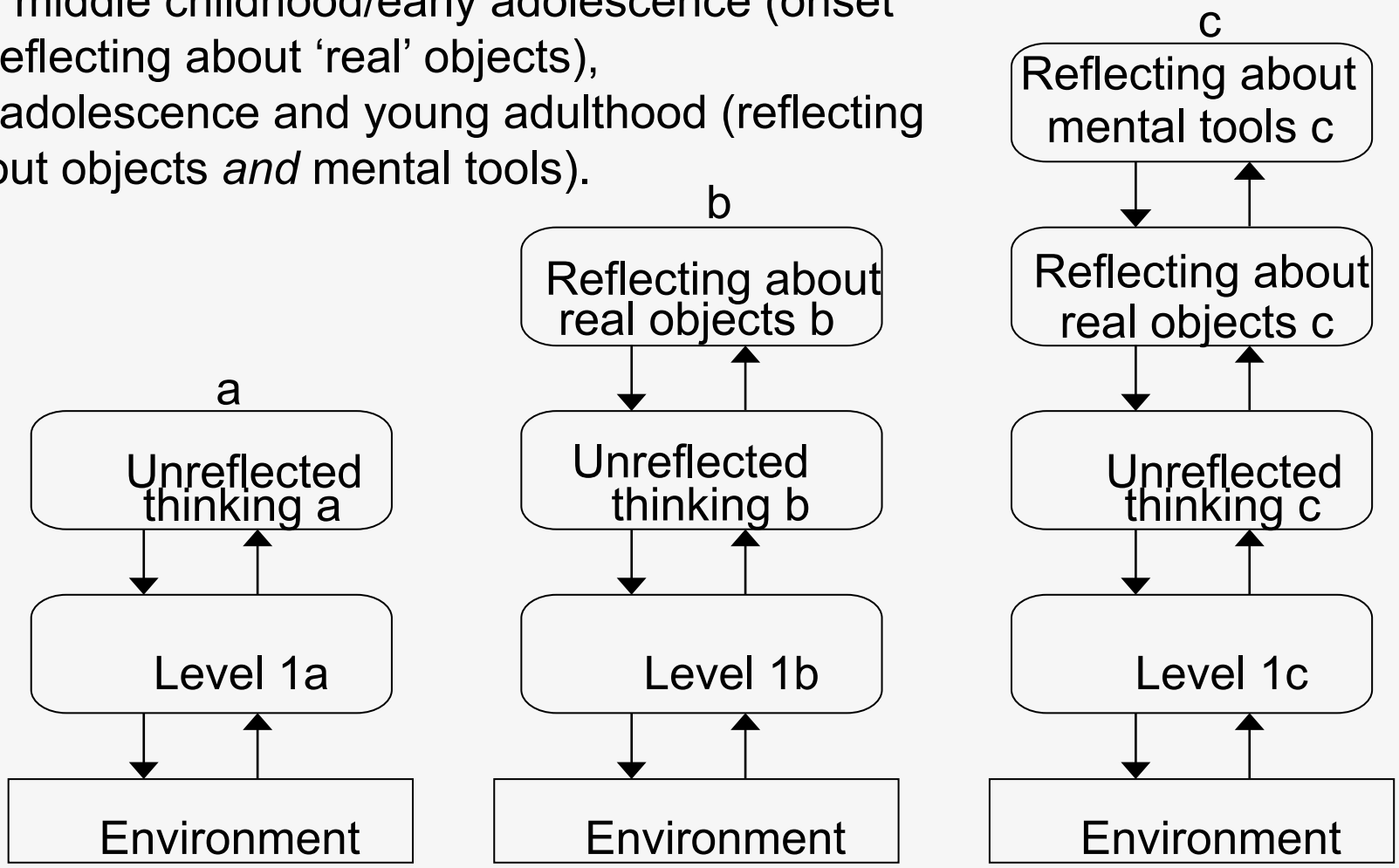
Evolution of cognition aimed at 'seizing up' the environment (perceived reality) in the course of age-related cognitive development.

