How to Develop Valid Assessments Using Logic-Based Measurement

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What are Logic-Based Measurement Questions?

- Logic-Based Measurement questions are developed according to a methodology, conceived by Magda Colberg (1983), which uses formal logic to test reasoning skills.
- Logic-based reasoning questions are similar to reading comprehension questions in one way:
  - Both types of questions require test-takers to read a passage and make an inference about the information in the passage.

How are Logic-Based Reasoning Questions Different from Reading Comprehension Questions?

- In Reading Comprehension questions, the inference is informal. The correctness of the key is based on the judgment of the review panel.
- In LBM questions, the inference is formal, i.e., it conforms to the rules of logic. The correctness of the key is guaranteed by the correctness of the logical formula.

How are Logic-Based Reasoning Questions Different from Reading Comprehension Questions?

- In Reading Comprehension questions, a limited range of inference processes is tested.
  - “What is the main idea of the passage?”
  - Restatement of an idea expressed in the passage
- In LBM questions, there is a taxonomy that represents a wide range of inference processes.
  - Sampling from this taxonomy ensures that questions cover this range.

Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

- Logic-based questions measure Reasoning, which is a well-established construct in the psychometric literature
- Reasoning skills are among most important job skills
- Logical formulas define the content domain of reasoning

Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

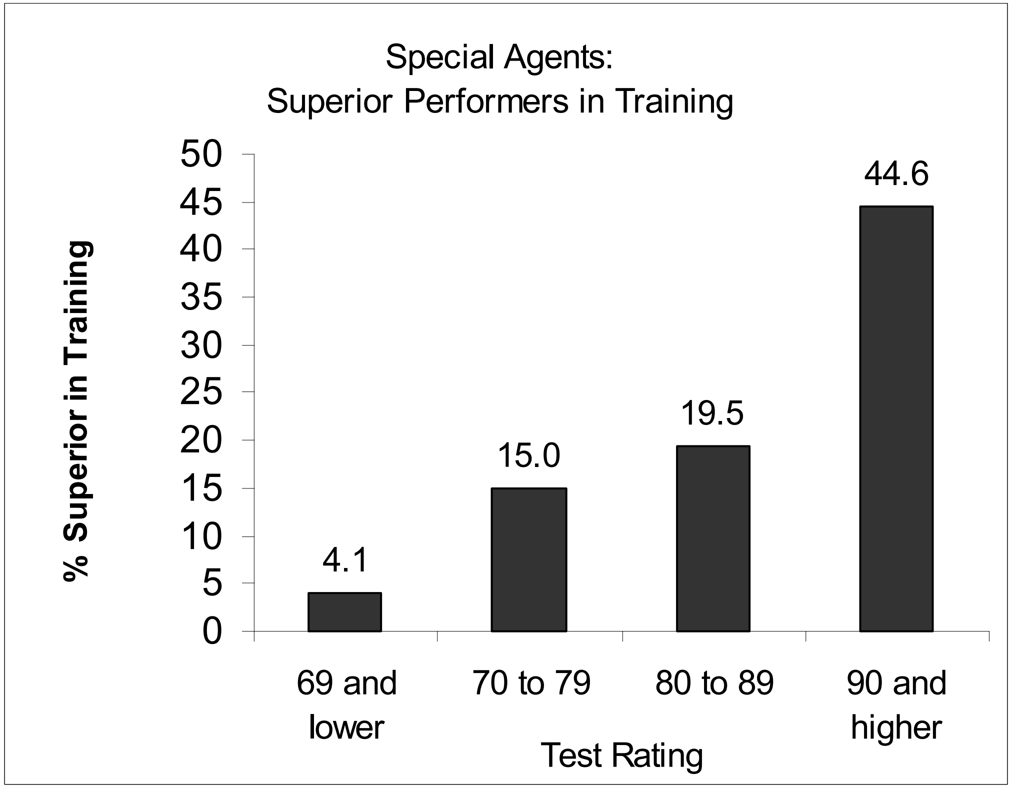
- LBM questions replicate the logical formulas that are used on the job (Simpson, 1999).
  - formulas involving SETS were prevalently used in laws - that is, in defining categories of things, people, etc. for legal purposes.
  - formulas involving CONNECTED STATEMENTS were used prevalently in describing policies and procedures
- This study demonstrated the content validity of logic-based tests.

Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

- LBM questions have proven to be excellent predictors of training success and job performance.
- Average validities (Hayes et al., 2003):
  - training r = .60, lcv = .6
  - work simulation r = .60, lcv = .6
  - supervisory ratings r = .27, lcv = .2

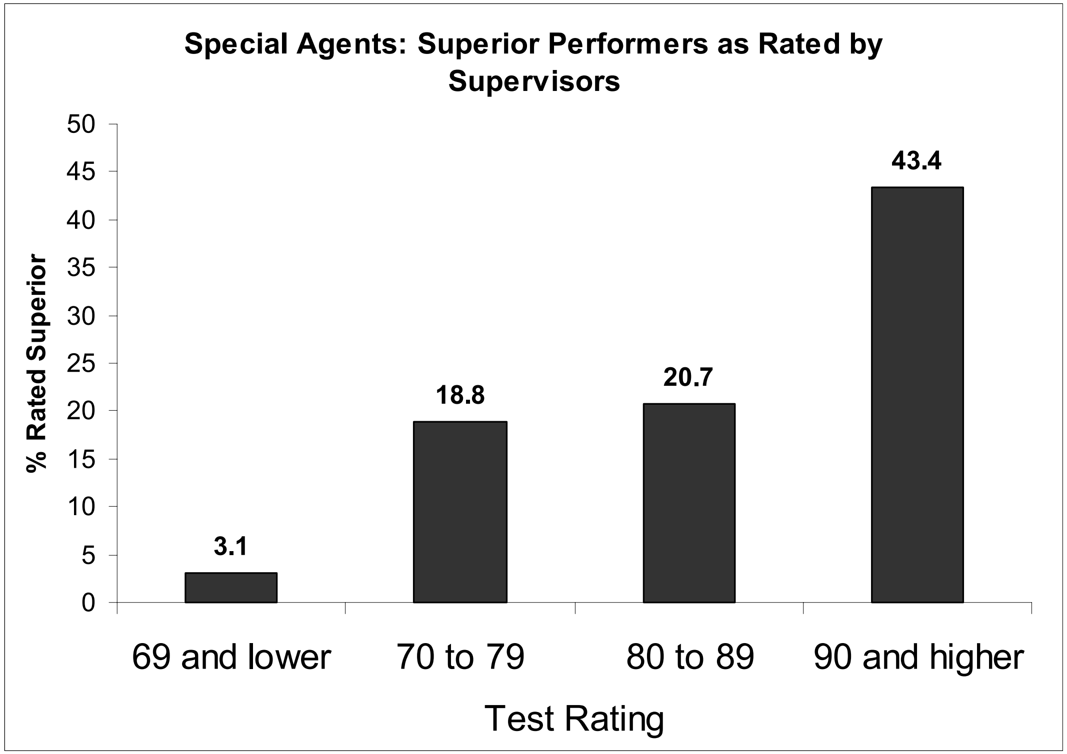
Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

High Scorers Excel in Training



Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

High Scorers Excel on the Job



Why Should Logic-Based Reasoning Questions Be Used in Selection Tests?

