledge structure (both analytic and concrete) and the prevailing state of knowledge**. As such, Scope should have an impact in belief revision.

A statement's Scope—separate from its believability--may be an indicator of whether it will be retained in the context of a counterfactual inference. This is because **the size of an inclusion relation may be presumed a fixed entity** by a reasoner. In contrast, the credibility or believability of a statement is not a fixed attribute of it. For example, Hasson & Johnson-Laird (2003) showed that belief in statements **like *If A then B* and *this X is an A* varies with context and the order in which the same statements are presented**. This is not to say that the degree

of belief is unimportant for retention: **highly believed or credible statements are retained more in belief revision contexts than are disbelieved statements** (e.g., Revlin, Cate, & Rouss, 2001). And for artificial relations, where prior believability is minimal, retention is at chance (Byrne & Walsh, 2002). However, our previous work (Chambers & Revlin, 2011) suggests that **Scope of quantified relation (even for artificial categories presented in a paragraph form) makes a difference in belief revisions**.

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Paradigm

We use a pretty much standard paradigm to investigate belief-revision processes. It was discussed in the philosophy literature by Rescher (1964) and introduced into psychology by Revlis, Lipkin & Hayes (1971). There is a **consistent set of facts and an assumption that introduces an inconsistency into the set**. The reasoner's task is to **resolve the inconsistency by assigning some statements as true and others as false**.

Let's revisit a network of knowledge consisting of propositions 1a-1c and it is confronted with an incontrovertible fact, the assumption, just as we saw earlier (slide # 3). Notice that 1a-1c is a **quantified version of Modus Tollens Argument**. Although standard logic informs us that there is an inconsistency to be resolved, **the belief-revision situations are tantamount to counterfactual reasoning** and as such, logic alone cannot tell us how to resolve the inconsistencies. The **same dilemma occurs in an MP structure** (2a-2c).

A number of proposals have been offered since these problems were first introduced into the cognitive literature (Revlis Lipkin, & Hayes, 1971) that ranged from **pattern matching of key terms** (Revlis & Hayes, 1972), **mental models** (Byrne & Walsh, 2002), **to notions of minimal change** (e.g., Elio & Pelletier, 1997), **the latter of which seems to be a permanent**

element of discussion of this topic from AI (e.g., Alchourrón, Gärdenfors, & Makinson, 1985) to **Psychology** (James, 1907). We propose here that the variability in the type of materials used in **prior studies has obscured an aspect of fact knowledge, called Scope, that plays a key role** in knowledge updating and belief-revision.

Pretest for Scope

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To assess the importance of Scope for belief revision, we developed a pretest to create stimulus materials. It consisted of 24 universally quantified statements created by crossing **2 levels of Ontology** (Definitionally True: *All trees are plants* or Empirically True: *All professors are teachers*) by **2 levels of Relation** (Class Inclusion: *All oranges are fruits* or Property Assignment: *All mammals have hair*).

Eighty-seven undergraduates identified the Scope of each statement on an 8-point scale. The scale **was anchored by "zero" and "more than 1 million." A range that reflected multiples of 10 represented the other points**. For example, a student could decide that the **Scope of a generality exists in the range of "100-1,000" instances**.

As anticipated from findings of Quillian (Collins & Quillian, 1969) and by Rips (1989), **Definitionally true statements were given higher Scope than Empirically true statements** ($F(1, 86) = 104.79$, $p < .001$) and **Class-Inclusion statements were given higher Scope than Property-Assignment statements** ($F(1, 86) = 26.42$, $p < .001$).

Experiment 1

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The purpose of this experiment is to **determine the importance of the assessed value of Scope for the pattern of belief-revision**. The **prediction is that the greater the Scope of the**

generality the more likely it will be retained in the face of an assumption. A total of 68 students **solved either MT or MP belief revision problems**.

Results and Discussion. When reasoners seek to revise True beliefs in order to return consistency to a set of statements, **they show a stronger commitment to the generalities when the logical relations are expressed as an MT argument than as an MP argument**--even though the generalities are **identical in the two conditions** ($F(1, 66) = 18.44$, $p < .001$).

Scope (MT: $\beta = .89$) significantly predicts overall retention rates [$F(1, 10) = 19.4$, $p < .001$, $R^2 = .80$; MP $\beta = -.55$ negative predictor, $R^2 = .31$]. The scope of the category relations was **positively correlated with the tendency to retain generalities in MT logic, but negatively in MP arguments**.