(a) early childhood,

(b) middle childhood/early adolescence (onset of reflecting about 'real' objects),

(c) adolescence and young adulthood (reflecting about objects *and* mental tools).



System analysis and decision making[1]

Young children (pre-schoolers) may take years to come fully to grips with such issues.

There are four reasons for this.

(a) they are understandably inclined to look primarily at the exterior striking features

(as distinct from the 'inner' or abstract characteristics that are not infrequently used as definition by adults, e.g., metabolism for being alive)

(b) they start from their own experiences and make analogical inferences not admitted by adults

('as a child, I thought that God eats or drinks because I ate and drank')

(c) they often concentrate on just *one* aspect, presumably due mostly to their limited working memory

(d) they assume that everybody has the same knowledge and understanding as they have, and therefore do not feel the need to formulate and discuss their views to the extent that older children, adolescents, and adults do

Logical arguments are used to elaborate the ontological tree.

Logical development has to do with acquiring competence in classical logical operations where applicable (like making a valid inference, making use of transitivity, arguing by means of a logical implication), and gaining knowledge about logical quantifiers and their use.

It also involves coming to grips with **modality** logic (necessity, possibility, 'all' statements, 'there exists' statements)

SYSTEM ANALYSIS AND DECISION MAKING

HYPOTHETICAL POSSIBILITIES

Human beings engage in a kind of thinking that requires consideration of hypothetical possibilities.

Hypothetical thinking is a uniquely human facility that is a distinguishing characteristic of our intelligence.

The importance of hypothetical thinking is associated with dual processes in thinking and reasoning.

There are distinct cognitive mechanism sunder lying implicit and explicit thinking

The implicit system provides automatic input to human cognition in the form of pragmatic processes whose tendency is to contextualise the current environment in the light of background beliefs and knowledge.

System analysis and decision making

The explicit system is linked to language and reflective consciousness, and providing the basis for reasoning.

Explicit thinking requires working memory and is therefore sequential and sharply limited in processing capacity compared with the implicit system.

Effective functioning of the explicit system is also linked to measures of general intelligence