- LBM questions always have excellent psychometric statistics (item analysis)
- Because questions almost always "work," you do not need to write lots of extra items.

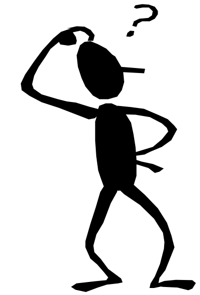
What is the drawback to using Logic-Based Reasoning Questions?

- Item writers must spend time becoming familiar with basic principles of logic.
  - This workshop will give you a good start in the process of familiarization.

Logic-Based Measurement

- After becoming familiar with logic, the next step is to create or adapt a taxonomy of logical formulas.
  - A taxonomy defines the content domain of the reasoning construct, both for the job and for the selection test
  - A taxonomy will be provided in this workshop

LBM QUESTION

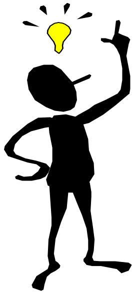


Explosives are substances or devices capable of producing a volume of rapidly expanding gases that exert a sudden pressure on their surroundings. Chemical explosives are the most commonly used, although there are mechanical and nuclear explosives. All mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air. While nuclear explosives are by far the most powerful, all nuclear explosives have been restricted to military weapons.

From the information given above, it can be validly concluded that

A) all explosives that have been restricted to military weapons are nuclear explosives
B) no mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air
C) some nuclear explosives have not been restricted to military weapons
D) all mechanical explosives have been restricted to military weapons
E) some devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air, are mechanical explosives

LBM QUESTION



All mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air.

From the information given above, it can be validly concluded that

E) some devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air, are mechanical explosives

Getting Started

Learn to diagram a sentence logically.

- Four Parts of a Statement
  - Quantifier - All, No, Some
  - Subject term - noun
  - Verb - to be
  - Predicate term - noun, adjective, adjectival phrase or clause (that which is affirmed or denied of the subject)

Statement: All computers are tools.

Parts: Q S V P

Four Basic Statements of Two-Set Logic

"All are" Statement

Statement:	All	computers	are	tools.
Parts:	Q	S	V	P

"No are" Statement

Statement:	No	computers	are	levers.
Parts:	Q	S	V	P

Four Basic Statements of Two-Set Logic

"Some are" Statement

Statement: Some tools are levers.

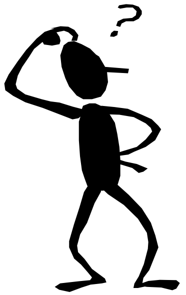
Parts: Q S V P

"Some are not" Statement

Statement: Some tools are not levers.

Parts: Q S V P

EXERCISE



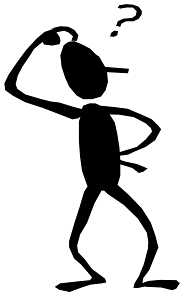
Sentence: All desks in the office are new.

Logical Statement: All S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

EXERCISE

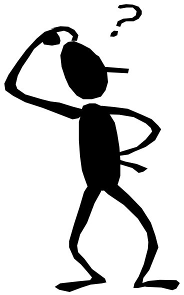


Sentence: All of the courses that are being revised are technical training courses.

Statement: All S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -



EXERCISE

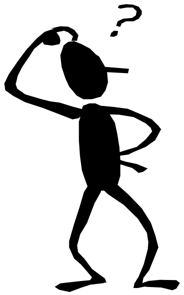
Sentence: No officers are convicted felons.

Logical Statement: No S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

EXERCISE



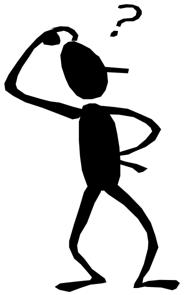
Sentence: No technical training courses were revised last year.

Logical Statement: No S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

EXERCISE



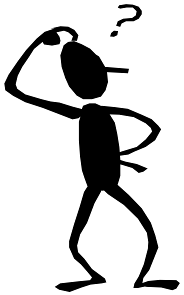
Sentence: Some firefighters are supervisors.

Logical Statement: Some S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

EXERCISE

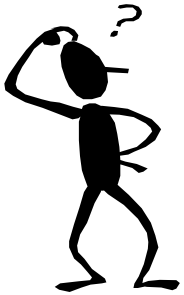


Sentence: There are some state government employees who are attending the IPMAAC conference.

Logical Statement: Some S are P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -



EXERCISE

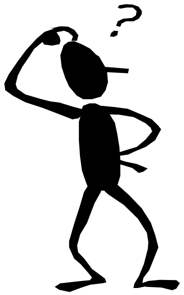
Sentence: Some of these clerks are not trainees.

Logical Statement: Some S are not P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

EXERCISE



Sentence: Some tools are not levers.

Logical Statement: Some S are not P

Logical Parts:

1. Quantifier -
2. Subject Term -
3. Verb -
4. Predicate Term -

LBM QUESTION

All mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air.

From the information given above, it can be validly concluded that

E) some devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air, are mechanical explosives

Learning to Manipulate Parts of a Statement

- Negating Terms
- Exchanging Terms
- Reversing the Quality of Verbs
- Changing the Quantifier

Negating Terms

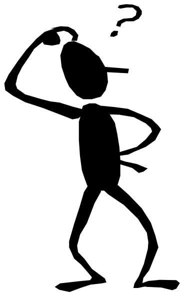
- *To negate a term* is to alter a term so that the altered term does not refer to the same set of things to which the unaltered term refers.
- The set of things to which the original term refers and the set of things to which the negated term refers have NO members in common.

Negating Terms

Examples:

- the negated set of "combatants" is "noncombatants"
- the negated set of "attainable goals" is the set "unattainable goals"
- the negated set of "logic textbooks" is "textbooks other than logic textbooks"

Negating Terms



Exercise:

Statement: Some Federal officers are armed.

Negated subject term:

Negated predicate term:

Exchanging Terms

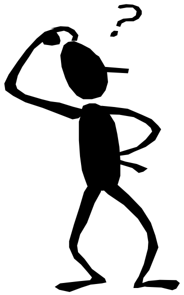
- *To exchange terms* is to predicate the predicate term with the subject term. A new statement is created wherein the old predicate term becomes the new subject term and the old subject term becomes the new predicate term.

✍ **Logic note: the new statement is called the *converse* of the original statement.**

Exchanging Terms

- **Original Statement**
  - **Statement:** All computers are tools.
  - **Term S** computers
  - **Term P** tools
  - **Logical Statement** All S are P
- **Statement with Exchanged Terms**
  - **Statement:** All tools are computers.
  - **Term S** computers
  - **Term P** tools
  - **Logical Statement** All P are S

Exchanging Terms



EXERCISE:

Statement: All of the courses that are being revised are technical training courses.

