Human Reasoning in the Suppression Task: The Relevance of Commonsense Knowledge

Master's Thesis

Author:
Céline De Jong
Studentnr.: 4293126
ECTS-credit: 45

Supervisor:
Prof. dr. Rosalie Iemhoff
Second examiner:
Dr. Chris Janssen

Universiteit Utrecht

Graduate School of Natural Sciences
Artificial Intelligence
Utrecht University
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Abstract

A new model for human reasoning during logical tasks is proposed, which possesses the intuitive quality of recognizability in the way it describes the process of reasoning. Experiments have shown that humans do not reason according to classical logic during logical tasks. To solve the question of how humans do reason, alternative logical models have been created to replicate the reasoning during these logical tasks. The logical task focussed on here is the Suppression Task. The most relevant model for the human reasoning in this task is based on a notion of abnormality predicates, and lacks intuitive recognizability both in it's set-up and the conclusions it yields. The proposed new model is based on a notion of commonsense knowledge. The experiment shows that participants performing the Suppression Task reason in line with this commonsense knowledge based logical model, in stead of the abnormality predicates that have been proposed in previous models.

Keywords— suppression task, human reasoning, commonsense knowledge, three-valued logic

Contents

Part I
Introduction

The way in which humans reason has been a much researched question for centuries. Since the rise of AI, this question has become even more relevant. A large field within AI aims to create computer-based models of human reasoning, for which it is necessary to first understand human reasoning.

There is no consensus yet of what such a general model of human reasoning would look like, however many researchers are trying to solve parts of the puzzle by looking at selective parts of human reasoning. One such part is the logical reasoning that can be observed when human subjects are asked to perform a certain logical task. Evaluating both how humans come to conclusions during these tasks, and what these conclusions are, sheds light on a part of human reasoning that can be used to create more understanding on the whole of human reasoning.

One such a logical task is the 'Suppression Task'. This logical task asks participants to draw logical conclusions from the given information. This information consists of multiple conditionals of the form 'if A then B'. Performed experiments with the Suppression Task have shown that human reasoners do not yield the same conclusions that classical logical theory does [Byrne, 1989]. This raises the question, if people do not reason according to classical logic during a logical task, how *do* they reason?

To answer this question, several researchers have proposed alternative logical models that should represent human reasoning during logical tasks. I will evaluate the most relevant of these models, which is a combination of the results from multiple researchers [Stenning and Van Lambalgen, 2012] [Dietz et al., 2012] [Hölldobler et al., 2011]. This model proposes that humans reason in logical tasks according to a notion of 'abnormality predicates'; they are continuously evaluating a scenario according to whether anything *abnormal* might be happening. After evaluating this model, I will argue that it lacks the intuitive recognizability that any human reasoner should feel when they read about a model for human reasoning. This shortcoming is seen not only in the theoretical set-up of the model, but also in the conclusions it yields.

A solution for this apparent shortcoming would be an alternative model. This alternative model should posses the intuitive recognizability mentioned above, and gets alternative logical conclusions where necessary. Therefore, I propose a new model that focusses not on these abnormality predicates, but on a notion of 'commonsense knowledge'. After a new theoretical outline is given, this model is tested with an experiment. The focus of this experiment is to determine whether participants reasoning in a logical task (where it has been shown they do not reason according to classical logic), reason in line with a logical model that possesses a notion of commonsense knowledge, in stead of the abnormality predicates that have been proposed in previous models.

Part II

Literary Research

In this part I describe the Suppression Task, the task that plays a central role in my thesis. Not only do I describe the task itself and it's relevance, I also discuss the research that has been done on the topic so far, as to create a solid framework through which we will look at a new model for the Suppression Task in Part III (p. 21).

1 The Suppression Task

1.1 The Task

Human reasoners have been shown to suppress logically valid inferences when extra premises containing additional information are added to what at first is a simple combination of premises. An example (as given in [Byrne, 1989]) of such a simple combination of premises would be:

1. If she has an essay to write she will study late in the library.
2. She has an essay to write.

When humans are given these premises as information and are then asked whether she will study late in the library, the majority of people (96%) will answer that she will indeed study late in the library [Byrne, 1989]. Using Modus Ponens (MP) and reasoning with classical logic, this is indeed a logically valid inference based on conditional 1 and proposition 2.

The conditionals that are then added to this information are either alternative or additional premises, based on their content. An alternative premise would be of the form:

3. If she has a textbook to read she will study late in the library.

Whereas an additional premise would be of the form:

4. If the library is open she will study late in the library.

One such premise is added to the information given to a human subject, and the same question is then asked; 'will she study late in the library?'. This is where classical logic and MP no longer seem to explain human reasoning correctly. With the alternative premise (3) added, still 96% of subjects answer that she will indeed study late in the library, a logically valid inference once again [Byrne, 1989]. However, when the additional premise (4) is added, the amount of people answering 'she will study late in the library' drops to only 38% [Byrne, 1989]. Earlier conclusions are *suppressed* in the presence of additional premises. This is a notable observation, because according to classical logic, the earlier conclusion is still valid. To answer the question why and how people come to these unexpected conclusions, is researched in the Suppression Task experiment.

1.2 Experiment

The Suppression Task then, is the logical task that researches this suppression by asking different questions based on a selection of premises. These premises are 1, 2, 3, 4 from the previous section, but for the sake of describing the original experiment from [Byrne, 1989] I will now introduce their notation for each of the subtasks.

For each of the four subtasks either one simple premise is given (premise 1), a simple premise in combination with an alternative premise (premises 1 and 3), or a simple premise in combination with an additional premise (premises 1 and 4).

An alternative premise is called alternative because it adds an alternative reason as to why the conclusion might become true, whereas an additional premise gives additional information that could make the conclusion true. The difference between these kinds of premises is similar to the difference between a logical 'and' or 'or' relation; the alternative premise then coincides with the 'or' and the additional with the 'and' relation.

Modus Ponens (MP) In this subtask, the premises (simple or otherwise), are given in the combination with proposition p: she has an essay to write (proposition 2 in the list above). Participants are asked whether q (she will study late in the library) is true.

Modus Tollens (MT) In this subtask, what is given is the premises and the proposition $\neg q$: she will not study late in the library. Participants are asked whether $\neg p$ (she does not have an essay to write) is true.

Denial of the antecedent (DA) Here, the given information are the premises and the proposition $\neg p$: she does not have an essay to write. Participants are asked whether $\neg q$ (she will not study late in the library) is true.

Affirmation of the consequent (AC) For this subtask, the premises are combined with proposition q: she will study late in the library. Participants are asked whether p (she has an essay to write) is true.

These four subtasks and the possible combinations of premises together are the full Suppression Task, of which the results (percentages of inferences made, confirming the queried proposition) are shown in Table 1. A high percentage means that many subjects drew the conclusion whose validity was queried; this is not per se the logically valid conclusion, only the conclusion as seen above for each subtask.

Given premisses	MP	MT	DA	AC
Simple (1)	96	92	46	71
Alternative (1, 3)	96	96	4	13
Additional (1, 4)	38	33	63	54

Table 1: Result of the full Suppression Task experiment in [Byrne, 1989] as percentages of inferences made.

These results show that suppression of inferences happens in the case of MP and MT when additional premises are added, and in the case of DA and AC when alternative premises are added. The subjects systematically do not make the inferences that would be valid through classical logic in these cases. For clarification, the logically valid inferences are as follows:

MP In the case that p is given, the logically valid inference would be q for each combination of premisses. So what is asked is the true conclusion according to classical logic.

MT In the case that $\neg q$ is given, the logically valid inference would be $\neg p$ for each combination of premisses. So what is asked is the true conclusion according to classical logic.

DA In the case that $\neg p$ is given, it is unknown, according to classical logic, whether q or $\neg q$ is definitively true. So what is asked is *not* the true conclusion according to classical logic.

AC In the case that q is given, it is unknown, according to classical logic, whether p or $\neg p$ is definitively true. So what is asked is *not* the true conclusion according to classical logic.

These inferences are not necessarily dependent on the additional information, but adding information does change the inferences humans make. The consequence of this is that, apparently, classical logic is not a sufficient model for human reasoning in this task. Therefore, different models need to be created that do in fact explain these results.

1.3 The Goal

The research that has been done on the subject of the Suppression Task is focussed on finding a model that correctly describes human reasoning. The Suppression Task indicates that classical two-valued logic might not be a sufficient model to explain the results of the Suppression Task, because inferences that are valid through classical logic are not the inferences that are made by human reasoners. Since the claim is that classical logic is not sufficient, an alternative model is necessary that would do the job in a more successful way. A model that will give the same results as the human reasoners do; not what is valid through classical two-valued logic.

In the following section, subsequent research on the Suppression Task and it's result, and in particular the models that this research has come up with trying to explain human behaviour in the Suppression Task will be discussed.

2 Models based on Byrne's experiment: Logic programming and three-valued logics

The literature on the topic contains a considerable amount of models that are extensions of previous models. One particular model that has been extended multiple times starts with the model described in the chapter on the Suppression Task in [Stenning and Van Lambalgen, 2012, pp. 173-216] (the S&L model from here on). This is the starting point of what is arguably the most relevant model within this topic so far. This model (the S&L starting point and it's extensions) is described in detail in this section.

2.1 Stenning and van Lambalgen

While Byrne uses her results to argue against a rule-based account of logical reasoning, Stenning and van Lambalgen (S&L) argue that even though a form of non-classical logic is used by the subjects, this is nevertheless still logical reasoning. What this means, is that the conclusions that human subjects draw are not inherently logically invalid, the classical logic model is simply insufficient to account for the kind of reasoning the subjects perform.

To support this claim, their experiment goes into great detail of the reasoning of individual subjects. They show many transcripts of the conversations during the experiments in order to show how individuals do reason in a logical (and valid) way, just not the way we might expect if we have classical logic in mind [Stenning and Van Lambalgen, 2012, pp. 173-216].

If the argument is that the subjects do indeed reason according to some logic, a model needs to be created that explains this specific kind of logical reasoning; that is, a model that gets the same answers as the subjects do in experiments. The model that S&L propose contains some important factors that Byrne did not introduce in her experiment: closed-world reasoning; logic programming; and three-valued logic. In this subsection (2.1) an outline is given of how these three factors come together to create the S&L model.

2.1.1 Informal overview of the model

The S&L model proposes that humans reason during logical tasks using ‘abnormality predicates’. This means that during the evaluation of given conditionals with the aim of coming to a conclusion, human reasoners are also evaluating the value of these conditionals according to the value of the abnormality predicates. The value of a certain conditional can be influenced by whether anything *abnormal* is currently happening. This intuition is a guiding line within the S&L model, but is combined with several other factors. These factors where mentioned above and are closed-world reasoning, logic programming and three-valued logic. Closed-world reasoning has a similarly intuitive quality as the notion of abnormality predicates. The other two factors are based less on intuition, but all factors are related to the creation of a formal definition. This formal definition yields conclusions that can be evaluated, which is discussed in the following section.

2.1.2 Formal definition of the model

Closed world reasoning is systematically used in day-to-day life; if we have no explicit information that would eventually (through repeated application of modus ponens) lead to some conclusion P, we have no reason to believe P to be true, and even more so, assume P to be false [Stenning and Van Lambalgen, 2012, pp. 184-185]. For example, if we were to check into a hotel and were upon arrival given a list of what is prohibited in this particular hotel, closed-world reasoning would lead us to derive that whatever is not on this list, is allowed in the hotel. In what follows we will see that S&L apply this in such a way that in their model whenever a proposition is not explicitly known to be true, it is considered false.