THE THREE PRINCIPLES OF HYPOTHETICAL THINKING

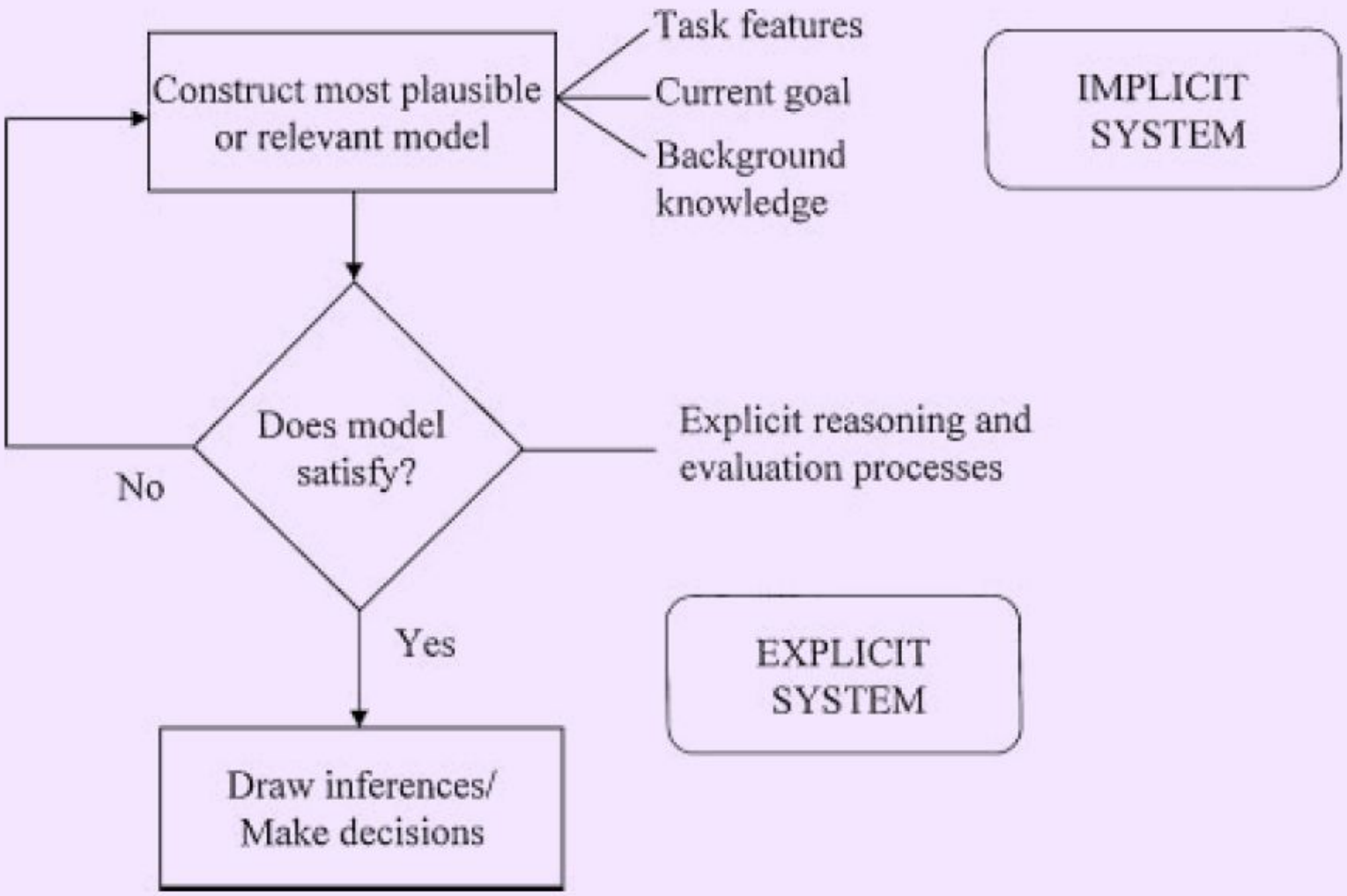
The singularity principle. People consider a single hypothetical possibility, or mental model, at one time.

The relevance principle. People consider the model which is most relevant (generally the most plausible or probable) in the current context.

The satisficing principle. Models are evaluated with reference to the current goal and accepted if satisfactory.

System analysis and decision making

Hypothetical thinking model



The explicit system evaluates the hypothesis against evidence and accepts it if it satisfies (is consistent with the evidence).

Only when a falsifying case is encountered is the evaluation unsatisfying, and the model (hypothesis) abandoned and a new one generated.

Both relevance and satisficing principles come into play here, in the model-generating and model-evaluation stages, respectively.

System analysis and decision making

The normative account of decision making suggests that people can hold in mind two or more possibilities at the same time.

But people represent only one relevant possible world at a time as a mental model.

If they are making a decision, they may model two or more possible worlds sequentially, but not simultaneously.

People tend to focus quickly on one of these possibilities and to draw out only some of its consequences, and they give it up, or switch attention from it, only if they discover a negative consequence.

Decision making does not involve any systematic attempt at optimising choice, as people often focus on the most immediately plausible, attractive or relevant option.