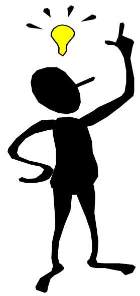
Term S: courses that are being revised

Term P: technical training courses

Logical Statement: All S are P

Statement with terms exchanged:

Exchanging Terms



EXERCISE:

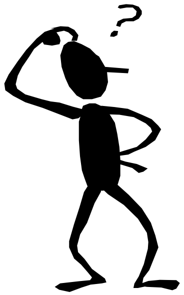
Statement: All of the technical training courses are courses that are being revised.

Statement: All of the technical training courses are being revised.

Logical Statement: All P are S

✍ **Logic note: The *converse* of the "All are" statement is not logically equivalent to the original statement.**

Exchanging Terms



EXERCISE:

Statement: No officers are convicted felons.

Term S: officers

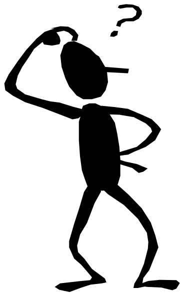
Term P: convicted felons

Logical Statement: No S are P

Statement with terms exchanged:

✍ **Logic note: The *converse* of the "No are" statement IS logically equivalent to the original statement.**

Exchanging Terms



EXERCISE:

Statement: Some tools are levers.

Term S: tools

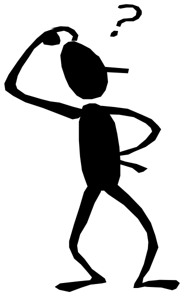
Term P: levers

Logical Statement: some S are P

Statement with terms exchanged:

✍ **Logic note: The *converse* of the "Some are" statement IS logically equivalent to the original statement.**

Exchanging Terms



EXERCISE:

Statement: Some of these clerks are not trainees.

Term S: these clerks

Term P: trainees

Logical Statement: some S are not P

Statement with terms exchanged:

✍ **Logic note: The *converse* of the "Some are not" statement is not logically equivalent to the original statement.**

Reversing the Quality of Verbs

- *To reverse the quality of a verb* is to alter a verb so that the altered verb has the opposite quality.
- How do you reverse the quality of a verb?
  - –With the verb "to be," usually, you can add or subtract the word "not."

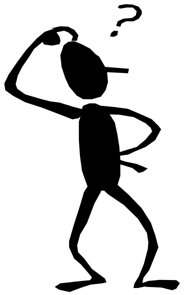
Reversing the Quality of Verbs

Examples:

- Statement: Some tools are levers.
- Negated: Some tools are not levers.

- Statement: Some tools are not levers.
- Negated: Some tools are levers.

Exercise



"some are" statement: Some computers are tools.

logical statement: some S are P

negated statement:

logical negated statement:

"some are not" statement: Some officers are not managers.

logical statement: some S are not P

negated statement:

logical negated statement:

Changing the Quantifier

- Three basic quantifiers: all, no, some
- Equivalent quantifiers:
  - All: each, every, in every case, without exception
  - No: never, none, in no case
  - Some: there are some, sometimes, several
- *To change the quantifier* is to replace a given quantifier with one of the remaining two quantifiers.

Changing the Quantifier

- **All** computers are tools.
  - All S are P
- **No** computers are tools.
  - No S are P (invalid)
- **Some** computers are tools.
  - Some S are P (valid)

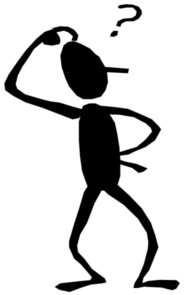
Changing the Quantifier

- **No** computers are levers.
  - No S are P
- **All** computers are levers.
  - All S are P (invalid)
- **Some** computers are levers.
  - Some S are P (invalid)

Changing the Quantifier

- Some tools are levers.
  - Some S are P
- **All** tools are levers.
  - All S are P (invalid)
- **No** tools are levers.
  - No S are P (invalid)

Exercise



All managers are salaried employees.

all S are P

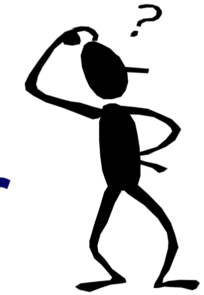
_____ managers are salaried employees.

____ S are P

_____ managers are salaried employees.

____ S are P

Putting It All Together

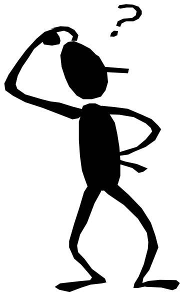


Premise: All reasonable leads are investigated. (All S are P)

Exercise: Write a statement that represents:

Some S are not non-P

Putting It All Together

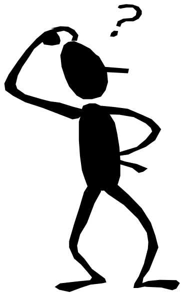


Premise: All reasonable leads are investigated. (All S are P)

Exercise: Write a statement that represents:

Some non-P are not non-S

Putting It All Together



Premise: No firearms courses were revised last year. (No S are P)

Exercise: Write statements to represent:

All S are non-P

No non-P are non-S

LBM Question

Explosives are substances or devices capable of producing a volume of rapidly expanding gases that exert a sudden pressure on their surroundings. Chemical explosives are the most commonly used, although there are mechanical and nuclear explosives. All mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air. While nuclear explosives are by far the most powerful, all nuclear explosives have been restricted to military weapons.

From the information given above, it can be validly concluded that

A) all explosives that have been restricted to military weapons are nuclear explosives
B) no mechanical explosives are devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air
C) some nuclear explosives have not been restricted to military weapons
D) all mechanical explosives have been restricted to military weapons
E) some devices in which a physical reaction is produced, such as that caused by overloading a container with compressed air, are mechanical explosives

Using the Taxonomy

Table A: "all are"

A Premise All S are P.

Valid Conclusions		Invalid Conclusions	
A1	No S are non-P.	**A5**	No S are P.
A2	No non-P are S.	**A6**	Some S are not P.
A3	Some P are S.	**A7**	Some P are not S.
A4	All non-P are non-S.	**A8**	All P are S.
		A9	All S are non-P.
		A10	All P are non-S.
		A11	No P are S.

Using the Taxonomy

- Building an LBM question with valid and invalid conclusions
- Steps
  1. Choose a statement for the premise
  2. Parse the statement logically
  3. Go to the table in the taxonomy that serves your premise
  4. Choose one valid conclusion
  5. Choose invalid conclusions

Using the Taxonomy

- Premise: All computers are tools.

  Q S V P

- Valid Conclusion:

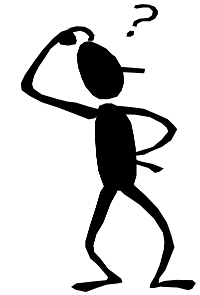
  A2 No non-tools are computers.

- Invalid Conclusions:

  A6 Some computers are not tools.

  A9 All computers are things other than tools.

  A11 No tools are computers.