The formal definition of the closed-world reasoning described above is given through logic programming. S&L use a form of logic called non-monotonic logic, or more specifically, first-order constraint logic programming with negation as failure. Logic programming uses planning as computations; it sets a goal and devises a sequence of actions that will achieve that goal [Stenning and Van Lambalgen, 2012, p. 185]. The derivations that the program comes up with are built on backward chaining (regression). The closed-world reasoning comes in here, because during the process of derivation, any positive atomic proposition is false as long as we have no reason to believe it is true. Therefore, the logic program reasons with 'minimal models'. S&L's hypothesis is that 'the automatic process of constructing a minimal model which underlies planning also subserves discourse integration.' In other words, they expect to see that they model not only the process of planning in human reasoners, but also the way this connects to the discursive part of the logical task at hand.

S&L's model should represent human reasoning as much as possible, and human reasoners do not use closed-world reasoning to every fact in life. More specifically, humans can remain agnostic about facts; their truth-values are unknown until proven true or false. This is why S&L introduce a three-valued semantics, in terms of which they define their model. This semantics is Kleene's strong three-valued semantics [Kleene et al., 1952], consisting of the truth-values true (1), false (0) and undecided (u).

Negation in this model is 'negation as failure', which intuitively means that the negation of a proposition φ is true if 'the attempt to derive φ from the program P fails in finitely many steps.' [Stenning and Van Lambalgen, 2012, p. 187] Their logical programs consist of clauses, and the definition of a clause is given as follows.

Definition 2.1. A *definite clause* is a formula of the form $(\neg)p_1 \wedge ... \wedge (\neg)p_n \rightarrow q$, where the p_i are either proposition letters, $\top$ or $\bot$, and q is a propositional variable. *Facts* are clauses of the form $\top \rightarrow q$, which will usually be abbreviated to q. Empty antecedents are not allowed. A *definite logic program* is a finite conjunction of definite clauses.

The definition of a model is given as follows.

Definition 2.2.

a. If q is a proposition letter occurring in a program P, the *definition* of q with respect to P is given by:

   1 take all clauses $\phi_i \rightarrow q$ whose head is q and form the expression $\bigvee_i \phi_i \rightarrow q$;

   2 if there is no such ϕ_i, then the expression $\bot \rightarrow q$ is added;

   3 replace the $\rightarrow$'s by $\leftrightarrow$'s (here, $\leftrightarrow$ has a *classical* interpretation given by: $\psi \leftrightarrow \varphi$ is true if ψ, φ have the same truth-value, and false otherwise).

b. The *completion* of a program P, denoted by $\textsc{comp}(P)$, is constructed by taking the conjunction of the definitions of atoms q, for all q in P.

c. More generally, if S is a set of atoms occurring in P, the completion of P relativized to S, $\textsc{comp}_s(P)$, is obtained by taking the conjunction of the definitions of the atoms q which are in S.

d. If P is a logic program, define the nonmonotonic consequence relation $\approx\!\!\!|$ by

$$P \mathrel{|\!\!\approx}_3 \phi \text{ iff } \textsc{comp}(P) \models_3 \phi$$

where $\mathrel{|\!\!\approx}_3$ denotes consequence with respect to three-valued models. For $\textsc{comp}(P)$ one may also read $\textsc{comp}_s(P)$; in which case one should write, strictly speaking, $P \mathrel{|\!\!\approx}_3^S \phi$.

[Stenning and Van Lambalgen, 2012, p. 188]

In this definition, step (a.2) and (a.3) are where closed-world reasoning is applied.

Now that the formal definition of the model is stated, S&L's hypothesis for explaining the data found by Byrne is reformulated using the previously introduced terminology:

> a. the conditionals used in the Suppression Task, far from being material implications can be captured much more adequately by logic programming clauses of the form $p \wedge \neg ab \rightarrow q$, where ab is a proposition letter indicating that something abnormal is the case;
> b. when making interpretations, subjects usually do not consider *all* models of the premises, but only *minimal* models, defined by a suitable completion.
> [Stenning and Van Lambalgen, 2012, p. 189]

In the preceding hypothesis, minimal models seem to play a large role. However, constructing minimal models of definite logic programs requires an efficient method; not all created models are minimal, and only the minimal models are of interest for the task ahead. The required minimal models are the fixed points of a three-valued consequence operator T_P^3. This operator is three-valued, because Kleene's three-valued logic [Kleene et al., 1952] is used with the values 0,1, and u. The operator T_P^3 assigns truth-values to the proposition letters in the program.

Definition 2.3. Let P be a program.

a. The operator T_P^3 applied to formulas constructed using only $\neg, \wedge$, and $\vee$ is determined by the truth-tables describing Kleene's three-valued logic.
b. Given a three-valued model M, $T_P^3(M)$ is the model determined by
   (a) $T_P^3(M)(q) = 1$ iff there is a clause $\varphi \rightarrow q$ such that $M \vDash \varphi$,
   (b) $T_P^3(M)(q) = 0$ iff there is a clause $\varphi \rightarrow q$ in P and for all such clauses, $M \vDash \neg\varphi$,
   (c) $T_P^3(M)(q) = u$ otherwise.

[Stenning and Van Lambalgen, 2012, 194]

The connection between this construction of minimal models and that in definition 2.2, is given in the following lemma, particular in point 3.:

Lemma 2.1. Let P be a definite program

1. The operator T_P^3 has a least fixed point, obtained by starting from the model M_0 in which all proposition letters have the value u. The least fixed point of T_P^3 can be shown to be the minimal model of P.
2. The least fixed point of T_P^3 is reached in finitely many steps ($n+1$ if the program consists of n clauses).
3. All models M of $\textsc{comp}(P)$ are fixed points of T_P^3, and every fixed point is a model.

2.1.3 Application of the model on the Suppression Task

With the formal definition given in the previous paragraph, we can create the minimal models that represent the Suppression task. In S&L, the Suppression Task consists of the following definite clauses (propositional variable names are changed):

1. If she has an essay to write, she will study late in the library.
   $p \wedge \neg ab \rightarrow q$
2. If the library is open, she will study late in the library.
   $r \wedge \neg ab' \rightarrow q$
3. If she has a textbook to read, she will study late in the library.
   $t \wedge \neg ab' \rightarrow q$

Where ab and ab' are abnormality predicates, and $\neg ab$ intuitively meaning that 'nothing abnormal is happening'. ab' is used for both 2 & 3 because according to the experiment outline, these two clauses are never used at the same time. There are only combinations of 1 & 2 or 1 & 3, so ab and ab' are sufficient variable names. These three clauses are combined into programs, to create the subtasks described in section 1.1.1; MP, MT, DA and AC. These then either contain just one conditional premise, or an additional premise is added (if the library stays open, ...), or an alternative premise is added (if she has a textbook to read, ...).

For each of these clause combinations, the logic programs are constructed and minimal models are found. Table 3 below shows for each of the clause combinations what model follows from them. The closed-world reasoning and completion step will be done for all three clause combinations, for subtask MP, in Table 2, so that it can be omitted in Table 3, since these completion steps all work similarly.

Clauses	Initial program	Application of closed-world reasoning and completion	Interpretation
$p \wedge \neg ab \rightarrow q$	$\top \rightarrow p; p \wedge \neg ab \rightarrow q$	$\top \rightarrow p; p \wedge \neg ab \rightarrow q$ $\top \rightarrow p; p \wedge \neg ab \rightarrow q; \bot \rightarrow ab$ $\top \leftrightarrow p; p \wedge \neg ab \leftrightarrow q; \bot \leftrightarrow ab$	$\top \rightarrow p; p \leftrightarrow q$
$p \wedge \neg ab \rightarrow q$ $r \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q;$ $r \wedge \neg ab' \rightarrow q\}$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q; r \wedge \neg ab' \rightarrow q\}$ $\{\top \rightarrow p; p \wedge \neg ab \rightarrow q; r \wedge \neg ab' \rightarrow q;$ $\neg p \rightarrow ab'; \neg r \rightarrow ab; \bot \rightarrow ab; \bot \rightarrow ab'\}$ $\{\top \leftrightarrow p; (p \wedge \neg ab) \vee (r \wedge \neg ab') \leftrightarrow q;$ $ab \leftrightarrow (\bot \vee \neg q); ab' \leftrightarrow (\bot \vee \neg p)\}$	$\top \rightarrow p; (p \wedge r) \leftrightarrow q$
$p \wedge \neg ab \rightarrow q$ $t \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q;$ $t \wedge \neg ab' \rightarrow q\}$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q; t \wedge \neg ab' \rightarrow q\}$ $\{\top \rightarrow p; p \wedge \neg ab \rightarrow q; t \wedge \neg ab' \rightarrow q;$ $\bot \rightarrow ab; \bot \rightarrow ab'\}$ $\{\top \leftrightarrow p; p \wedge \neg ab \leftrightarrow q; t \wedge \neg ab' \leftrightarrow q;$ $\bot \leftrightarrow ab; \bot \leftrightarrow ab'\}$	$\top \rightarrow p; (p \vee t) \leftrightarrow q$

Table 2: Examples of the application of closed-world reasoning and completion

Subtask	Clauses	Initial program	Interpretation	Derivable conclusion
MP	$p \wedge \neg ab \rightarrow q$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q\}$	$\top \rightarrow p; p \leftrightarrow q$	q
AC	$p \wedge \neg ab \rightarrow q$	$\{\top \rightarrow q; p \wedge \neg ab \rightarrow q\}$	$\top \rightarrow q; p \leftrightarrow q$	No conclusion possible.
DA	$p \wedge \neg ab \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q\}$	$\bot \rightarrow p; p \leftrightarrow q$	No conclusion possible.
MT	$p \wedge \neg ab \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q\}$	$\bot \rightarrow q; p \leftrightarrow q$	$\neg p$
MP	$p \wedge \neg ab \rightarrow q$ $r \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q;$ $r \wedge \neg ab' \rightarrow q\}$	$\top \rightarrow p; (p \wedge r) \leftrightarrow q$	No conclusion possible. Suppression is expected.
AC	$p \wedge \neg ab \rightarrow q$ $r \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow q; p \wedge \neg ab \rightarrow q;$ $r \wedge \neg ab' \rightarrow q\}$	$\top \rightarrow q; (p \wedge r) \leftrightarrow q$	$p \wedge r$ No suppression expected.
DA	$p \wedge \neg ab \rightarrow q$ $r \wedge \neg ab' \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q;$ $r \wedge \neg ab' \rightarrow q\}$	$\bot \rightarrow p; (p \wedge r) \leftrightarrow q$	No conclusion possible. Suppression is expected.
MT	$p \wedge \neg ab \rightarrow q$ $r \wedge \neg ab' \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q;$ $r \wedge \neg ab' \rightarrow q\}$	$\bot \rightarrow q; (p \wedge r) \leftrightarrow q$	No conclusion possible. Suppression is expected.
MP	$p \wedge \neg ab \rightarrow q$ $t \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow p; p \wedge \neg ab \rightarrow q;$ $t \wedge \neg ab' \rightarrow q\}$	$\top \rightarrow p; (p \vee t) \leftrightarrow q$	q No suppression expected.
AC	$p \wedge \neg ab \rightarrow q$ $t \wedge \neg ab' \rightarrow q$	$\{\top \rightarrow q; p \wedge \neg ab \rightarrow q;$ $t \wedge \neg ab' \rightarrow q\}$	$\top \rightarrow q; (p \vee t) \leftrightarrow q$	No conclusion possible. Suppression is expected.
DA	$p \wedge \neg ab \rightarrow q$ $t \wedge \neg ab' \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q;$ $t \wedge \neg ab' \rightarrow q\}$	$\bot \rightarrow p; (p \vee t) \leftrightarrow q$	No conclusion possible. Suppression is expected.
MT	$p \wedge \neg ab \rightarrow q$ $t \wedge \neg ab' \rightarrow q$	$\{\bot \rightarrow p; p \wedge \neg ab \rightarrow q;$ $t \wedge \neg ab' \rightarrow q\}$	$\bot \rightarrow q; (p \vee t) \leftrightarrow q$	$\neg p$ and $\neg t$ No suppression expected.