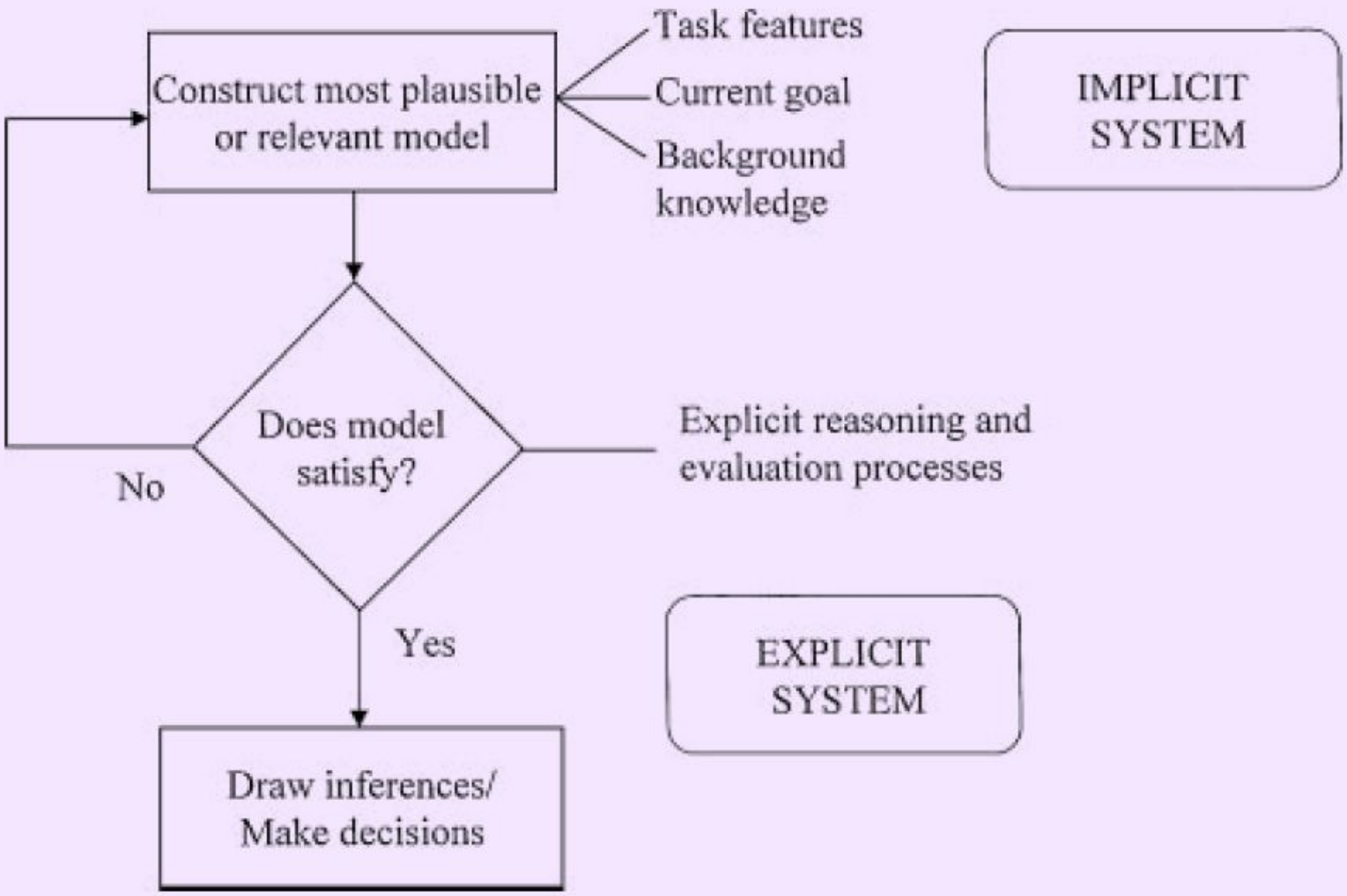
The Relevance Principle

The models people consider are preconsciously cued by the implicit system in accordance with the relevance principle.

This pragmatic process reflects the interplay of three factors, as illustrated in Figure

System analysis and decision making

Hypothetical thinking model



First, there are the features of the task or the environment that need to be processed by the participant.