Exercise

No computers are levers.

From the information given above, it can be validly concluded that

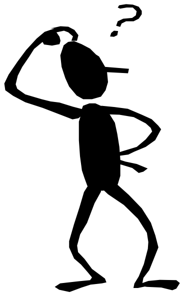
A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Exercise



Some supervisors will attend training this month.

From the information given above, it can be validly concluded that

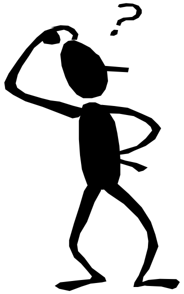
A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Predicate Sets



Some supervisors will attend training this month.

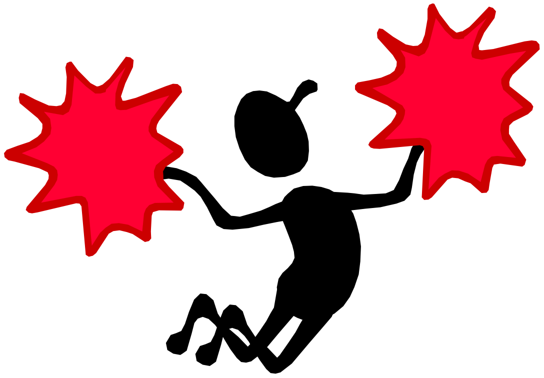
Some (quantifier) supervisors (subject) are (verb) people who will attend training this month (predicate).

Some fish fly.

Some (quantifier) fish (subject) are (verb) flying things (predicate).

Writing Logic-Based Questions

GOING LIVE!!



Exercise: Writing a Test Question

The personnel office of a certain government agency is required to conduct two types of recruitment programs — nationwide campaigns and local programs. All of the publicity material for the nationwide campaigns must be approved by the agency's Office of Public Affairs.

From the information given above, it can be validly concluded that

A)

B)

C)

D)

Exercise: Writing a Test Question

A font, or typeface, is a set of characters, including letters, numbers, and symbols, of a particular design. Wordprocessing applications have a variety of fonts, which serve a variety of uses. For example, no italic font is acceptable for general use in formal agency correspondence. However, all italic fonts are useful for creating special effects, such as setting of words or phrases in a sentence.

From the information given above, it can be validly concluded that

A)

B)

C)

D)

Checklist for Writing LBM Items

- Reading passage contains a premise or premises from which the conclusion will be drawn.
- In “affirmative lead” questions, the correct answer choice represents a valid conclusion from the information in the reading passage.
  - Wrong answer choices represent invalid conclusions.
  - All answer choices (correct and incorrect) must be schematic. That is, they should be representable in logical formulas.

Checklist for Writing LBM Items-2

- Have a target schema or class of schemas in mind.
- Choose passage from relevant reading matter (look for latent logical structure)
- Sketch out question:
  - Logical form of premise: write corresponding sentence
  - Logical form for key: write corresponding sentence
  - Logical form for other answer choices: write corresponding sentences

Checklist for Writing LBM Items-3

- Write passage (50-100 words, context clearly described, sentences coherently related)
- Write lead phrase:
  - include introductory contextual phrase, if necessary
- Write key and 3 or 4 answer choices
  - use good item construction skills
- Vary language so language is not stilted
  - e.g., in place of *some*, use *there are some, sometimes, several*

Checklist for Writing LBM Items-4

- Represent premises and answer choices in symbols; verify correctness of key and incorrect answer choices.
- Assign code according to premise and correct conclusion.

Checklist for Reviewing LBM Items

- Reviewers should translate premises and answer choices into symbols and verify the code.
- All reviewers should review questions for :
    - correctness of keyed response
    - incorrectness of other answer choices
    - nonschematic problems with key:
        - implausible, offensive, contrary to fact
        - may be derived on the basis of knowledge rather than reasoning
    - smoothness of language and coherence of passage

Exercise: Writing a Test Question

In a certain Federal agency, Freedom of Information Act (FOIA) requests are placed in one of two tracks for processing. Requests that require 20 days or less to process are in Track 1. Track 2 is for complex requests that require more than 20 days to locate, review, and prepare the records for disclosure. The FOIA specialists in Team A process all of the requests in Track 1 and a few of the Track 2 requests. Specialists in Teams B and C process the remainder of the requests.

From the information given above, it can be validly concluded that

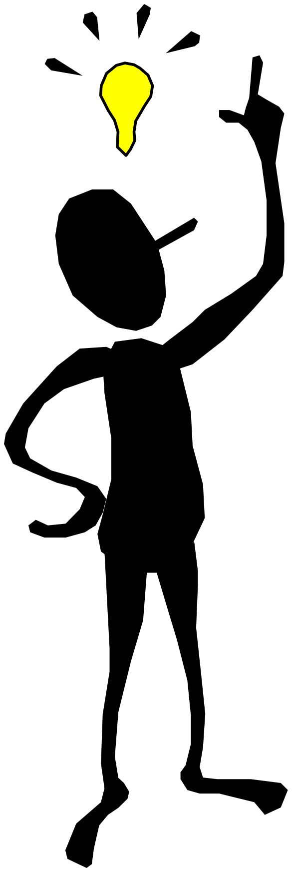
A)

B)

C)

D)

Reasoning with Three Sets



Introduction

to

Syllogisms

Reasoning with Three Sets

- Two statements are used together to draw a new conclusion about the relationship between two sets.
- The two statements contain a total of three sets, one of which is contained in both statements.

Reasoning with Three Sets

Example:

- Premise 1: All recently hired employees are very well qualified. (All M are P)
- Premise 2: All of our trainees are recently hired employees. (All S are M)
- Conclusion: All of our trainees are very well qualified. (All S are P)

Reasoning with Three Sets

- The form of the categorical syllogism

  All M are P

  All S are M

  Therefore, All S are P

- The set that is common to both premises is called the *term of comparison* or the *middle term*.

Reasoning with Three Sets

- Example with negative premise
  - No recently hired employee is certified in CPR. (No M are P)
  - All trainees are recently hired employees. (All S are M)
  - Conclusion: No trainee is certified in CPR. (No S are P)

Exercise

For this pair of statements, underline the middle term and write a valid conclusion relating the other two terms in the space provided.

All DHS employees are Federal employees.
All BCIS employees are DHS employees.
Conclusion:

Exercise with Taxonomy

For this pair of statements, find the appropriate table in the taxonomy. Then write one valid conclusion and one invalid conclusion from the choices in the taxonomy.

No Canadian citizens are U.S. citizens.

All citizens of Quebec are Canadian citizens.

Valid conclusion:

Invalid conclusion:

LBM Question

Usually an officer cannot search an individual without a warrant. However, there are some exceptions. For example, if the safety of an officer is involved, the officer may search an individual without a warrant.