Table 3: Derivations for each subtask

The framework set up by S&L leads to models that accurately show in what parts of the experiment suppression will occur. Using the construction steps given in [Stenning and Van Lambalgen, 2012], what is modelled is 'how subjects reason toward an interpretation of the premises by suitably adjusting the meaning of the abnormalities' [p. 197] through closed-world reasoning and completion. Once this process has lead to a suitable interpretation, subjects reason from this interpretation and derive a conclusion. This is then also what is done within the model; once an interpretation is found (4th column for each of the combinations in both Table 2 and 3), some conclusion is derived. These conclusions match the results from the subjects in the actual experiment; this leads to the final conclusion that this model already quite accurately describes the human behaviour seen in the Suppression Task. This conclusion is similar for all literature about models for the Suppression Task; if the conclusions match the results from the human subjects a model is considered accurate and successful. The ambiguity of these conclusions and what they mean will be discussed further in section 4.1.

Now that we have seen the initial model by S&L, we will continue with some additions that have been made by other researchers. These are extensions to the model created by S&L, and therefore still use the same framework as proposed by S&L. Where they differ is the focus point of each of the following sections on these extended models.

2.2 A computational logic approach to the Suppression Task

In [Stenning and Van Lambalgen, 2012], the task is divided into two main parts; reasoning towards an interpretation, and reasoning from an interpretation. This first part is seen in Table 3, column 2,3 and 4. The fifth column can be seen as involving the reasoning from an interpretation, the second part. This part involves the three-valued (true, false and unknown) semantics. S&L use the three-valued semantics proposed by Kleene [Kleene et al., 1952], however there are more three-valued semantics than just this one. Why exactly S&L use this particular one they do not say; this lead other researchers to propose other three-valued semantics.

This is exactly what is done in [Dietz et al., 2012]. They agree with the model set up by S&L for the first part (reasoning towards an interpretation), but they propose a different three-valued semantics be used (in the second part; reasoning from an interpretation). In fact, the one they propose is called Łukasiewicz semantics [Łukasiewicz, 1920]. The difference in this logic compared to Kleene, can be seen clearly when we put the truth-tables for each semantics next to each other, which is done in Table 4. According to Dietz et al., it is this difference in assigning truth-values that makes the Łukasiewicz semantics more fitting for the task.

p	q	$\wedge$	$\vee$	$\leftarrow_L$	$\leftrightarrow_L$	$\leftarrow_K$	$\leftrightarrow_K$
$\top$	$\top$	$\top$	$\top$	$\top$	$\top$	$\top$	$\top$
$\top$	$\bot$	$\bot$	$\top$	$\top$	$\bot$	$\top$	$\bot$
$\top$	U	U	$\top$	$\top$	U	$\top$	$\bot$
$\bot$	$\top$	$\bot$	$\top$	$\bot$	$\bot$	$\bot$	$\bot$
$\bot$	$\bot$	$\bot$	$\bot$	$\top$	$\top$	$\top$	$\top$
$\bot$	U	$\bot$	U	U	U	U	$\bot$
U	$\top$	U	$\top$	U	U	U	$\bot$
U	$\bot$	$\bot$	U	$\top$	U	$\top$	$\bot$
U	U	U	U	$\underline{\top}$	$\top$	$\underline{\text{U}}$	$\top$

Table 4: Truth-tables for the three-valued logics

Kleene's logic consists of the connectives $\{\neg, \wedge, \vee, \leftarrow_K, \leftrightarrow_K\}$, where $\leftrightarrow_K$ is the 'strong equivalence' that Kleene introduces in [Kleene et al., 1952]; this is only mapped to $\top$ when each side of the bi-implication has the same truth-value. The $\leftarrow$ is a mirrored version of the $\rightarrow$ (implication) seen in the previous paragraph describing [Stenning and Van Lambalgen, 2012]. Łukasiewicz' logic uses the connectives $\{\neg, \wedge, \vee, \leftarrow_L, \leftrightarrow_L\}$. The most relevant difference in these logics is underlined in the last row of the table; the two logics give a different valuation to a formula containing two unknown propositions and an implication. According to Dietz et al., this is a crucial difference.

Once again, the goal of creating models for the Suppression Task is explaining human reasoning. A good model therefore should accurately produce the same results as the human subjects do in an experiment. Accurately producing the same results here means that the model comes to the same conclusions as the human reasoners do; if most human subjects for example conclude $\neg q$ in a certain subtask, the model should too.

In lemma 2.1, S&L describe the operator that creates the minimal models through which the same results as the human subjects are found (Lemma 4 in [Stenning and Van Lambalgen, 2012]). Dietz et al. use a different approach, but the operators are in fact equivalent. Therefore, the only difference is the *reasoning from an interpretation* that is done with these models. This part is done using the three-valued semantics, either the Kleene or the Łukasiewicz version.

To prove that the approach by Dietz et al. using Łukasiewicz semantics indeed solves the technical bugs they found in S&L, a counterexample is needed. This is given in [Dietz et al., 2012], when they give an example that is a model according to Łukasiewicz, but not according to Kleene's semantics, and is indeed a desired model according to the Suppression Task results. Interpretations in [Dietz et al., 2012] are represented as a tuple of the form $\langle I^\top, I^\perp \rangle$, where $I^\top$ consists of all the propositions mapped to true, and $I^\perp$ false. All propositions that are not in either of these sets are mapped to unknown. In the example, this notation will also be used. The counterexample is as follows.

Counterexample Suppose we are given the conditionals *if she has an essay to write, she will study late in the library* and *if the library is open, she will study late in the library*, and the knowledge that *she has an essay to write.* According to [Stenning and Van Lambalgen, 2012] Lemma 4 and the operator they introduce here, the minimal model is computed as follows, with interpretation $I_0 = \langle \emptyset, \emptyset \rangle$:

$$I_1 = \langle \{p\}, \emptyset \rangle$$
$$I_2 = \langle \{p\}, \{ab'\} \rangle$$

According to this model and Kleene semantics, the clause $q \leftarrow r \wedge \neg ab'$ (or $r \wedge \neg ab' \rightarrow q$ in S&L) in this example is mapped to U. Therefore, according to Kleene semantics as used by S&L, this is no model, despite the fact that it should be a model according to the experiment results. If it was created using Łukasiewicz semantics, this clause is mapped to $\top$ and the result of the operator is indeed a model. Thus, this is a counterexample for S&L's approach.

This counterexample shows how using Łukasiewicz' three-valued semantics can solve the technical bugs that arise when using the approach by S&L. This is not the only counterexample given by Dietz et al., so the interested reader is referred to [Dietz et al., 2012]. However, one last note on the difference between the two semantics is that under Łukasiewicz semantics, the logic programs have the 'model intersection property', which means that the intersection of all models is also a model. The Kleene semantics, however, does not have this desirable property. This property is useful because this guarantees finding a minimal model; exactly the models that are needed for the reasoning towards an interpretation-step.

When the Łukasiewicz semantics is adopted, the resulting model is extended compared to the one given in [Stenning and Van Lambalgen, 2012], which already produces more accurate results when we look at the data gathered from human subjects performing the Suppression Task. As stated before, this extension is not the only extension possible, therefore in the next section another proposed extension will be evaluated and then added to the extension in this section.

2.3 An abductive model for human reasoning

The search for a logic which adequately models human reasoning as seen in the Suppression Task has been the drive for creating the framework proposed in the previous sections. The solution consists so far of logic programs under (weak) completion semantics that involve non-monotonicity; reasoning towards an appropriate logical form (using the logic programs); three-valued Lukasiewicz logic used on least models; an appropriate semantic operator where least fixed points are least models and these least fixed points can be computed by iterating the operator, and finally; reasoning with respect to the least models.

The framework that has been designed so far works sufficiently well for the deductive cases for the task, that is, the MP and DA subtasks. However, according to [Dietz et al., 2012], the AC and MT subtasks are not cases of deductive reasoning, but in fact 'abductive reasoning', or 'forward reasoning' and 'backward reasoning' in the S&L framework.

> 'The second part of the Suppression Task deals with the affirmation of the consequent and modus tollens. These reasoning processes can best be described as abductive, that is, a plausible explanation is computed given some observation.' [Dietz et al., 2012, p. 1503]

The difference between these kinds of reasoning in a practical sense, means that the reasoning towards an interpretation works just as well for AC and MT as for the other cases, but the second step of reasoning from an interpretation needs some kind of extension to model these experiments.

One such extension is given in [Hölldobler et al., 2011]. Here, the proposed model is the framework first set up by S&L and then extended by Dietz et al. using the Łukasiewicz semantics, with the *added* extension of abduction. This is done by creating abductive frameworks for logic programs through which a 'minimal explanation' can be found; these minimal explanations then are conclusions that *follow skeptically by abduction* (credulous reasoning was shown to be inconsistent with the results in [Byrne, 1989]). What this means, is that the the minimal explanations are not entirely definitive conclusions as much as deductive conclusions, but they are the most likely explanation for the observations made. The definition of the abductive frameworks is as follows:

Definition 2.4. Let $\mathcal{L}$ be a language, $\mathcal{K} \subseteq \mathcal{L}$ a set of formulas called *knowledge base*, $\mathcal{A} \subseteq \mathcal{L}$ a set of formulas called *abducibles* and $\models \subset 2^{\mathcal{L}} \times \mathcal{L}$ a logical *consequence relation.* The triple $\langle \mathcal{K}, \mathcal{A} \models \rangle$ is called an *abductive framework.* An *observation* $\mathcal{O}$ is a subset of $\mathcal{L}$; it is *explained* by $\mathcal{E}$ iff $\mathcal{E} \subseteq \mathcal{A}$, $\mathcal{K} \cup \mathcal{E}$ is satisfiable, and $\mathcal{K} \cup \mathcal{E} \models \mathcal{L}$ for each $\mathcal{L} \in \mathcal{O}$. An explanation $\mathcal{E}$ for $\mathcal{O}$ is said to be *minimal* iff there is no explanation $\mathcal{E}' \subset \mathcal{E}$ for $\mathcal{O}$. [Hölldobler et al., 2011, pp.136-137]

This abstract definition can be clarified by some intuitive explanation. In the subtasks AC and MT, the proposition q (or $\neg q$) that is given to the participants would be an 'observation' according to this definition. It is observed that q (or $\neg q$), and this observation is to be explained. Explanations are given through abducibles. These abducibles are propositions which are allowed to be incompletely defined, as opposed to the knowledge base, where completely defined formulas are found. Explanations combined with the knowledge base should always be satisfiable, so the world should allow both of these things to be true at the same time. Explanations being minimal, means that the explanation would not suffice if any parts of it were removed (so no smaller explanation is possible). Before moving on to the instantiation of such abductive frameworks, a straightforward example should clarify the main idea here enough.

Example:

Take a knowledge base $\mathcal{K}$:
{If the lake is frozen, then it is below 0 degrees Celsius outside.
If the lake is frozen, then a wizard magically froze the lake.
It is 35 degrees Celsius outside.}

and an observation $\mathcal{O}$:
{The lake is frozen.}

The abducibles are 'it is below 0 degrees Celsius outside' and 'a wizard magically froze the lake'. 'It is 35 degrees Celsius outside' and 'it is below 0 degrees Celsius outside' could not be true at the same time, so this is a constraint on our explanations. There are two possible explanations: 1) 'it is below 0 degrees Celsius outside' and 2) 'a wizard magically froze the lake', but only 2) satisfies the constraint above. Since there is only one explanation, there is no need to look for a minimal explanation. Thus, the abductive conclusion is 'a wizard magically froze the lake'.