The second influence is the current goal that the person has adopted.

The final input comes from long-term memory or stored knowledge.

By a process which remains a great mystery in cognitive science (the “frame” problem), the human brain is able automatically and rapidly to extract from vast stores of knowledge just those items relevant to the problem at hand.

Two principles of relevance:

First (cognitive) principle of relevance. **Human cognition tends to be geared towards the maximisation of relevance.**

Second (communicative) principle of relevance. **Every act of ostensive communication communicates a presumption of its own optimal relevance**.

Relevance is always related to the current goals, both practical and epistemic, of the individual.

Principle of truth leads people to represent true rather than false possibilities.

This principle useful in accounting for the various phenomena as “cognitive illusions”, we are not convinced that there is any such principle.

The default representation of likely possibilities can easily be changed, however, if the goal adopted by the individual makes other possibilities more relevant to the task in hand.

Such a goal may be set by experimental instructions to identify false cases of conditional rules, as in the truth-table task.

Experiment, Manktelow and Over (1991).

If a customer spends more than £100, they may take a free gift. When given the perspective of a customer, people were concerned to check people spending more than £100 and not receiving gifts.

When given the perspective of a store manager, however, participants wanted to check customers who spent less than £100 and still took the gift. It is evident that the customers' goal is to make sure that the store is not cheating (there are no cases where people spend the money and do not receive the gift), but the store manager's goal is to ensure that customers do not cheat (by taking a gift while spending less than £100).

Hence, it is clear that pragmatic relevance is driving card selections on these problems.

The Satisficing Principle

Satisficing means **employing heuristics that find solutions which are satisfactory, or good enough, but are not guaranteed to be optimal.**

The point is, of course, that in a world of unlimited complexity and with brains of limited informationprocessing capacity, optimisation is usually a practical impossibility.

Engineers use satisficing strategies in design problems where very complex search spaces are involved

HYPOTHETICAL THINKING IN DEDUCTIVE REASONING TASKS

The general theory of mental models proposes **three stages in deductive reasoning.**

First, reasoners form a mental model to represent a situation in which all of the premises are true.

Next, they formulate a provisional conclusion that is true in this model but semantically informative (not a repetition of a premise, for example).

Finally, they validate the conclusion by searching for counterexample cases - models in which the premises hold, but the conclusion does not. If no such counterexample is found, the argument is declared valid.

Syllogistic Reasoning

The syllogisms were classified a priori into three types:

Necessary. The conclusion must be true if the premises are true. These are normally termed valid syllogisms.

Possible. The conclusion could be true if the premises are true.

Impossible. The conclusion cannot be true if the premises are true.

Evidence for mental model theory in syllogistic reasoning has also been claimed in interpretation of the “belief-bias” effect, in which people endorse more believable than unbelievable conclusions as valid, regardless of the logical validity of the syllogism.

The initial process of constructing a model is biased by the conclusion presented. In line with the relevance principle, people try to construct a model which is plausible or probable given their background beliefs.

Hence, if the conclusion is believable, they tend to construct a model which supports it, but if it is unbelievable, they tend to construct a model which excludes the conclusion.

Propositional Reasoning

The mental model theory of reasoning with propositional connectives such as “if” and “or” is built around the idea that **people can represent multiple mental models corresponding to different lines in a truth table.**

This appears to conflict with the singularity principle, so we will consider the proposals in a little detail.

The connective if p then q is typically represented initially by a single explicit model:

[p] q

…

[p] q

…

First of all, there is an exhaustivity marker, or “mental footnote”, in the form of the square brackets around p, indicating that it is exhaustively represented with respect to q.

That is, p must appear in any mode that in which q does.

[p] q

…

Second, there is an implicit model which indicates that other models are possible but not explicitly represented at this time.

Thus, modus ponens, given p, conclude q, could be made immediately from this initial representation.