From the information given above, it can be validly concluded that

A) an officer may search an individual without a warrant if the safety of the officer is not involved

B) if an officer may not search an individual without a warrant, then the safety of the officer is not involved

C) if the safety of an officer is involved, the officer may not search an individual without a warrant

D) an officer may search an individual without a warrant only if the safety of the officer is involved

E) if the safety of an officer is not involved, then the officer may not search an individual without a warrant

Connectives

- Parts of Connective Statements
- Types of Connective Statements
  - Valid Conclusions
  - Invalid Conclusions

Connective Statements

- Two types of parts:
  1) simple statements
  2) connectives, such as *if…then*

Con-nective	Statement	Con-nective	Statement
If	a person is an employee of DHS	then	the person is a Federal employee

Connective Statements

- Any one connective statement must have two simple statements and one connective.
- However, any one connective statement can have more than two simple statements and more than one connective: the compound conditional.

Example: embedded connective

Con-nective	Statement	Con-nective	Statement
If	a person is an employee of DHS or a person is an employee of DOJ	then	the person is a Federal employee
	a person is an employee of the DHS	or*	a person is an employee of DOJ

*embedded connective: the ‘or’ is embedded within the main conditional ‘if … then’

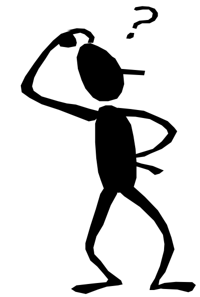
Simple and Complete Statements

- Connective statements are compound sentences.
- The statements that make up the components of the compound sentences are of the form *A is B*.
- They are simple statements, but they are complete statements.
- For example, “John” is not a simple statement. “if a person is an officer, then John” is not a connective statement.

Simple Statements

- Example: If a person is an employee of DHS or of DOJ, then the person is a Federal employee.
- Connectives: if ... then, or
- Statements
  - a person is an employee of DHS
  - a person is an employee of DOJ
  - a person is a Federal employee

Exercise



Underline the simple statements:

- There is a record of a deduction on your biweekly earnings statement if you contribute to the Combined Federal Campaign through payroll deduction.
- You can take the advanced supervisory course only if you have taken the basic supervisory course.
- A person is European if the person is German.
- If an international flight arrives, Inspectors process the arriving passengers.
- You can stay in the condo for free if and only if you attend the sales seminar.
- If a person is an Immigration Inspector, the person works for DHS.

Connectives

- if ... then (sometimes ‘then’ is tacit)
- only if
- when
- both ... and
- either ... or
- neither ... nor

Representation

- Simple statements are represented by lower case letters, such as *p, q, r*.
  - p = a person is an employee of DHS
  - q = a person is an employee of DOJ
  - r = a person is a Federal employee

Roadmap

- Conditional
- Biconditional
- Extended conditional

Conditional

- If A is B, then C is D.
- If p, then q.
- $p \supset q$.

Two Logical Parts

- The conditional statement has two logical parts, other than connectives;
  - 1) a condition
  - 2) a result of the condition being true

- Example: if the car is out of gas, the car will not run.

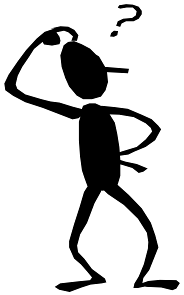
Conditional

- Condition = antecedent, Result = consequent
  - If the car is out of gas, then the car will not run
    - antecedent = car is out of gas
    - consequent = the car will not run

- The conditional sentence says that if the antecedent is true, then the consequent must also be true.

- If the student is eligible for this class, then he/she has completed the prerequisites.

Conditional



- The budget will be approved if the department requests a smaller spending level than last year.
- The deal will fall through if Lisa cannot attend the meeting.
- If a person is hired as a Border Patrol agent, the person attends training at FLETC.
- The computer was purchased by David only if the computer lacks a floppy drive.
- The neighborhood streets are dark during the day if there is a total eclipse of the sun.
- Rachel is eligible only if she has signed a waiver.

Conditional

- if 💻 only if
- The bank is not open if today is a holiday. (true: if p, then q)
- The bank is not open only if today is a holiday. (not true: if q, then p)
  - p = today is a holiday
  - q = the bank is not open

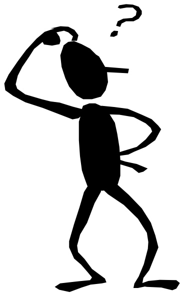
Manipulating Parts of a Connective Statement

- Negating Simple Statements
- Exchanging Simple Statements
- Changing the Connectives

Negating Simple Statements

- *To negate a simple statement* is to reverse the quality of the simple statement.
- For example:
  - John is mad.
  - John is not mad.
  - Congress will adjourn before passing the legislation.
  - Congress will not adjourn before passing the legislation.

Negating Simple Statements



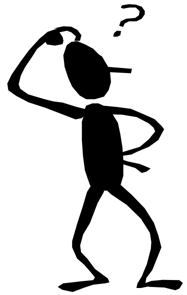
Exercise:

If the levy breaks, the harvest will be ruined.

Negated antecedent:

Negated consequent:

Negating Simple Statements



Exercise:

The bill will not be passed if the legislature does not meet.

Negated antecedent:

Negated consequent:

Negating Simple Statements

✍ **Logic note: When both the antecedent and the consequent are negated, the new statement is called the *inverse* of the original statement.**

- **Premise**
  - **If a child is dehydrated, the child should drink small amounts of Gatorade.**
- **Inverse**
  - **A child who is not dehydrated should not drink small amounts of Gatorade.**

K The inverse of the conditional statement is an Illogical Bias

Exchanging Simple Statements

- *To exchange simple statements* is to make the antecedent become the consequent and make the consequent become the antecedent.

✍ **Logic note: the new statement is called the *converse* of the original statement.**

K **The converse of the conditional statement is an Illogical Bias**

Exchanging Simple Statements

- **Original Conditional Statement**
  - **Statement:** If tanks breach the wall, the rebellion is lost.
  - **Antecedent** tanks breach the wall
  - **Consequent** the rebellion is lost
  - **Symbols** if p, then q
- **Statement with Exchanged Simple Statements**
  - **Statement:** If the rebellion is lost, then tanks breached the wall.
  - **Antecedent** the rebellion is lost
  - **Consequent** tanks breach the wall
  - **Symbols** if q, then p

Exchanging Simple Statements

EXERCISE:

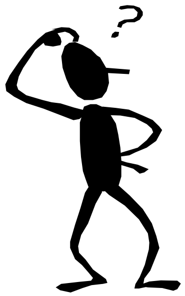
Statement: If the contract is valid, then the contract is notarized.

Antecedent: the contract is valid

Consequent: the contract is notarized

Logical Statement: if p, then q

Statement with terms exchanged:



Exchanging Simple Statements

EXERCISE:

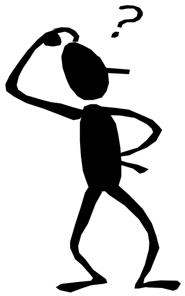
Statement: The train does not operate on holidays.