Instantiation of frameworks goes as follows:
The knowledge base $\mathcal{K}$ is a logic program $\mathcal{P}$ in the language $\mathcal{L}$. Let $\mathcal{R}_\mathcal{P}$ be the set of relation symbols occurring in $\mathcal{P}$, let

$$\mathcal{R}_\mathcal{P}^\mathcal{D} = \{A \in \mathcal{R}_\mathcal{P} \mid A \leftarrow \mathit{body} \in \mathcal{P}\}$$

be the set of *defined relation symbols* in $\mathcal{P}$ and let $\mathcal{R}_\mathcal{P}^\mathcal{U} = \mathcal{R}_\mathcal{P} \setminus \mathcal{R}_\mathcal{P}^\mathcal{D}$ be the set of *undefined relation symbols* in $\mathcal{P}$. Then, the set of abducibles is

$$\mathcal{A} = \{A \leftarrow \top \mid A \in \mathcal{R}_\mathcal{P}^\mathcal{U}\} \cup \{A \leftarrow \bot \mid A \in \mathcal{R}_\mathcal{P}^\mathcal{U}\}$$

The consequence relation $\models$ is $\models_{3\text{Ł}}^{\text{lm wc}}$, where $\mathcal{P} \models_{3\text{Ł}}^{\text{lm wc}} F$ iff F is mapped to $\top$ under the least model of the weak completion of P using the three-valued Łukasiewicz semantics (the result of the reasoning towards an interpretation step). If the observation $\mathcal{O}$ is a singleton set $\{L\}$, we simply write $\mathcal{O} = L$. A formula $F \in \mathcal{L}$ *follows skeptically by abduction* from $\mathcal{P}$ and $\mathcal{O}$, iff $\mathcal{O}$ can be explained and for all minimal explanations $\mathcal{E}$ we find $\mathcal{P} \cup \mathcal{E} \models_{3\text{Ł}}^{\text{lm wc}} F$. [Hölldobler et al., 2011, p. 137]

Below each of the 6 abductive subtasks of the Suppression Task will be worked out in the notation from S&L to show the intuition behind this abstract definition. Interpretation I is the result of the weak completion and closed-world reasoning step (so the reasoning towards an interpretation step) and then applying the three-valued Łukasiewicz semantics.

1 $\mathcal{P} = \{p \wedge ab \rightarrow q, \bot \rightarrow ab\}$
$\mathcal{O} = q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p\}$
$I = \langle \emptyset, \{ab\} \rangle$
$\{\top \rightarrow p\}$ explains q and $\mathcal{P}, q \models p$

2 $\mathcal{P} = \{p \wedge ab \rightarrow q, \bot \rightarrow ab\}$
$\mathcal{O} = \neg q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p\}$
$I = \langle \emptyset, \{ab\} \rangle$
$\{\bot \rightarrow p\}$ explains $\neg q$ and $\mathcal{P}, \neg q \models \neg p$

3 $\mathcal{P} = \{p \wedge ab \rightarrow q, \neg r \rightarrow ab, r \wedge ab' \rightarrow q, \neg p \rightarrow ab'\}$
$\mathcal{O} = q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p, \top \rightarrow r, \bot \rightarrow r\}$
$I = \langle \emptyset, \emptyset \rangle$
$\{\top \rightarrow p, \top \rightarrow r\}$ explains q and $\mathcal{P}, q \models p$

4 $\mathcal{P} = \{p \wedge ab \rightarrow q, \neg r \rightarrow ab, r \wedge ab' \rightarrow q, \neg p \rightarrow ab'\}$
$\mathcal{O} = \neg q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p, \top \rightarrow r, \bot \rightarrow r\}$
$I = \langle \emptyset, \emptyset \rangle$
$\{\bot \rightarrow p\}$ & $\{\bot \rightarrow r\}$ explain $\neg q$ and $\mathcal{P}, \neg q \models \neg p$

5 $\mathcal{P} = \{p \wedge ab \rightarrow q, \bot \rightarrow ab, t \wedge ab' \rightarrow q, \bot \rightarrow ab'\}$
$\mathcal{O} = q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p, \top \rightarrow t, \bot \rightarrow t\}$
$I = \langle \emptyset, \{ab, ab'\} \rangle$
$\{\top \rightarrow p\}$ & $\{\top \rightarrow t\}$ explain q and $\mathcal{P}, q \models p$

6 $\mathcal{P} = \{p \wedge ab \rightarrow q, \bot \rightarrow ab, t \wedge ab' \rightarrow q, \bot \rightarrow ab'\}$
$\mathcal{O} = \neg q$
$\mathcal{A} = \{\top \rightarrow p, \bot \rightarrow p, \top \rightarrow t, \bot \rightarrow t\}$
$I = \langle \emptyset, \{ab, ab'\} \rangle$
$\{\bot \rightarrow p, \bot \rightarrow t\}$ explains $\neg q$ and $\mathcal{P}, \neg q \models \neg p$

These conclusions are equivalent to the results found in [Byrne, 1989], and therefore this formalization is adequate. (See section 4.1 for an in-depth discussion of this conclusion)

2.4 SLDH-framework

This past section (section 2) has described the framework that is arguably the most relevant in current research on human reasoning in logic tasks, in particular based on the reasoning seen in the Suppression Task. The framework consists of the reasoning towards an interpretation step proposed by S&L in [Stenning and Van Lambalgen, 2012], extended with the Łukasiewicz semantics as proposed in [Dietz et al., 2012] and finally extended with abduction as proposed in [Hölldobler et al., 2011]. This framework will from here on be called the SLDH-framework, but will not be the only model used for explaining the behaviour found in human subjects performing the Suppression Task. In part 3, a new extension for this model will be added; a deviation in the step from S&L that handles reasoning towards an interpretation.

The SLDH-framework gives a clear outline of how human reasoners supposedly handle the Suppression Task, however it gives a non-intuitive explanation of how the reasoning steps are done in a human reasoner. Their proposition that human reasoners use abnormality predicates to reason towards an interpretation lacks the recognizability a human reasoner would expect when she thinks about the steps she takes when handling a logical task. Therefore, what the New Model will consider is what is according to us a more intuitive framework for the reasoning towards an interpretation step.

3 Relevance within the field of AI

The idea that classical logic models human reasoning has been a long researched notion within the fields of cognitive science and formal (logic) theories. The results from experiments such as the Suppression Task show that in fact classical logic does *not* model human reasoning successfully, since it can not explain the behaviour found in the human subjects doing the task. The specific intersection between the fields of cognitive science and formal theories is shaped through research on the connection between human reasoning and logic. Thus, if classical logic, and with this formal theories that model human reasoning, are shown to not be up to the task, this asks for a realignment of relevant theories within the field. Insights such as the ones gained through the Suppression Task are problematic for formal theories that were expected to model human reasoning.

Human reasoning has long been a topic of interest, however within the last century it has been increasingly more relevant. With the emergence of computer systems and the rise of (strong) AI, modelling human reasoning has become an even more popular topic than before. Human reasoning has so far been the most efficient and successful reasoning found in nature; if we would want to create equally or increasingly efficient reasoners through computer systems we must first understand the way it works within ourselves. This is the core of (classical) AI; understanding human behaviour (including reasoning) through the use of machines and modelling.

There is a large field within AI and cognitive science that has been focussed on modelling human reasoning in order to create a greater understanding of how humans reason. Logical and psychological process models are one way of doing this kind of research, for example the work on mental models by Byrne and Johnson-Laird [Byrne and Johnson-Laird, 2009]. These mental models are representations of human reasoning, consisting of both internal and external relations that shape the behaviour of a human reasoner. Mental models are a rather abstract definition of multiple ways of representing human reasoning, and therefore it is complicated to formally define what is and is not a mental model.

Partly due to the lack of a formal framework for the mental models, this kind of modelling perhaps seems more general than what is seen in the modelling for the Suppression Task. However, a model that can successfully explain the behaviour seen in one logical task always creates a greater understanding of the whole of human reasoning. Each successful model sheds light on the topic, which leads to more successful research on other subjects within the field of human reasoning. This means that a more general model such as the mental models research by Byrne and Johnson-Laird is always helped by the insights created through research on smaller parts of human reasoning. Therefore, research on a model that explains the reasoning in one logical task is an equally valuable endeavour as trying to create a more general model for human reasoning.

The relevance of this thesis within the field of AI can be mainly applied to the formal theories of reasoning. Within philosophy, there is also an immense amount of research being done on reasoning processes. I am aware of the discussions on reasoning processes that remain undecided within philosophy of mind and that this research is just as relevant for AI. I am also aware that these philosophical discussions are necessary for creating a wider understanding of reasoning as a whole, and therefore also relevant for the topic I am discussing. However, this thesis focusses on the formal theoretical parts of this topic more than the abstract (but equally compelling) philosophical theories, and thus these theories will not be discussed any further here.

4 Discussion

4.1 The ambiguity of the task results and model results

The conclusions in the literature are considerably ambiguous. Results that are similar to that of the experiment are said to accurately model human reasoning instantly, but there is no threshold given for this similarity. Neither are there any bare minima given for when we are able to conclude 'success'.

> In this paper, we evaluate the inferential adequacy of our computational logic approach by examining that our approach gives the same answers as subjects in the Suppression Task experiments. [Dietz et al., 2012, p. 1501]

These 'same answers' are hardly a strong argument, since results are given in the form of percentages. But when for example it is said that 4% of subjects conclude something, what are the 'same answers as subjects in the Suppression Task experiments'?

Conditionals	Fact	Experimental findings
Single	p	96% conclude q
Alternative	p	96% conclude q
Additional	p	38% conclude q
Single	$\neg p$	46% conclude $\neg q$
Alternative	$\neg p$	4% conclude $\neg q$
Additional	$\neg p$	63% conclude $\neg q$
Single	q	53% conclude p
Alternative	q	16% conclude p
Additional	q	55% conclude p
Single	$\neg q$	69% conclude $\neg p$
Alternative	$\neg q$	69% conclude $\neg p$
Additional	$\neg q$	44% conclude $\neg p$

Table 5: Table 2. from [Dietz et al., 2012, p. 1500]: The drawn conclusions in the experiment of Byrne.

This is only a clear statement for the high amounts; they give no threshold for when answers are considered similar to the experiment results, and no alternative answers than the ones given in the table (agreeing with the conclusion). One might guess that if 4% conclude 'yes, the query can be concluded' then 96% conclude 'no', but this is guesswork. It is not clearly stated in the articles what all possible answers are, so perhaps the percentages are not just binary; 4% 'yes' may mean 50% 'no' and 46% 'I don't know'. Neither does the table give results for the logically valid inferences, or for the most made inferences by human reasoners. Therefore the numbers chosen to represent the choices made by human reasoners seem to leave a lot to the imagination. Looking at articles that have cited these articles [Dietz et al., 2013, Pereira et al., 2014, Hölldobler, 2015, Dietz and Hölldobler, 2015] doesn't give any clearer answers; no threshold or clarification is stated anywhere.

Because of this ambiguity of the results, we will assume that the percentages given in table 5 above represent the people answering 'yes, the query can be concluded', and that all others, so the complement of these percentages, are the subjects that either answered ‘no’ or ‘not sure’ on the query. This still leaves some ambiguity in the results, however this will be the way that the experiment with the New Model (Part IV), will be conducted as well.

On top of this, in Part III, there will be a thorough evaluation of multiple possible thresholds for the ‘similarity of answers’. Because there is no possible threshold stated in any of the literature, two thresholds are chosen to be evaluated. Through these thresholds combined with the experiment results (represented in percentages), the success of multiple models is evaluated.

Part III
New Model

5 Framework

5.1 Why this model?

The following New Model is created to battle the counter-intuitive reasoning that is used to explain the subtasks using additional premises; in particular the conditional *if the library is open, she will study late in the library.* This conditional creates arguably more confusion in human subjects than can be explained with the abnormality predicates, and the framework described in this section models this difficulty. This will be shown in section 5.3 with the application of this framework on the subtasks of the Suppression Task.