MODUS PONENDO PONENS (MP or modus ponens) or implication elimination is a rule of inference.

It can be summarized as "P implies Q and P is asserted to be true, so therefore Q must be true."

The modus ponens rule may be written in sequent notation:

$P \rightarrow Q, P \vdash Q$

where $\vdash$ is a metalogical symbol meaning that Q is a syntactic consequence of $P \rightarrow Q$ and P in some logical system;

or as the statement of a truth-functional tautology or theorem of propositional logic:

$((P \rightarrow Q) \wedge P) \rightarrow Q$

where P, and Q are propositions expressed in some formal system.

An example of an argument that fits the form modus ponens:

If today is Monday, then John will go to work.

Today is Monday.

Therefore, John will go to work.

Justification via truth table

The validity of modus ponens in classical two-valued logic can be clearly demonstrated by use of a truth table.

p	q	$p \rightarrow q$
T	T	T
T	F	F
F	T	T
F	F	T

In instances of *modus ponens* we assume as premises that $p \rightarrow q$ is true and p is true.

Only one line of the truth table - the first - satisfies these two conditions (p and $p \rightarrow q$).

On this line, q is also true. Therefore, whenever $p \rightarrow q$ is true and p is true, q must also be true.

The theory also proposes that the representation can be “fleshed out” to include explicit representation of other truth-table cases compatible with the rule.

Modus tollens, given not-q, conclude not-p, is a valid inference made by about 60 per cent of student participants. According to the theory, presentation of not-q leads to an inference only if people succeed in fleshing out the fully explicit model set:

p q

¬p q

¬p ¬q

The premise “not-q” eliminates all but the last model, so enabling the conclusion “not-p” to be drawn.

One problem with this proposal is that it commits the model theory to an interpretation of the conditional as material implication, with all the paradoxes that entails.

In order to explain differences in inference rates between (logically equivalent) “if then” and “only if” conditionals, they suggested that the statement “p only if q” was represented as

[p]q
¬p q

“If p then not-q” might be represented as:

[p]¬q q

How would the hypothetical thinking model account for the moderate competence to perform the modus tollens inference?

Given the premise "**If p then q**," people consider the most relevant case: p and q. Given the second premise "**not-q**", however, this model no longer satisfies and is rejected.

If the model **¬p ¬q** is found, the modus tollens conclusion is endorsed.

This requires an inference based on the fact that any p's must be with q's, and hence in the possible world in which there **is no q there is no p either**

suppose p were the case;

then q would have to be present,

but q is absent,

so p cannot be the case.

suppose p were the case;

then q would have to be present,

but q is absent,

so p cannot be the case.

The difficulty here lies in the mental models theory's concept of "fleshing out".

Supposedly, deductions in the model theory are based upon the observation that all the models are consistent with the conclusion.

However, in cases such as modus tollens, the model that supports the inference can be discovered only by fleshing out where fleshing out is itself an inferential process.

This problem arises whether one accepts the current argument that people are “fleshing out” an alternative model to the one rejected, or the original claim that people flesh out three explicit models.

If people are asked to classify the four truth-table cases for a conditional If p then q, they tend to answer as follows:

p and q - true (TT)

p and ¬q - false (TF)

¬p and q - irrelevant (FT)

¬p and ¬q - irrelevant (FF)

The problem is this:

How do people know the difference between false and irrelevant cases unless they flesh out all true cases?

Or if they do flesh them out, why are not “irrelevant” cases regarded as true?

Why do people find it easy to identify the correct falsifying case as TF?

The reasoner can certainly discover TF by arguing as follows:

every case with a p must have a q, so we cannot have a case with a p and no q.

Suppositional Reasoning

The suppositional strategy of interest was based on a logical principle known as reductio ad absurdum.

According to this principle, if a supposition, or temporary assumption, leads to a contradiction, the negation of that supposition can be drawn as a logical conclusion.