Experiment 2

SLIDE #14, 15

Although **Scope is a good predictor of belief-revision, what about alternative views**? Take the notion that **reasoners will *not* retain generalities if they can find disabling conditions**. In this case, suppose a special location is referred to in the generality (e.g., *Rich lives in a desert where all the snakes slither*). Such a **locative would invite the conjecture that there must be something peculiar about the location or why else would the speaker introduce it**? This would be the kind of context fitting a **disabling condition** as proposed by Khemlani & Johnson-Laird (2011), **where the reasoner decomposes the elements of the general statement and considers ways in which one or more elements fail, undermining the importance of the generality**. If **this decomposition assessment is correct, Scope should *not* be the primary factor operating in belief retention** and, with such locatives present, the **preference to retain the generality should be reduced**.

Alternatively, the **locative may activate the retrieval of physical properties of the categories in semantic memory as suggested in the findings of Barsalou** et al. (e.g., Barsalou, Simmons, Barbey & Wilson, 2003), which may **add to the Scope values and enhance the retention of the generalities**. To test these views, a total of **78 students solved either MT or MP belief-revision problems that each had a unique locative phrase**.

Results and Discussion. Reasoners show a preference, in all conditions, for retaining the general statement (more often than would be expected by chance). Logical Structure was important to revisions: **participants who solved MT contradictions (M = .88, *SD* = .33) were more likely to retain the generality of the problem than those who solved MP contradictions** (M = .71, *SD* = .34; *F(1,* 63) = 7.69, *p* = .007). The Ontology of the statements' relations was also critical, with participants **retaining the Definitional generalities (M = .82, *SD* = .25) more often than Empirical ones** (M = .77, *SD* = .27; *F(1,* 63) = 3.62, *p* = .06). There was no effect of Relation (Class vs. Property) and no interaction among the variables in this study.

The **presence of the locative resulted an increase in the retention of generalities in every condition, which obscured the differential importance of Scope**: Scope was not found to be **a significant predictor of retention rates for either MT contradictions (β = .27, *p* = .39) or MP contradictions** (β = .21, *p* = .51). **We suggest that this is because the locative activates physical features that are added to the values of Scope and produces a kind of ceiling effect for Scope**. The overwhelming nature of **physical properties has been shown in studies of semantic retrieval** (Johnson-Laird, Hermann, & Chaffin, 1984).

Experiment 3

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In previous studies, artificial set inclusion generalities, embedded in unreal contexts, were

associated with weak preferences for the retention of statements (e.g., *All Frups are Toves*—Revlis & Hayes, 1972). The **present experiment tested whether real categories such as ones used in Experiment 2 (with implicit Scope + physical properties), but embedded in unreal or at least "unnatural" contexts, would replicate previous weak findings, OR would they show a similar preference as expressed in Experiment 2 by virtue of the addition of physical features to the generalities**.

Fifty-four undergraduate students participated in this experiment and solved either MT or MP belief revision problems. There were four groups of students resulting from the orthogonal **crossing of two levels of Set-Size by two levels of Logic**. Set-Size was expressed as either a **small proportion or a large proportion of the total members of the reasoning categories (e.g., *Kelly has a hive where 5 bees out of 104 insects have wings* vs. *Logan has a honeycomb where 91 bees out of 104 insects have wings.*). Set-Size is analogous to observed levels of Scope**. The instructions and procedures were the same as Experiment 1 and 2.

Results and Discussion. As in the artificial context of Experiment 2, reasoners show a distinct preference for **retaining generalities when faced with an indisputable assumption**. This **uniform elevated preference across conditions once again shows that Scope does not exercise a unique contribution to the decisions** when physical properties have been added to it.

General Discussion

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In three experiments we **tested the ability of Scope to predict overall retention of statements in belief-revision contexts**. In Experiment 1, **implicit Scope was a predictor of overall retention of statements in a belief-revision** context that was free of location information. In Experiment 2, **we sought to create an environment that would promote**

disabling conditions and therefore reduce preferences for retaining generalities. The manipulation had the **opposite effect: the physical context enhanced the retention of generalities possibly by virtue of semantic memory of physical features adding to those of Scope.** Finally, in Experiment 3, we **challenged the general Scope values and thereby reduce the acceptance of generalities. We did this by explicitly stating that the Set-Size of the category relations was less than the implicit Scope derived from the pretest**. The manipulation had the **opposite effect: it appears that as in Experiment 2, focus on the system of physical features of instances adds to the basic values of Scope and contributes to an enhanced retention of generalities**.

These findings tell us that **belief-revision in artificial contexts can involve the same cognitive decision processes as in natural contexts so long as the categories reasoned about are themselves previously available to the reasoner's semantic and physical networks** (i.e., reality-based as in "suppose there is a teacher named Joe", but not "suppose there is a Martian named Joe"). An **essential component in belief-revision is a sense of the implicit Scope of the categories being reasoned about**.