There also seems to be a paradox in the SLDH-framework between the appliance of closed-world reasoning, as well as the abnormality predicates. The abnormality predicates model the way a subject might think of *anything* abnormal that could stand in the way of the validity of a clause. However, when S&L introduced the closed-world reasoning for their framework it was to model the way people do not reason with any more information than what is directly known to them. This leads to an intuitive paradox; modelling the reasoning with additional information in abnormality predicates seems to be perpendicular to the closed-world reasoning that models the way humans do not reason with this additional information.

All extensions seen previously showed changes in the *reasoning from an interpretation*-step, but the model introduced in this section in fact deviates from the SLDH-framework in the *reasoning towards an interpretation step*, because this is the part where their framework is counter-intuitive. Where S&L introduce abnormality predicates to create their logical programs, this New Model introduces a predefined set of conditionals that represent the *Commonsense Knowledge*; a set of conditionals that are expected to be known by all human reasoners through each subtask. Using the commonsense knowledge-approach, this New Model still creates logical programs, simply with no abnormality predicates and through a consistency with the commonsense knowledge. Therefore, the resulting programs may not always deviate from the SLDH-framework, but *how* these results were acquired should be closer to the way human reasoners acquire their results. In the following subsection it is shown how the reasoning towards an interpretation-step is performed with the New Model. In Part IV (p. 40) of this thesis, two experiments will be performed based on this New Model. The first, a simple questionnaire based Suppression Task, does not yield specific evidence for our approach. The second experiment however, which consists of interviews of the Suppression Task, shows indeed some evidence for our adaptation of the SLDH-framework.

5.2 Theoretical outline

Reasoning towards an interpretation while still being consistent with a predefined set of conditionals asks for a deviation in the way the logical programs are created. Below is an abstract step-by-step definition followed by a concrete example. What should be noted is that this definition assumes that the propositions necessary for each subtask of the Suppression Task (either one of $\{p, q, \neg p, \neg q\}$) are not added to the logical program that goes through the steps below. These propositions are added later on to the result of these modifications. This means that during the experiment, the subjects will first receive some inferences to be seen as true with which they can start to reason, in combination with their commonsense knowledge. After this, they will receive the facts (categoricals) and then draw their final conclusions.

Reasoning towards an interpretation is done as follows:

Definition 5.1. Let $\mathcal{P}$ be a program and $\mathcal{C}$ a set of conditionals. Let $\mathcal{P} \cup \mathcal{C}$ be closed under transitivity.

1. For each clause in $\mathcal{P}$ perform the following steps:
   (a) Let clause E of the form $A \to q \in \mathcal{P}$, with $A = a_1 \wedge ... \wedge a_n$. For each proposition $p_1, ..., p_n \in P$ (either atomic or in the body of another clause, where $p \neq q$ for each $p \in P$), create a disjunction $(p_1 \vee \neg p_1)$. Update E into a conjunction of the form $A \wedge (p_1 \vee \neg p_1) \wedge ... \wedge (p_n \vee \neg p_n)$.
   (b) Applying classical logic rules, rewrite the conjunctive clause into a disjunctive clause.
   (c) For each clause in $\mathcal{C}$, see if they are consistent with each disjunct in the disjunctive clause according to classical logic. If not, remove this disjunct from the disjunctive clause. Note in this step the effect of the transitive closure of $\mathcal{P} \cup \mathcal{C}$.
2. Take all separate disjunctive clauses and combine them into one large disjunct.
3. Replace the $\to$ by a $\leftrightarrow$. (Note the resemblance with the SLDH-framework.) This final disjunctive clause contains all necessary information and is therefore the only clause in $\mathcal{P}$

5.2.1 Example

This abstract definition can be made concrete when looking at an example. Let $\mathcal{C} = \{e \wedge a \to \neg b\}$ and $\mathcal{P} = \{e \to q, a, b\}$. Starting with taking the first (and only) clause from $\mathcal{P}$ produces $e \to q$.
Update $e \to q$ into $e \wedge (x \vee \neg x) \to q$ for each proposition $x \in \mathcal{P}$. Since $a, b \in \mathcal{P}$, the clause is replaced with
$e \wedge (a \vee \neg a) \wedge (b \vee \neg b) \to q$.
Then using classical logic, the conjunctive clause is rewritten into a disjunctive clause:
$(e \wedge a \wedge b) \vee (e \wedge a \wedge \neg b) \vee (e \wedge \neg a \wedge b) \vee (e \wedge \neg a \wedge \neg b) \to q$.
For the third step, we must eliminate all inconsistencies with regard to $\mathcal{C}$. Since $\mathcal{C} = \{e \wedge a \to \neg b\}$, the only inconsistency in the large disjunctive clause is the disjunct $(e \wedge a \wedge b)$. The disjunctive clause is updated to
$(e \wedge a \wedge \neg b) \vee (e \wedge \neg a \wedge b) \vee (e \wedge \neg a \wedge \neg b) \to p$.
Lastly, replacing the $\to$ creates the final clause
$(e \wedge a \wedge \neg b) \vee (e \wedge \neg a \wedge b) \vee (e \wedge \neg a \wedge \neg b) \leftrightarrow p$, which is now the only element of $\mathcal{P}$.

5.3 Application of the New Model

Now that the formal framework for this New Model, and especially the 'reasoning towards an interpretation'-step has been defined, we can use this New Model on the Suppression Task.

With this model, a logical program will be created for each combination of conditionals, the same conditionals that were seen in the literature so far. The possible combinations are thus again as follows:

a. If she has an essay to write she will study late in the library.

b. If she has an essay to write she will study late in the library.
If she has a textbook to read she will study late in the library.

c. If she has an essay to write she will study late in the library.
If the library is open she will study late in the library.

The same notation will be used here for each proposition as in the previous sections, so the notational translation is as follows:

1. $\{p \to q\}$
2. $\{p \to q\}$
$\{t \to q\}$
3. $\{p \to q\}$
$\{r \to q\}$

Note that there are no more abnormality predicates necessary, so this simple notation will in fact be sufficient for each of the conditionals.

As described above, the set of 'commonsense knowledge', $\mathcal{C}$ is the same during each of the subtasks. In this case, this set would be $\mathcal{C} = \{q \to r\}$ during the entire experiment. The reason for this is that the only intuitive commonsense knowledge that we expect all subjects to have, is that *she will not study late in the library if it is not open*; therefore, it is inherent that if she is in the library, the library must be open. Therefore, $q \to r$ should always hold. The program $\mathcal{P}$ will be different for each combination of conditionals: it will consist of the clauses in 1., 2., and 3. above.

5.3.1 Creating the logical programs

Now that we have established the set $\mathcal{C}$ and $\mathcal{P}$ for each conditional combination, we can create the actual logical programs according to definition 5.1. This New Model does not entail greatly distinctive final logical programs; however the fact that it sometimes actually creates simpler and more intuitive programs and models is according to us an advantage. The crucial difference will be found more in the process that results in the conclusions, than the results themselves.

The logical programs created below are the set-up for each combination of conditionals; not for each subtask. What is added in each subtask is either of the propositions $\{p, q, \neg p, \neg q\}$, but these are not included in the steps necessary for creating the logical programs according to definition 5.1.

Simple (1):
$\mathcal{P} = \{p \to q\}$
$\mathcal{C} = \{q \to r\}$
For this conditional combination, the only applicable steps are checking for

inconsistencies with $\mathcal{C}$ (which there are none of) and replacing the $\rightarrow$ with a $\leftrightarrow$. This leaves us with $\mathcal{P} = \{p \leftrightarrow q\}$.

Alternative (1 & 2):
$\mathcal{P} = \{p \rightarrow q; t \rightarrow q\}$
$\mathcal{C} = \{q \rightarrow r\}$
Taking each of the clauses in $\mathcal{P}$ and updating them into a conjunction creates $\{(p \wedge (t \vee \neg t)) \rightarrow q; (t \wedge (p \vee \neg p)) \rightarrow q\}$.
Rewriting these clauses using classical logic creates $\{((p \wedge t) \vee (p \wedge \neg t)) \rightarrow q; ((t \wedge p) \vee (t \wedge \neg p)) \rightarrow q\}$.
There are no inconsistencies with $\mathcal{C}$. Using classical logic we see that these clauses are equivalent to $\{p \rightarrow q; t \rightarrow q\}$. Now combining them into one large conjunctive clause generates $\{(p \vee t) \rightarrow q\}$. Lastly, replacing the arrow-connective generates the final program $\mathcal{P} = \{(p \vee t) \leftrightarrow q\}$.

Additional (1 & 3):
$\mathcal{P} = \{p \rightarrow q; r \rightarrow q\}$
$\mathcal{C} = \{q \rightarrow r\}$
Taking each of the clauses in $\mathcal{P}$ and updating them into a conjunction creates $\{(p \wedge (r \vee \neg r)) \rightarrow q; (r \wedge (p \vee \neg p)) \rightarrow q\}$.
Rewriting these clauses using classical logic creates $\{((p \wedge r) \vee (p \wedge \neg r)) \rightarrow q; ((r \wedge p) \vee (r \wedge \neg p)) \rightarrow q\}$.
The only disjunct with conclusion q that is inconsistent with $\mathcal{C}$ is $(p \wedge \neg r)$, since $\mathcal{C} = \{q \rightarrow r\}$. Therefore, this disjunct is removed, generating $\{p \wedge r \rightarrow q; (r \wedge p) \vee (r \wedge \neg p) \rightarrow q\}$. Using classical logic we see that these clauses are equivalent to $\{(p \wedge r) \rightarrow q; r \rightarrow q\}$. Now combining them into one large conjunctive clause generates $\{(p \wedge r) \vee r \rightarrow q\}$. This clause is again equivalent to $\{r \rightarrow q\}$. Lastly, replacing the arrow-connective generates the final program $\mathcal{P} = \{r \leftrightarrow q\}$.

5.4 Subtasks

The logical programs created in definition 5.1 where explained to not contain the propositions for each subtask at the moment of their creation. This is because there are two fundamentally different processes at hand. Firstly, reasoning with the given information is performed which leads to a logical program. Then, the task is performed (where the propositions are added) and the logical program is applied. Therefore, the final logical programs specific to each subtask are shown in Table 5 below:

Clause combination	MP	MT	DA	AC
Simple	$\mathcal{P} = \{p \leftrightarrow q; p\}$	$\mathcal{P} = \{p \leftrightarrow q; \neg q\}$	$\mathcal{P} = \{p \leftrightarrow q; \neg p\}$	$\mathcal{P} = \{p \leftrightarrow q; q\}$
Alternative	$\mathcal{P} = \{p \vee t \leftrightarrow q; p\}$	$\mathcal{P} = \{p \vee t \leftrightarrow q; \neg q\}$	$\mathcal{P} = \{p \vee t \leftrightarrow q; \neg p\}$	$\mathcal{P} = \{p \vee t \leftrightarrow q; q\}$
Additional	$\mathcal{P} = \{r \leftrightarrow q; p\}$	$\mathcal{P} = \{r \leftrightarrow q; \neg q\}$	$\mathcal{P} = \{r \leftrightarrow q; \neg p\}$	$\mathcal{P} = \{r \leftrightarrow q; q\}$

Table 6: Logical programs for each subtask according to the New Model

5.5 Reasoning to an interpretation

The logical programs in Table 6. show where the New Model varies from the SLDH-framework, namely for the additional subtask. For clarification, the four logical programs according to the SLDH-framework were as follows:

MP $\{\top \rightarrow p; p \wedge r \rightarrow q\}$

MT $\{\bot \rightarrow q; p \wedge r \rightarrow p\}$

DA $\{\bot \rightarrow p; p \wedge r \rightarrow q\}$

AC $\{\top \rightarrow q; p \wedge r \rightarrow p\}$

During the reasoning towards an interpretation steps, the three valued Łukasiewiecz semantics will be used. Section 6 will focus on comparing the results from reasoning towards an interpretation for both the SLDH-framework and our newer model. Due to the simplicity of the new logical programs as made through the New Model, abduction as used in the SLDH-framework is no longer necessary. The addition of the abnormality predicates made this abduction useful, since the reasoning process is complicated when more variables are added.