Antecedent: today is a holiday

Consequent: the train does not operate

Logical Statement: q when p

Statement with terms exchanged:



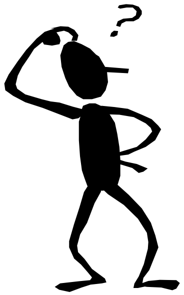
Changing the Connectives

- Basic connectives: if/then, only if, if, and, or
- Equivalent connectives to if/then:
  - When/then, After/then
- *To change the connective* is to replace a given connective with another connective.

Changing the Connectives

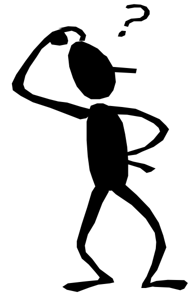
- If Smith's license is invalid, then he may not drive the company van.
  - If p, then q
- Smith's license is invalid only if he may not drive the company van.
  - p only if q (valid)
- Smith's license is invalid if he may not drive the company van.
  - p if q (invalid)

Exercise



- If an applicant is eligible to become a Federal law enforcement officer, then the applicant has not been convicted of domestic violence. (if p, then q)
  - p only if q (valid)
  - p if q (invalid)

Putting It All Together



Premise: If I leave the house before 5:30 a.m., then I cannot read my newspaper before work. (if p, then q)

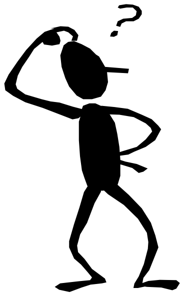
Write a statement that represents:

if non-p, then non-q

if q, then non-p

if non-q,then non-p

Putting It All Together



Premise: The operation will succeed only if the extraction team does not get caught. (p only if q)

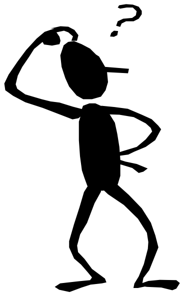
Write a statement that represents:

if p, then q

non-p only if non-q

if non-q,then non-p

Putting It All Together



Premise: The engine should be turned off if the gauge turns red.

Write a statement that represents:

if p, then q

non-p if non-q

if q,then p

LBM Question

Usually an officer cannot search an individual without a warrant. However, there are some exceptions. For example, if the safety of an officer is involved, the officer may search an individual without a warrant. (if p, then q)

From the information given above, it can be validly concluded that

A) an officer may search an individual without a warrant if the safety of the officer is not involved (q if non-p)

B) if an officer may not search an individual without a warrant, then the safety of the officer is not involved (if non-q, then non-p)

C) if the safety of an officer is involved, the officer may not search an individual without a warrant (if p, then non-q)

D) an officer may search an individual without a warrant only if the safety of the officer is involved (q only if p)

E) if the safety of an officer is not involved, then the officer may not search an individual without a warrant (if non-p, then non-q)

Using the Taxonomy

Table S:

S Premise If p, then q.

Valid Conclusions

S1 if p, then q.

S2 if non-q, then non-p.

Invalid Conclusions

S3	if p, then non-q	**S7**	if q, then non-p
S4	if non-p, then q	**S8**	if non-q, then p
S5	if non-p, then non-q		
S6	if q, then p		

Using the Taxonomy

- Building an LBM question with valid and invalid conclusions
- Steps
  1. Choose a statement for the premise
  2. Parse the statement logically
  3. Go to the table in the taxonomy that serves your premise
  4. Choose one valid conclusion
  5. Choose invalid conclusions

Using the Taxonomy

- Premise: If David goes to the movies, then Suzie will go shopping.

  if p, then q
- Valid Conclusion:

  S2 If Suzie does not go shopping, then David did not go to the movies.
- Invalid Conclusions:

  S6, E2 David went to the movies if Suzie goes shopping.

  S5 If David does not go to the movies, then Suzie will not go shopping.

  S8 If David goes to the movies, then Suzie will not go shopping.

Using the Taxonomy

- Premise: Bill and Shirley are workers at the same office. At this office, if a worker leaves the vault open, the worker will be dismissed. Bill left the vault open.

  if p, then q; and p

- Valid Conclusion:

  S1 Bill will be dismissed.

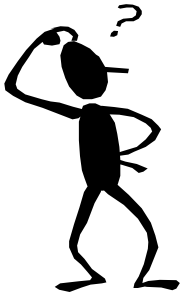
- Invalid Conclusions:

  S3 Bill will not be dismissed.

  S6, E1 Shirley will be dismissed only if she leaves the vault open.

  S8, E2 Shirley left the vault open if she will not be dismissed.

Exercise



Premise: If the belt is broken, then the fan will stop.

From the information given above, it can be validly concluded that

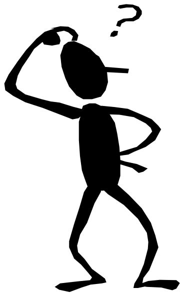
A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Exercise



Premise: If a person is hired as a Border Patrol agent trainee, the person will attend training at FLETC. Sherry has applied to become a Border Patrol agent trainee.

From the information given above, it can be validly concluded that

A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Roadmap

- Conditional
- Biconditional
- Extended conditional

Biconditional

- If A is B, then C is D; and if C is D, then A is B
- If p then q; and if q then p
- p if and only if q
- $p \equiv q$
- The Secretary of the DHS is the director of your agency if and only if you are an employee of DHS.

Biconditional

- p if and only if q
  - p if q = if q, then p
  - p only if q = if p, then q
- if q, then p; if p, then q

Biconditional

p if and only if q

- Valid (T5 - T8)
  - if p, then q — if ~q, then ~p
  - if q, then p — if ~p, then ~q
- Invalid (T13 - T16)
  - if p, then ~q — if ~q, then p
  - if q, then ~p — if ~p, then q

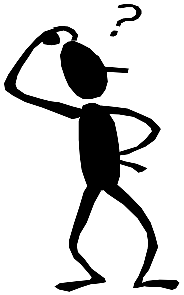
LBM Question

Rhett and Abby both received a special offer to receive the free use of a condo in Florida. However, there was a catch. They were told that they can stay in the condo for free if and only if they attend the sales seminar. Rhett attended the sales seminar, but Abby did not.

if p, then q; and q (Rhett) and ~q (Abby)

- Valid Conclusion:
  - T7Rhett can stay in the condo for free.
- Invalid Conclusions:
  - T16 Abby can stay in the condo for free.
  - T15 Rhett cannot stay in the condo for free.

Exercise



Premise: The Secretary of the DHS is the director of your agency if and only if you are an employee of the DHS.

From the information given above, it can be validly concluded that

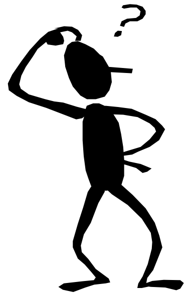
A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Exercise



The local water utility chairman has been accused of providing false testimony. Although the utility's executive board wishes the chairman to resign because of the accusations, thus far the chairman has refused. In fact, the chairman has vowed to resign if and only if there is an actual conviction.