Belief alone in a set of statements does not seem to enrich our understanding of the commitment to an epistemic set of facts (as stated earlier by Hasson & Johnson-Laird). What is important is the **entire knowledge base that is drawn upon when revising our beliefs**—including the **presence of the physical properties of instances and categories that are added to the core Scope values**.

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Belief-revision does not proceed by Scope alone, once there is Scope.

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Belief Revision

- Knowledge updating
- Belief change
- Belief revision

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Belief Revision Structure

A Network of Relations

- (1a) All whales are mammals
- (1b) This creature is not a mammal
- (1c) This creature is not a whale

An Assumption

- Assume that this creature is a whale

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Belief Revision Contradiction

A Network of Relations

- (1a) ~~All whales are mammals~~
- (1b) ~~This creature is not a mammal~~
- (1c) ~~This creature is not a whale~~

An Assumption

- Assume that this creature is a whale

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The Paradox of Belief Revision

- Standard logic tells us there is an inconsistency
- Standard logic does not tell us how to resolve the inconsistency
- Our goal is to revise our beliefs with minimal collateral disruption

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True Belief Must Be At Stake

- Revlis & Hayes, 1972
- Elio & Pelletier, 1997
- Politzer & Carles, 2001
- Byrne & Walsh, 2002

- Revlin, Cate, & Rouss, 2001
- Revlin, Calvillo, & Ballard, 2005
- Van Hoeck, Revlin, Dieussaert, & Schaeken, 2012

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Scope

Restricted Scope

All coins in my pocket on VE Day are silver (Goodman, 1954)

Large Scope

All whales are mammals (Ryle, 1949)

Commitment = Scope & Credibility

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Paradigm: Logical Structure

- Modus Tollens (MT) Contradiction

(1a) All whales are mammals
(1b) This creature is not a mammal
(1c) This creature is not a whale

Assume
This creature is a whale

- Modus Ponens (MP) Contradiction

(2a) All whales are mammals
(2b) This creature is a whale
(2c) This creature is a mammal

Assume
This creature is not a mammal

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Pretest: Indicator of Scope

- DEFINITIONAL: all trees are plants
- EMPIRICAL: all professors are teachers
- CLASS-INCL: all oranges are fruit
- PROPERTY: all mammals have hair

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Pretest: Scope Scale

- **1. All whales are mammals.**

|---|---|---|---|---|---|---|

Zero 1 – 10 10 – 100 100 – 1,000 1,000 – 10,000 10,000 – 100,000 100,000 – 1Mil > 1Mil

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Pretest: Indicator of Scope

- DEFINITIONAL: all trees are plants **(6.26)**
- EMPIRICAL: all professors are teachers **(5.65)**
- CLASS-INCL: all oranges are fruit **(6.09)**
- PROPERTY: all mammals have hair **(5.81)**

Scale was converted to an 8-point scale for analysis

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Experiment 1

- Determine the importance of the assessed values for Scope

- Prediction: Greater Scope, more likely generality statement will be retained

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Experiment 1

Average Retention Rates of the Generality Statements by Logic Structure and Ontology

Ontology	**MT Logic**	**MP Logic**
Definitional	92%	62%
Empirical	75%	47%
	84%	**54%**

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Experiment 2

- Scope was found to be a good predictor in belief revision (Exp. 1)
- Materials**: *Rich lives in a desert where*** *all the snakes slither*
- Disabling conditions (Khemlani & Johnson-Laird, 2011) vs. Physical properties (Barsalou et al., 2003)

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Experiment 2

Average Retention Rates of the Generality Statements with Locatives by Logic Structure and Ontology

Ontology	**MT Logic**	**MP Logic**
Definitional	90%	74%
Empirical	85%	69%
	88%	**72%**

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Experiment 3

- Artificial Scope tested with the materials of Experiment 2
- Predictions: Replicate previous weak findings vs. findings of Experiment 2
- Materials:
  - Small: ***Kelly has a hive where 5 bees out of 104 insects have wings***
  - Large: ***Logan has a honeycomb where 91 bees out of 104 insects have wings***

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Experiment 3

Average Retention Rates of the Generality Statements with Locatives by Logic Structure and Set-Size Proportion

Set-Size	**MT Logic**	**MP Logic**
Small Set-Size	87%	74%
Large Set-Size	91%	81%
	89%	**78%**

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Discussion

- Experiment 1: Scope was a predictor of retention of generalities
- Experiment 2: Introduced physical properties to reduce retention; opposite effect
- Experiment 3: Added explicit Scope of statement to reduce retention; opposite effect
- Addition of physical features increased retention rates
- Belief alone is not an indicator of retention; whole knowledge set is used (additive to Scope)

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Belief-revision does not proceed by Scope alone, once there is Scope

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Thank You

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QUESTIONS?