6 An evaluation of multiple models

In this section we will see an in depth evaluation of the two models for the Suppression Task discussed above. These models are the SLDH-framework and the New Model. What will be compared is which of these comes closest to the answers given by human subjects in the Suppression Task.

6.1 Finding the right answers

Each subtask of the Suppression Task has a different query to be answered. These were first mentioned in Section 1.2. Participants of the Suppression Task are given a model (where some premisses are given as rules, and some propositions as truths), and are asked about the validity of a possible conclusion. For clarification, the queried conclusions are stated below for each subtask:

MP: Proposition p is given as a truth, q is the queried conclusion.

DA: Proposition $\neg p$ is given as a truth, $\neg q$ is the queried conclusion.

AC: Proposition q is given as a truth, p is the queried conclusion.

MT: Proposition $\neg q$ is given as a truth, $\neg p$ is the queried conclusion.

These queries are the same for the single, alternative and additional configuration for each MP, DA, AC or MT subtask. The human subjects that have done the Suppression Task are asked through natural language to decide the validity of these statements, which means that the results seen in Tables 1 (p. 6) and 5 (p. 19) are in fact percentages of subjects answering yes or no. Thus these percentages can be used to decide on what the preferred outcome should be from a model in which such a logical statement should be proven.

However, as was discussed in Section 4, there is no mention of a threshold in any of the experiments discussed before. This means that these 'preferred answers' are ambiguous to say the least. No definitive conclusion can be drawn, since it is never stated how much percent of the participants has to conclude something for it to be the preferred answer. A different threshold can in fact be decisive in finding such a preferred answer; two thresholds can make a different answer the preferred one, for the same subtask and configuration. Therefore, two different thresholds will be tested in this section.

Table 1 gave the resulting percentages from Byrne's experiment, and Table 5 gave the percentages from Dietz et al. These two tables describe the same experiment, but they differ slightly in their contents. Thus a threshold might have different effects on Byrne's results than they do on Dietz et al. as well, which will be taken into account in the evaluation.

The evaluation of two different thresholds already has the variable of the different experiments (Byrne, Dietz et al.), but next to this there is the effect of the used connective within the logical programs. The effect of using a $\rightarrow$ or a $\leftrightarrow$ as a connective, and it's corresponding truth-value assignments will therefore also be evaluated. In the SLDH-framework as well as in the New Model, the $\rightarrow$ operator is turned into a $\leftrightarrow$ through the process of completion. This is as to represent the way closed-world reasoning is applied by human reasoners. However, the experiments discussed in part II do not in fact use the $\leftrightarrow$ as the logical operator and it's truth assignments. The use of the $\leftrightarrow$ is only as a symbol of the completion that has been applied. This means that in the SLDH-framework, a $\leftrightarrow$ is written, but still the truth-value assignments from the $\rightarrow$ is used. Thus, the logical operator is $\rightarrow$, but written as $\leftrightarrow$ to represent closed-world reasoning.

Comparing the effects of using the truth-value assignments from $\rightarrow$ with those of $\leftrightarrow$ demonstrate the validity of this approach by S&L, Dietz et al. and Hölldobler. When this is evaluated in the following sections, the $\leftrightarrow$ and $\rightarrow$ will represent the logical operators and their corresponding truth assignments as found in Table 4, not the symbol of completion $\leftrightarrow$ is in the SLDH-framework.

There is a difference between the New Model and the SLDH-framework in the final programs they produce only in the additional subtask; in SLDH the resulting logical program is $\{p \wedge r \leftrightarrow q\}$, in the New Model the program is $\{r \leftrightarrow q\}$. These programs will also both be evaluated and compared to establish which comes closest to the answers by human subjects.

6.1.1 Summary of comparisons

Above is described a set of variable parts of the Suppression Task-models that need to be evaluated. Since all of these will be compared thoroughly in the coming section, below is a coherent list of what will be evaluated:

1. Different thresholds to decide on the 'preferred answers'; the answers given by most human subjects.
   (a) The (possibly) different effects of such a threshold for the results by Byrne and by Dietz et al.
2. Using the truth-value assignments for the logical operator $\leftrightarrow$ or $\rightarrow$.
3. The final program for the additional subtask from the SLDH-framework and the one from the New Model.

6.2 Thresholds

In Table 7, the percentages from the Byrne experiment and the Dietz et al. experiment are shown. These percentages differ only in the last 4 columns; the percentages for the AC and the MT subtasks. Using these two percentages, the effects of different thresholds will be compared.

A threshold is used as a strong line to be drawn between preferred and not-preferred answers. A threshold of X means that at least $X\%$ of participants must have answered

Byrne								
	MP %	Conclusion	DA %	Conclusion	AC %	Conclusion	MT %	Conclusion
Single	96	q	46	$\neg q$	71	p	92	$\neg p$
Alternative	96	q	4	$\neg q$	13	p	96	$\neg p$
Additional	38	q	63	$\neg q$	54	p	33	$\neg p$
Dietz et al.								
	MP %	Conclusion	DA %	Conclusion	AC %	Conclusion	MT %	Conclusion
Single	96	q	46	$\neg q$	53	p	69	$\neg p$
Alternative	96	q	4	$\neg q$	16	p	69	$\neg p$
Additional	38	q	63	$\neg q$	55	p	44	$\neg p$

Table 7: Conclusions and percentages for both Byrne and Dietz et al.

some answer Q, for Q to be the preferred answer. Q, then, has to come out of the logical model (either the SLDH-framework, or the New Model) as a conclusion as well. Where in the human participants the answer is simply asked, in the logical models it has to be proven.

For the logical models this evaluation will be as follows. For each subtask, a logical statement of the form $P \vdash Q$ is given. What this means, is that in every model where P is true, Q must also be true. Then the valid conclusion of the model is Q. These logical statements are based on the 'preferred answers' given by participants, using a certain threshold. This means that if the conclusion as seen in Table 7 is given by less participants than the threshold, the logical statement is of this form: $P \nvdash Q$. This means that through the framework, there should be at least one model where P is true, and Q is not.

These statements are evaluated through the logical framework using three-valued semantics on the final logical program. The proposition that is given to participants is represented by either a $\top$ or a $\bot$ behind this particular proposition, for each configuration of truth-assigments. If the logical statements are proven, the framework is said to give the same answers as the human subjects. Since this was inherently the aim of the models, their success should be measured as such.

6.2.1 50%

The first threshold to be evaluated is 50%. This means that if a resulting percentage from Table 7 is below 50%, the preferred answer is then to *not* conclude the conclusions from Table 7. In Table 8, the preferred answers for this threshold are given for each subtask, and both for the results from Byrne and Dietz et al..

It is visible in Table 8 that the conclusions for Byrne and Dietz et al. are the same when we use a threshold of 50%. This means that what needs to be evaluated for this threshold is only the difference between $\leftrightarrow$ and $\rightarrow$, and between the final program of the SLDH-framework and the New Model.

For each conclusion in Table 8, it must be investigated whether each model comes to this conclusion as well. This means that if the conclusion contains a $\vdash$ (turnstile), each model where the part before the turnstile is true should also make the part after the turnstile true. However if the conclusion contains a $\nvdash$, we need only one counterexample; a model where the part before the turnstile is true, but the part after

Byrne				
	MP	DA	AC	MT
Single	$p \vdash q$	$\neg p \nvdash \neg q$	$q \vdash p$	$\neg q \vdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional	$p \nvdash q$	$\neg p \vdash \neg q$	$q \vdash p$	$\neg q \nvdash \neg p$
Dietz et al.				
	MP	DA	AC	MT
Single	$p \vdash q$	$\neg p \nvdash \neg q$	$q \vdash p$	$\neg q \vdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional	$p \nvdash q$	$\neg p \vdash \neg q$	$q \vdash p$	$\neg q \nvdash \neg p$

Table 8: Preferred answers for a threshold of 50%

it is not.

Single Tasks

MP $\rightarrow$: What should hold through the frameworks is $p \vdash q$; whenever p is true in a valid model, so is q. The logical program we have in the single task is $\mathcal{P}=\{p \rightarrow q\}$, where in the MP subtask the fact p is added. Now for each possible truth-value for q, the validity of the model is tested. The full model in this case consists only of the logical program $\mathcal{P}$. That makes the truth-assignments possible seen in Table 9, the first column.

$(p^{\top} \rightarrow q^{\top})^{\top}$	$(p^{\top} \leftrightarrow q^{\top})^{\top}$
$(p^{\top} \rightarrow q^{\perp})^{\perp}$	$(p^{\top} \leftrightarrow q^{\top})^{\top}$
$(p^{\top} \rightarrow q^{U})^{U}$	$(p^{\top} \leftrightarrow q^{\top})^{\top}$

Table 9

The only truth-assignment that makes the total model true is the first (row 1), the other assignments give the model a value of either false, or unknown. Therefore, the conclusion is that indeed $p \vdash q$; whenever p is true in a valid model, so is q, according to three-valued semantics and the logical program created through the framework (both SLDH and the New Model).

$\leftrightarrow$: Now doing the same for the version with $\mathcal{P}=\{p \leftrightarrow q\}$ produces the truth-assignments as seen in Table 9, the second column.
Here, there is no difference between using the logical operator $\rightarrow$ or $\leftrightarrow$, each time the conclusion is $p \vdash q$.

DA $\rightarrow$: The logical program is again $\mathcal{P} = \{p \rightarrow q\}$, but what needs to hold now is $\neg p \nvdash \neg q$. Therefore, a counterexample to $\neg p \vdash \neg q$ needs to be found; a valid model where $\neg p$ is true, but $\neg q$ is not. The truth-assignments in Table 10, column 1 produce two counterexamples to $\neg p \vdash \neg q$, namely on the second and third row. Here q is true or unknown, the model is valid and $\neg p$ is true. Thus, $\neg p \nvdash \neg q$.

$(p^{\perp} \rightarrow q^{\top})^{\top}$	$(p^{\perp} \leftrightarrow q^{\top})^{\perp}$
$(p^{\perp} \rightarrow q^{\perp})^{\top}$	$(p^{\perp} \leftrightarrow q^{\perp})^{\top}$
$(p^{\perp} \rightarrow q^{U})^{\top}$	$(p^{\perp} \leftrightarrow q^{U})^{U}$

Table 10

$\leftrightarrow$: Doing the same for $\mathcal{P} = \{p \leftrightarrow q\}$ produces the models in Table 10 column 2. Here, no counterexample can be found, so there is a difference between using the logical operator $\rightarrow$ and $\leftrightarrow$. The conclusion here is $\neg p \vdash \neg q$.

AC $\rightarrow$: The program is again $\mathcal{P} = \{p \rightarrow q\}$, what needs to hold is $q \vdash p$. The possible models seen in Table 11, column 1. The models on row 1 and 2 are counterexamples, since the model and q are true, but p is not. Thus $\neg p \nvdash \neg q$.

$(p^{\top} \rightarrow q^{\top})^{\top}$	$(p^{\top} \leftrightarrow q^{\top})^{\top}$
$(p^{\perp} \rightarrow q^{\top})^{\top}$	$(p^{\perp} \leftrightarrow q^{\top})^{\perp}$
$(p^{U} \rightarrow q^{\top})^{\top}$	$(p^{U} \leftrightarrow q^{\top})^{U}$

Table 11

$\leftrightarrow$: With program $\mathcal{P} = \{p \leftrightarrow q\}$ the possible models are seen in Table 11, column 2. No counterexamples are found, so this operator gives a different conclusion, namely the preferred $\neg p \vdash \neg q$.