From the information given above, it can be validly concluded that, assuming that the chairman's vow is adhered to,

A) the chairman has not been convicted if and only if the chairman has resigned

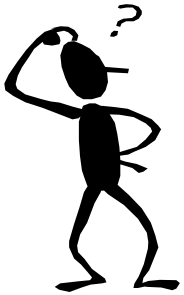
B) if the chairman has not resigned, then there is an actual conviction

C) the chairman has been convicted if the chairman has resigned

D) the chairman will resign only if there is not an actual conviction

E) the chairman has been convicted if and only if the chairman has not resigned

Exercise



The trial will consist of two phases. In the first, the jury will decide whether the defendant produced a defective product and thus incurred liability for damages. If and only if the jury finds liability for damages in phase one will the trial move to phase two. At that point, plaintiffs will have to prove that the defendant’s products caused their injuries and establish a monetary value for those injuries.

From the information given above, it can be validly concluded that

A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Roadmap

- Conditional ✔
- Biconditional ✔
- Extended conditional

Extended Conditional

If r, then q

if p, then r

therefore, if p, then q

$(r \supset q) \wedge (p \supset r); \; \wedge\, p; \; \therefore\; q.$

Extended Conditional

If <u>additional staff are assigned</u>, special funding will be needed. If it is a holiday weekend, <u>additional staff are assigned</u>.

Therefore, if it is a holiday weekend, special funding will be needed.

If <u>r</u>, then q
if p, then <u>r</u>
therefore, if p, then q

Inferences

If r, then q

if p, then r

<u>Valid</u>

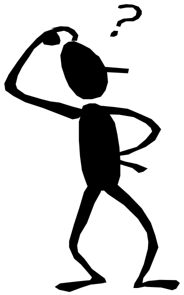
therefore, if p, then q

therefore, if ~q, then ~p

<u>Illogical Biases</u>

therefore, if ~p, then ~q	inverse
therefore, if q, then p	converse

Exercise



If there are not enough vehicles for everyone, some drivers will be placed on leave without pay. If the mechanics go on strike, then there will not be enough vehicles for everyone.

From the information given above, it can be validly concluded that

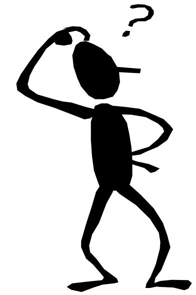
A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Exercise



Impressions made by the ridges on the ends of the fingers and thumbs are useful means of identification. If finger patterns from fingerprints are not decipherable, then they cannot be classified by general shape and contour or by pattern type. If they cannot be classified by these characteristics, then it is impossible to identify the person to whom the fingerprints belong.

From the information given above, it can be validly concluded that

A) if it is impossible to identify the person to whom fingerprints belong, then the fingerprints are not decipherable

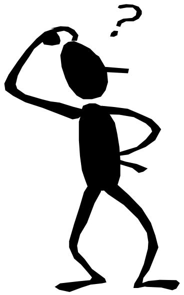
B) if finger patterns from fingerprints are not decipherable, then it is impossible to identify the person to whom the fingerprints belong

C) if fingerprints are decipherable, then it is impossible to identify the person to whom they belong

D) if fingerprints can be classified by general shape and contour or by pattern type, then they are not decipherable

E) if it is possible to identify the person to whom fingerprints belong, then the fingerprints cannot be classified by general shape and contour or pattern type

Exercise



If a person is hired as a Border Patrol agent trainee, the person will attend training at FLETC. While at FLETC trainees study immigration law and other relevant topics. Sherry has applied to become a Border Patrol agent trainee.

From the information given above, it can be validly concluded that

A) valid conclusion:

B) invalid conclusion:

C) invalid conclusion:

D) invalid conclusion:

Roadmap

- Conditional ✔
- Biconditional ✔
- Extended conditional ✔

THANK YOU

Taxonomy For Reasoning Questions Using Logic-Based Measurement

Robert W Simpson
Mary Anne Nester
LBM Class
June 2003

Taxonomy for Logic-Based Measurement

Introduction

This taxonomy should be used as a blueprint for both developing and documenting tests of job-related thinking skills. The thinking skills presented in the taxonomy are the basic forms of deductive reasoning. These forms of reasoning are the building blocks of complex forms of reasoning, such as decision-making.

The basic forms of deductive reasoning are divided into four Parts for this taxonomy. Each Part covers a different area of the domain of deductive reasoning. Unlike other taxonomies, this taxonomy presents both correct and incorrect responses possible for each area of deductive reasoning, enabling the test developer to be as sure of the "incorrectness" of incorrect responses as the "correctness" of correct responses.

In all four Parts of the taxonomy, tables are given that first show a certain type of premise or certain types of premises and that provide the valid and invalid conclusions for the premise or premises shown. Part A covers reasoning from a single premise. The premise is a statement containing two sets. The conclusions in Part A are a single statement containing two sets. Part B covers reasoning from two premises. Each premise is a statement that contains two sets. The two premises have one set in common. The conclusions are a single statement containing two of the three sets in the premises. Part C covers reasoning with two statements that are connected. The emphasis in this Part is on how the statements are connected instead of the sets that comprise the connected statements. Part D covers reasoning with three connected statements. As in Part C, the emphasis in Part D is on how the statements are connected.

Taxonomy for Logic-Based Measurement

Part A: Reasoning with Two Sets: Tables A, E, I, and O

In Part A, four tables are given showing the valid and invalid conclusions based on the four basic types of two-set premises. Each premise is a single statement containing two sets, and each conclusion is a single statement containing two sets. The first set of the premise is denoted by "S" and the second set is denoted by "P."

Table A: "all are"
One Premise with Two Sets and the Quantifier

A	Premise	All S are P.
A1	Valid Conclusion	No S are non-P.
A2		No non-P are S.
A3		Some P are S.
A4		All non-P are non-S.
A5	Invalid Conclusion	No S are P.
A6		Some S are not P.
A7		Some P are not S.
A8		All P are S.*
A9		All S are non-P.
A10		All P are non-S.
A11		No P are S.

*Illogical Bias

Table E: "no are "
One Premise with Two Sets

E	Premise	No S are P.
E1	Valid Conclusion	No P are S.
E2		All S are non-P.
E3		All P are non-S.
E4		Some P are not S.
E5	Invalid Conclusion	All S are P.
E6		All P are S.
E7		Some S are P.
E8		Some P are S.
E9		All non-S are P.
E10		All non-P are S.
E11		No non-P are non-S.*

*Illogical Bias

Taxonomy for Logic-Based Measurement

Table I: "some are"
One Premise with Two Sets and the Quantifier

I	Premise	Some S are P.
I1	Valid Conclusion	Some P are S.
I2		Some P are not non-S.
I3		Some S are not non-P.
I4	Invalid Conclusion	All S are P.
I5		No S are P.
I6		Some S are not P.*
I7		All P are S.
I8		No P are S.
I9		Some P are not S.

*Illogical Bias

Table O: "some are not"
One Premise with Two Sets, the Quantifier

O	Premise	Some S are not P.
O1	Valid Conclusion	Some S are non-P.
O2		Some non-P are S.
O3	Invalid Conclusion	All S are P.
O4		No S are P.
O5		Some S are P.
O6		Some P are not S.*
O7		No P are S.
O8		All P are S.