An example of a congruent problem is as follows:
If and only if p then q
p or q, or both

Here the reductio argument required is as follows: suppose not-p; it follows from the first premises that not-q, but from the second premise that q. Hence, not-p must be false, so conclude p.

If and only if p then q not-p or not-q, or both

In this case, the supposition of p leads to a contradiction, so that not-p is a valid conclusion.

- *All x are z.*
- *All y are z.*
- *Therefore, some x are y.*
- _____
- *Some x are y.*
- *All y are z.*
- *Therefore, some x are z.*
- _____
- *All x are y.*
- *Some y are z.*
- *Therefore, some x are z*
- _____

Incorrect or correct?

Strategy

In general, there are two categories of definition for the word “strategy”.

Broad definitions assert that any self-contained set of goal-directed procedures constitutes a strategy, as long as these are optional, so that their utilisation by any given person is not guaranteed.

A strategy is “any procedure that is non-obligatory and goal directed”.

Strategy is a set of cognitive processes which have been shown to be used for solving certain types of deductive reasoning tasks, but for which there is not sufficient evidence to assert that these processes themselves constitute all or part of the fundamental reasoning mechanism (optional processes cannot be asserted to be fundamental in the domain of deduction).

	Abby	Bess	Cody	Dana
Abby		*	*	
Bess			*	
Cody	*	*		*
Dana		*	*	

Abby likes Dana.

Dana does not like Abby.

Abby likes Cody or Dana.

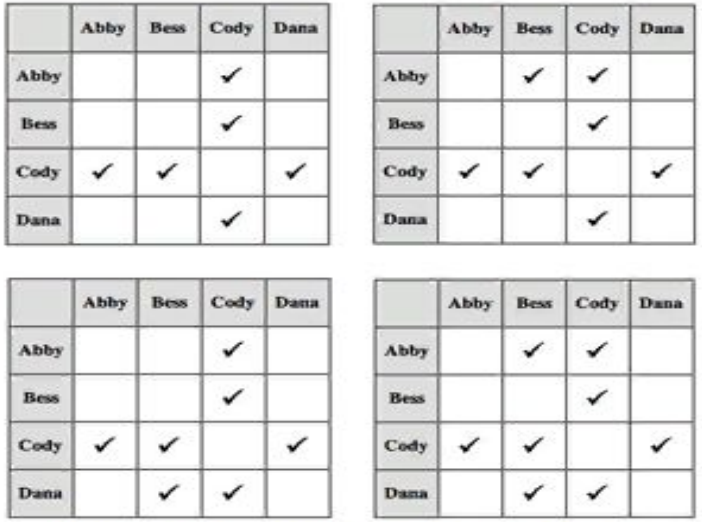
Abby likes someone who likes her.

Somebody likes everybody.

Consider the following premises about the state of Sorority World.

Dana likes Cody.
Abby does not like Dana.
Dana does not like Abby.
Bess likes Cody or Dana.
Abby likes everyone that Bess likes.
Cody likes everyone who likes her.
Nobody likes herself.

There are just four states of Sorority World that satisfy these sentences. They are shown below.



	Abby	Bess	Cody	Dana
Abby			✓	
Bess			✓	
Cody	✓	✓		✓
Dana			✓	

	Abby	Bess	Cody	Dana
Abby		✓	✓	
Bess			✓	
Cody	✓	✓		✓
Dana			✓	

	Abby	Bess	Cody	Dana
Abby			✓	
Bess			✓	
Cody	✓	✓		✓
Dana		✓	✓	

	Abby	Bess	Cody	Dana
Abby		✓	✓	
Bess			✓	
Cody	✓	✓		✓
Dana		✓	✓	

Figure 3 - Four states of Sorority World.

For each of the following sentences, say whether or not it is logically entailed by the premises shown above.

- a. Abby *likes Bess or Bess likes Abby.*
- b. *Somebody likes herself.*
- c. *Everybody likes somebody*