MT $\rightarrow$: $\mathcal{P} = \{p \rightarrow q\}$ and $\neg q \vdash \neg q$. Models are seen in Table 12, column 1. There is no counterexample, so $\neg p \vdash \neg q$.

$\leftrightarrow$: $\mathcal{P} = \{p \leftrightarrow q\}$ and $\neg p \vdash \neg q$, with models as seen in Table 12 column 2. There are no differences here between $\leftrightarrow$ and $\rightarrow$, so again the conclusion is the preferred $\neg p \vdash \neg q$.

$(p^\top \rightarrow q^\bot)^\bot$	$(p^\top \leftrightarrow q^\bot)^\bot$
$(p^\bot \rightarrow q^\bot)^\top$	$(p^\bot \leftrightarrow q^\bot)^\top$
$(p^U \rightarrow q^\bot)^U$	$(p^U \leftrightarrow q^\bot)^U$

Table 12

$\rightarrow$:	$\leftrightarrow$:
$(p^\top \vee t^\top \rightarrow q^\top)^\top$	$(p^\top \vee t^\top \leftrightarrow q^\top)^\top$
$(p^\top \vee t^\top \rightarrow q^\bot)^\bot$	$(p^\top \vee t^\top \leftrightarrow q^\bot)^\bot$
$(p^\top \vee t^\top \rightarrow q^U)^U$	$(p^\top \vee t^\top \leftrightarrow q^U)^U$
$(p^\top \vee t^\bot \rightarrow q^\top)^\top$	$(p^\top \vee t^\bot \leftrightarrow q^\top)^\top$
$(p^\top \vee t^\bot \rightarrow q^\bot)^\bot$	$(p^\top \vee t^\bot \leftrightarrow q^\bot)^\bot$
$(p^\top \vee t^\bot \rightarrow q^U)^U$	$(p^\top \vee t^\bot \leftrightarrow q^U)^U$
$(p^\top \vee t^U \rightarrow q^\top)^\top$	$(p^\top \vee t^U \leftrightarrow q^\top)^\top$
$(p^\top \vee t^U \rightarrow q^\bot)^\bot$	$(p^\top \vee t^U \leftrightarrow q^\bot)^\bot$
$(p^\top \vee t^U \rightarrow q^U)^U$	$(p^\top \vee t^U \leftrightarrow q^U)^U$

Table 13

Alternative Tasks For each subtask with operator $\rightarrow$, $\mathcal{P}=\{p \vee t \rightarrow q\}$. For each subtask with operator $\leftrightarrow$, $\mathcal{P}=\{p \vee t \leftrightarrow q\}$.

MP To be proven: $p \vdash q$

Possible models shown in Table 13. The conclusion for $\rightarrow$: is $p \vdash q$, for $\leftrightarrow$: it is $p \vdash q$, because neither logical operator leaves any counterexamples.

DA To be proven: $\neg p \nvdash \neg q$

Possible models shown in Table 14. The conclusion for $\rightarrow$: is $\neg p \nvdash \neg q$, for $\leftrightarrow$: it is $\neg p \nvdash \neg q$, because both logical operators produce counterexamples to $\neg p \vdash \neg q$. For $\rightarrow$ these counterexamples are in row 2 (so the first model) and 5, for $\leftrightarrow$ the only counterexample is in row 2.

AC To be proven: $q \nvdash p$

Possible models shown in Table 15. The conclusion for $\rightarrow$: is $q \nvdash p$, for $\leftrightarrow$: it is

$\rightarrow$:	$\leftrightarrow$:
$(p^{\bot} \vee t^{\top} \rightarrow q^{\top})^{\top}$	$(p^{\bot} \vee t^{\top} \leftrightarrow q^{\top})^{\top}$
$(p^{\bot} \vee t^{\top} \rightarrow q^{\bot})^{\bot}$	$(p^{\bot} \vee t^{\top} \leftrightarrow q^{\bot})^{\bot}$
$(p^{\bot} \vee t^{\top} \rightarrow q^{U})^{U}$	$(p^{\bot} \vee t^{\top} \leftrightarrow q^{U})^{U}$
$(p^{\bot} \vee t^{\bot} \rightarrow q^{\top})^{\top}$	$(p^{\bot} \vee t^{\bot} \leftrightarrow q^{\top})^{\bot}$
$(p^{\bot} \vee t^{\bot} \rightarrow q^{\bot})^{\top}$	$(p^{\bot} \vee t^{\bot} \leftrightarrow q^{\bot})^{\top}$
$(p^{\bot} \vee t^{\bot} \rightarrow q^{U})^{U}$	$(p^{\bot} \vee t^{\bot} \leftrightarrow q^{U})^{U}$
$(p^{\bot} \vee t^{U} \rightarrow q^{\top})^{U}$	$(p^{\bot} \vee t^{U} \leftrightarrow q^{\top})^{U}$
$(p^{\bot} \vee t^{U} \rightarrow q^{\bot})^{U}$	$(p^{\bot} \vee t^{U} \leftrightarrow q^{\bot})^{U}$
$(p^{\bot} \vee t^{U} \rightarrow q^{U})^{\top}$	$(p^{\bot} \vee t^{U} \leftrightarrow q^{U})^{\top}$

Table 14

$q \nvdash p$, because both logical operators produce counterexamples to $q \vdash p$. For $\rightarrow$ these counterexamples are in the last 6 rows, for $\leftrightarrow$ there are two counterexamples; in row 5 & 8.

MT To be proven: $\neg q \vdash \neg p$
Possible models shown in Table 16. The conclusion for $\rightarrow$: is $\neg q \vdash \neg p$, for $\leftrightarrow$: it is also $\neg q \vdash \neg p$, because both logical operators produce zero counterexamples; every model where $\neg q$ is true, $\neg p$ is true.

Additional Task SLDH-framework For each subtask with operator $\rightarrow$, $\mathcal{P}$: $\{p \wedge r \rightarrow q\}$. For each subtask with operator $\leftrightarrow$, $\mathcal{P}$: $\{p \wedge r \leftrightarrow q\}$.

MP To be proven: $p \nvdash q$ Possible models shown in Table 17. The conclusion for $\rightarrow$: is $p \nvdash q$, for $\leftrightarrow$: it is $p \nvdash q$, because both logical operators produce counterexamples to $p \vdash q$. For both logical operators, the two counterexamples are in row 6 and 10.

DA To be proven: $\neg p \vdash \neg q$ Possible models shown in Table 18. The conclusion for $\rightarrow$: is $\neg p \nvdash \neg q$, because it produces three counterexamples to $\neg p \vdash \neg q$, seen in row 2, 5 and 8. For $\leftrightarrow$: it is $\neg p \vdash \neg q$, because the $\leftrightarrow$ logical operator does not produce any counterexamples.

→:	↔:
$(p^\top \vee t^\top \to q^\top)^\top$	$(p^\top \vee t^\top \leftrightarrow q^\top)^\top$
$(p^\top \vee t^\bot \to q^\top)^\top$	$(p^\top \vee t^\bot \leftrightarrow q^\top)^\top$
$(p^\top \vee t^U \to q^\top)^\top$	$(p^\top \vee t^U \leftrightarrow q^\top)^U$
$(p^\bot \vee t^\top \to q^\top)^\top$	$(p^\bot \vee t^\top \leftrightarrow q^\top)^\top$
$(p^\bot \vee t^\bot \to q^\top)^\top$	$(p^\bot \vee t^\bot \leftrightarrow q^\top)^\bot$
$(p^\bot \vee t^U \to q^\top)^\top$	$(p^\bot \vee t^U \leftrightarrow q^\top)^U$
$(p^U \vee t^\top \to q^\top)^\top$	$(p^U \vee t^\top \leftrightarrow q^\top)^\top$
$(p^U \vee t^\bot \to q^\top)^\top$	$(p^U \vee t^\bot \leftrightarrow q^\top)^U$
$(p^U \vee t^U \to q^\top)^\top$	$(p^U \vee t^U \leftrightarrow q^\top)^U$

Table 15

→:	↔:
$(p^\top \vee t^\top \to q^\bot)^\bot$	$(p^\top \vee t^\top \leftrightarrow q^\bot)^\bot$
$(p^\top \vee t^\bot \to q^\bot)^\bot$	$(p^\top \vee t^\bot \leftrightarrow q^\bot)^\bot$
$(p^\top \vee t^U \to q^\bot)^\bot$	$(p^\top \vee t^U \leftrightarrow q^\bot)^\bot$
$(p^\bot \vee t^\top \to q^\bot)^\bot$	$(p^\bot \vee t^\top \leftrightarrow q^\bot)^\bot$
$(p^\bot \vee t^\bot \to q^\bot)^\top$	$(p^\bot \vee t^\bot \leftrightarrow q^\bot)^\top$
$(p^\bot \vee t^U \to q^\bot)^U$	$(p^\bot \vee t^U \leftrightarrow q^\bot)^U$
$(p^U \vee t^\top \to q^\bot)^\bot$	$(p^U \vee t^\top \leftrightarrow q^\bot)^\bot$
$(p^U \vee t^\bot \to q^\bot)^U$	$(p^U \vee t^\bot \leftrightarrow q^\bot)^U$
$(p^U \vee t^U \to q^\bot)^U$	$(p^U \vee t^U \leftrightarrow q^\bot)^U$

Table 16

$\to$:	$\leftrightarrow$:
$(p^\top \wedge r^\top \to q^\top)^\top$	$(p^\top \wedge r^\top \leftrightarrow q^\top)^\top$
$(p^\top \wedge r^\top \to q^\bot)^\bot$	$(p^\top \wedge r^\top \leftrightarrow q^\bot)^\bot$
$(p^\top \wedge r^\top \to q^U)^U$	$(p^\top \wedge r^\top \leftrightarrow q^U)^U$
$(p^\top \wedge r^\bot \to q^\top)^\top$	$(p^\top \wedge r^\bot \leftrightarrow q^\top)^\bot$
$(p^\top \wedge r^\bot \to q^\bot)^\top$	$(p^\top \wedge r^\bot \leftrightarrow q^\bot)^\top$
$(p^\top \wedge r^\bot \to q^U)^U$	$(p^\top \wedge r^\bot \leftrightarrow q^U)^U$
$(p^\top \wedge r^U \to q^\top)^U$	$(p^\top \wedge r^U \leftrightarrow q^\top)^U$
$(p^\top \wedge r^U \to q^\bot)^U$	$(p^\top \wedge r^U \leftrightarrow q^\bot)^U$
$(p^\top \wedge r^U \to q^U)^\top$	$(p^\top \wedge r^U \leftrightarrow q^U)^\top$

Table 17

$\to$:	$\leftrightarrow$:
$(p^\bot \wedge r^\top \to q^\top)^\top$	$(p^\bot \wedge r^\top \leftrightarrow q^\top)^\bot$
$(p^\bot \wedge r^\top \to q^\bot)^\top$	$(p^\bot \wedge r^\top \leftrightarrow q^\bot)^\top$
$(p^\bot \wedge r^\top \to q^U)^U$	$(p^\bot \wedge r^\top \leftrightarrow q^U)^U$
$(p^\bot \wedge r^\bot \to q^\top)^\top$	$(p^\bot \wedge r^\bot \leftrightarrow q^\top)^\bot$
$(p^\bot \wedge r^\bot \to q^\bot)^\top$	$(p^\bot \wedge r^\bot \leftrightarrow q^\bot)^\top$
$(p^\bot \wedge r^\bot \to q^U)^U$	$(p^\bot \wedge r^\bot \leftrightarrow q^U)^U$
$(p^\bot \wedge r^U \to q^\top)^\top$	$(p^\bot \wedge r^U \leftrightarrow q^\top)^\bot$
$(p^\bot \wedge r^U \to q^\bot)^\top$	$(p^\bot \wedge r^U \leftrightarrow q^\bot)^\top$
$(p^\bot \wedge r^U \to q^U)^U$	$(p^\bot \wedge r^U \leftrightarrow q^U)^U$