*Illogical Bias

Taxonomy for Logic-Based Measurement

Part B: Reasoning with Three Sets: Tables MA, ME, MI, and MO

In Part B, four tables are given showing the valid and invalid conclusions based on the four basic sets of conclusions for two-premise syllogisms. Each premise in a syllogism is a single statement containing two sets, and each conclusion is a single statement containing two sets. The two premises have one set in common, denoted by "M." The other two sets in the premises are denoted by "S" and by "P" as shown in the tables.

Table MA: Two Premises with Three Sets: S, M, and P

	Conclusions	
1	Valid Conclusion	All S are P.
2		No S are non-P.
3		No non-P are S.
4		Some P are S.
5		All non-P are non-S.
6	Invalid Conclusion	No S are P.
7		Some S are not P.
8		Some P are not S.
9		All P are S.
10		All S are non-P.
11		All P are non-S.
12		No P are S.

Name	Premises	Type	Logical Statement
1AA	Premise P	A	All M are P.
	Premise S	A	All S are M.

Table ME: Two Premises with Three Sets: S, M, and P

	Conclusions	
1	Valid Conclusion	No S are P.
2		No P are S.
3		All S are non-P.
4		All P are non-S.
5		Some P are not S.
6		Some S are not P.
7	Invalid Conclusion	All S are P.
8		All P are S.
9		Some S are P.
10		Some P are S.
11		All non-S are P.
12		All non-P are S.
13		No non-P are non-S.

Name	Premises	Type	Logical Statement
1EA	Premise P	E	No M are P.
	Premise S	A	All S are M.
2AE	Premise P	A	All P are M.
	Premise S	E	No S are M.
2EA	Premise P	E	No P are M.
	Premise S	A	All S are M.
4AE	Premise P	A	All P are M.
	Premise S	E	No M are S.

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Table MI: Two Premises with Three Sets: S, M, and P

	Conclusions	
1	Valid Conclusion	Some S are P.
2		Some P are S.
3		Some P are not non-S.
4		Some S are not non-P.
5	Invalid Conclusion	All S are P.
6		No S are P.
7		Some S are not P.
8		All P are S.
9		No P are S.
10		Some P are not S.

Name	Premises	Type	Logical Statement
1AI	Premise P	A	All M are P.
	Premise S	I	Some S are M.
3AA	Premise P	A	All M are P.
	Premise S	A	All M are S.
3AI	Premise P	A	All M are P.
	Premise S	I	Some M are S.
3IA	Premise P	I	Some M are P.
	Premise S	A	All M are S.
4IA	Premise P	I	Some P are M.
	Premise S	A	All M are S.

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Table MO: Two Premises with Three Sets: S, M, and P

	Conclusions	
1	Valid Conclusion	Some S are not P.
2		Some S are non-P.
3		Some non-P are S.
4	Invalid Conclusion	All S are P.
5		No S are P.
6		Some S are P.
7		Some P are not S.
8		No P are S.
9		All P are S.

Name	Premises	Type	Logical Statement
1EI	Premise P	E	No M are P.
	Premise S	I	Some S are M.
2AO	Premise P	A	All P are M.
	Premise S	O	Some S are not M.
2EI	Premise P	E	No P are M.
	Premise S	I	Some S are M.
3EA	Premise P	E	No M are P.
	Premise S	A	All M are S.
3EI	Premise P	E	No M are P.
	Premise S	I	Some M are S.
3OA	Premise P	O	Some M are not P.
	Premise S	A	All M are S.
4EA	Premise P	E	No P are M.
	Premise S	A	All M are S.
4EI	Premise P	E	No P are M.
	Premise S	I	Some M are S.

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Part C: Reasoning with Two Connected Statements: Tables S and T

In Part C, two tables are given showing the valid and invalid conclusions based on two basic types of connected statements. Each premise is a complex statement containing two statements, and each conclusion is complex statement containing two statements. The first statement of the premise is denoted by "p" and the second statement is denoted by "q."

The statements denoted by "p" and "q" can be the four basic two-set statements discussed in Parts A and B: All S are P, No S are P, Some S are P, and Some S are not P. If any of the four statements is used for "p" or "q," care must be taken in creating the negation of the statement. The following table shows the negation of the four basic statements.

Statement "p" (or "q")	**Negated statement "non-p" (or "non-q")**
All S are P	Some S are not P
No S are P	Some S are P
Some S are P	No S are P
Some S are not P	All S are P

Equivalencies of the Conditional Statement

The basic conditional statement has many equivalent statements. Some of these equivalent statements are merely different English phrasings of the same conditional statement (such as E2 below) and others are logically different from, but truth functionally equivalent to, the basic conditional statement (such as E5 below). These equivalencies may be used with valid and invalid response options.

	Statement	**Equivalence**
E1	if p then q	p only if q
E2	if p then q	q if p
E3	if p then q	not p unless q
E4	if p then q	not (both p and not-q)
E5	if p then q	either not-p or q

Table S: Two Statements Connected; p and q

S	Premise	if p then q
S1	Valid Conclusion	if p, then q
S2		if non-q, then non-p
S3	Invalid Conclusion	if p then non-q
S4		if non-p then q
S5		if non-p then non-q*
S6		if q then p*
S7		if q then non-p
S8		if non-q then p

*Illogical Bias

Table T: Two Statements Connected; p and q

T	Premise	p if and only if q
T1	Valid Conclusion	p if and only if q
T2		non-p if and only if non-q
T3		q if and only if p
T4		non-q if and only if non-p
T5		if p, then q
T6		if non-q, then non-p
T7		if q, then p
T8		if non-p, then non-q
T9	Invalid Conclusion	p if and only if non-q
T10		non-p if and only if q
T11		q if and only if non-p
T12		non-q if and only if p
T13		if p, then non-q
T14		if non-p, then q
T15		if q, then non-p
T16		if non-q, then p

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Part D: Reasoning with Three Connected Statements: Table RS

In Part D, a table is given showing the valid and invalid conclusions for a syllogism based on two connected statements. Each premise is a complex statement containing two statements, and each conclusion is complex statement containing two statements. The two premises have one statement in common, denoted by "r." The other two statements in the premises are denoted by "p" and "q" as shown in the table.

Note: The equivalencies of the conditional statement apply here also.

	Statement	**Equivalence**
E1	if p then q	p only if q
E2	if p then q	q if p
E3	if p then q	not p unless q
E4	if p then q	not (both p and not-q)
E5	if p then q	either not-p or q

Table RS: Three Statements Connected; p, q, and r

	Premise	if r then q
	Premise	if p then r
RS1	Valid Conclusion	if p, then q
RS2		if non-q, then non-p
RS3	Invalid Conclusion	if p then non-q
RS4		if non-p then q
RS5		if non-p then non-q*
RS6		if q then p*
RS7		if q then non-p
RS8		if non-q then p

*Illogical Bias