Table 18

$\rightarrow$:	$\leftrightarrow$:
$(p^\top \wedge r^\top \rightarrow q^\top)^\top$	$(p^\top \wedge r^\top \leftrightarrow q^\top)^\top$
$(p^\top \wedge r^\bot \rightarrow q^\top)^\top$	$(p^\top \wedge r^\bot \leftrightarrow q^\top)^\bot$
$(p^\top \wedge r^U \rightarrow q^\top)^\top$	$(p^\top \wedge r^U \leftrightarrow q^\top)^U$
$(p^\bot \wedge r^\top \rightarrow q^\top)^\top$	$(p^\bot \wedge r^\top \leftrightarrow q^\top)^\bot$
$(p^\bot \wedge r^\bot \rightarrow q^\top)^\top$	$(p^\bot \wedge r^\bot \leftrightarrow q^\top)^\bot$
$(p^\bot \wedge r^U \rightarrow q^\top)^\top$	$(p^\bot \wedge r^U \leftrightarrow q^\top)^\bot$
$(p^U \wedge r^\top \rightarrow q^\top)^\top$	$(p^U \wedge r^\top \leftrightarrow q^\top)^U$
$(p^U \wedge r^\bot \rightarrow q^\top)^\top$	$(p^U \wedge r^\bot \leftrightarrow q^\top)^\bot$
$(p^U \wedge r^U \rightarrow q^\top)^\top$	$(p^U \wedge r^U \leftrightarrow q^\top)^U$

Table 19

AC To be proven: $q \vdash p$ Possible models shown in Table 19. The conclusion for $\rightarrow$: is $q \nvdash p$, because it produces multiple counterexamples to $q \vdash p$, seen in the last 6 rows. For $\leftrightarrow$: it is $q \vdash p$, because the $\leftrightarrow$ logical operator does not produce any counterexamples.

MT To be proven: $\neg q \nvdash \neg p$ Possible models shown in Table 20. The conclusion for both $\rightarrow$ and $\leftrightarrow$ is $\neg q \nvdash \neg p$, because both logical operators produce a counterexample to $\neg q \vdash \neg p$, seen in row 3.

Additional Task New Model For each subtask with operator $\rightarrow$, $\mathcal{P}$ =$\{r \rightarrow q\}$. For each subtask with operator $\leftrightarrow$, $\mathcal{P}$ =$\{r \leftrightarrow q\}$. What needs to be proven in each subtask, is always a relation between the truth-values of p and q. However, as can be seen by looking at the logical programs above, there is no such relation whatsoever; only r and q occur in the model and can be reasoned about, p does not occur and therefore can't be reasoned about. Thus, all results below are rather simple:

MP To be proven: $p \nvdash q$
For both logical operators, the conclusion is $p \nvdash q$. There exists a model $\mathcal{N}$ where $p \in \mathcal{N}$ but $q \notin \mathcal{N}$, since the program $\mathcal{P}$ contains no information about p that would define a relation between q & p in $\mathcal{N}$.

DA To be proven: $\neg p \vdash \neg q$
For both logical operators, the conclusion is $\neg p \nvdash \neg q$. There exists a model $\mathcal{N}$ where

$\rightarrow$:	$\leftrightarrow$:
$(p^\top \wedge r^\top \rightarrow q^\perp)^\perp$	$(p^\top \wedge r^\top \leftrightarrow q^\perp)^\perp$
$(p^\top \wedge r^\perp \rightarrow q^\perp)^\top$	$(p^\top \wedge r^\perp \leftrightarrow q^\perp)^\top$
$(p^\top \wedge r^U \rightarrow q^\perp)^U$	$(p^\top \wedge r^U \leftrightarrow q^\perp)^U$
$(p^\perp \wedge r^\top \rightarrow q^\perp)^\top$	$(p^\perp \wedge r^\top \leftrightarrow q^\perp)^\top$
$(p^\perp \wedge r^\perp \rightarrow q^\perp)^\top$	$(p^\perp \wedge r^\perp \leftrightarrow q^\perp)^\top$
$(p^\perp \wedge r^U \rightarrow q^\perp)^\top$	$(p^\perp \wedge r^U \leftrightarrow q^\perp)^\top$
$(p^U \wedge r^\top \rightarrow q^\perp)^U$	$(p^U \wedge r^\top \leftrightarrow q^\perp)^U$
$(p^U \wedge r^\perp \rightarrow q^\perp)^\top$	$(p^U \wedge r^\perp \leftrightarrow q^\perp)^\top$
$(p^U \wedge r^U \rightarrow q^\perp)^U$	$(p^U \wedge r^U \leftrightarrow q^\perp)^U$

Table 20

$\neg p \in \mathcal{N}$ but $\neg q \notin \mathcal{N}$, since the program $\mathcal{P}$ contains no information about p that would define a relation between q & p in $\mathcal{N}$.

AC To be proven: $q \vdash p$
For both logical operators, the conclusion is $q \nvdash p$. There exists a model $\mathcal{N}$ where $q \in \mathcal{N}$ but $p \notin \mathcal{N}$, since the program $\mathcal{P}$ contains no information about p that would define a relation between q & p in $\mathcal{N}$.

MT To be proven: $\neg q \nvdash \neg p$
For both logical operators, the conclusion is $\neg p \nvdash \neg q$. There exists a model $\mathcal{N}$ where $\neg p \in \mathcal{N}$ but $\neg q \notin \mathcal{N}$, since the program $\mathcal{P}$ contains no information about p that would define a relation between q & p in $\mathcal{N}$.

Alternative Ways of Reasoning in the Additional Task for the New Model In the paragraph above, what has been used to reason from an interpretation is only the logical program that is created in the reasoning to an interpretation steps; $\{r \leftrightarrow q\}$. However, this is not the only way to do this last reasoning step. In this paragraph, two alternative ways are discussed. These ways create different conclusions less close to the preferred answers by human reasoners, because they make use of different knowledge bases than just the logical program in method I. In the experiment section these alternative methods (II, III) are discussed and researched as well as the method (I) discussed above, but they are expected to be further from how humans actually reason.

II In addition to using the logical program, the commonsense knowledge set ($\mathcal{C} = \{q \rightarrow r\}$) and it's transitive closure with the conditionals ($\mathcal{P}_{Con} = \{p \rightarrow q, r \rightarrow q\}$)is applied. This means that the additional knowledge of $\mathcal{C} \cup \mathcal{P}_{Con} = \{p \rightarrow r\}$ is used during the reasoning steps.
This additional knowledge is not subject to any completion steps, so the question of $\rightarrow$ or $\leftrightarrow$ is not applicable here; this formula always just has the $\rightarrow$ logical operator.
Adding this formula to the reasoning steps means that p and q now do have a relation to each other, so their truth-values are now indeed influenced by each other. It is no longer the case that none of the answers seen in Table 8 (p. 28) can be derived. However, a model now has to satisfy not only $\{r \rightarrow q\}$ (or $\{r \leftrightarrow q\}$), but also $\{p \rightarrow r\}$. Evaluating the possible models that do or do not satisfy this, gives the conclusions for this method seen in Table 21 (p. 37), row 2 and 3.

It is not expected that human reasoners use this approach; transitive closure of multiple knowledge sources seems like an intuitively unlikely method of reasoning, especially if subjects have no previous experience with logical theory. However, the experiment section will still give some attention to this method, if only to make sure it is *not* representative of human reasoning.

III The same intuitive unlikelihood of the previous method applies here. In addition to the logical program, this method also takes into account that human reasoners might apply again the other conditional they were given in the beginning, before all completion steps. In this case, that conditional is $\{p \rightarrow q\}$. Since this is just a conditional, without any of the completion steps, once again the question of $\rightarrow$ or $\leftrightarrow$ does not apply. What is assumed in this method is that the human reasoners reason with the following information: $\{r \rightarrow q\}$ (or $\{r \leftrightarrow q\}$) and $\{p \rightarrow q\}$. Therefore, possible models again need to satisfy both of these statements. Using this approach, the resulting conclusions are again seen in Table 21, now in the last two rows.
Since the questions asked are always about the relation between p and q, there is no difference between a $\rightarrow$ or a $\leftrightarrow$ in the logical program here. The only knowledge that influences the conclusion here is the conditional $\{p \rightarrow q\}$, so as is seen in Table 21 the conclusions for both logical operator are the same.

Since the logical program no longer influences the conclusion, this method inherently assumes that subjects 'forget' the additional information they were given, and only reason with the first conditional they hear. Especially because in this specific task the additional information is rather crucial ('If the library is open, she will study late in the library', which immediately adds the possibility that a library could be closed), it is very unlikely that subjects do not take this into account in their reasoning process. However, this possible method is also taken into account in the experiment.

Due to the reasons described above, these two methods are not discussed further in this section.

II	MP	DA	AC	MT
$\rightarrow$	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
$\leftrightarrow$	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$
III				
$\rightarrow$	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
$\leftrightarrow$	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$

Table 21: Conclusions in the additional task for the New Model using method II or III

Summary The threshold of 50% produces preferred answers as seen in Table 8, but these answers do not correspond with all resulting conclusions from each logical model. In particular, not corresponding results are seen in the Single Task with the AC configuration (with both models, since they produce the same results here), in the Additional Task with the DA and AC configurations (when the logical operator is $\rightarrow$ in the SLDH-framework, and for both logical operators with the New Model). However, as will be seen in the following section, these do correspond to all preferred answers when the threshold is increased to 75% (using Byrne's results. For Dietz et al. a threshold of 65% has the same effect.) If the logical operator is $\leftrightarrow$, the Single DA configuration is inconsistent with the preferred answers. This result cannot be changed by a threshold without influencing all other preferred answers and therefore the coherence of the model results.

The results for the Additional Task all contain a $\nvdash$, which Table 8 does not prescribe as preferred for each subtask. However, as will be seen below, the increase of the threshold to 75% has an effect here as well.

In Table 22, an overview of all results for each subtask is given.

$\rightarrow$	MP	DA	AC	MT
Single	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional SLDH	$p \nvdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$
Additional New Model	$p \nvdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$
$\leftrightarrow$				
Single	$p \vdash q$	$\neg p \vdash \neg q$	$q \vdash p$	$\neg q \nvdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional SLDH	$p \nvdash q$	$\neg p \vdash \neg q$	$q \vdash p$	$\neg q \nvdash \neg p$
Additional New Model	$p \nvdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$

Table 22: Conclusions from all possible models based on the logical programs. Conclusions in red do not correspond with the preferred answers in Table 8.

6.2.2 75%

The possible models, and therefore the conclusions from each subtask as seen in the previous section are not dependant on the threshold; these conclusions are simply the results of evaluating each possible model using logical programs and three-valued semantics. Therefore, it is not necessary to evaluate all possible models again for a different threshold, it is only necessary to evaluate the new preferred results that are produced by this threshold, and whether or not these correspond with the conclusions from the logical models.

As was seen in Table 22, there some inconsistencies between the preferred answers and the model results. These can be reduced impressively by increasing the threshold to 75% if using Byrne's results, and to 65% if using Dietz et al.'s results. The new preferred conclusions are shown in Table 23. It is visible that the preferred conclusions for both Byrne and Dietz et al. are the same when using these two thresholds.

Byrne				
	MP	DA	AC	MT
Single	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional	$p \nvdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$
Dietz et al.				
	MP	DA	AC	MT
Single	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Alternative	$p \vdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \vdash \neg p$
Additional	$p \nvdash q$	$\neg p \nvdash \neg q$	$q \nvdash p$	$\neg q \nvdash \neg p$

Table 23: Preferred answers for a threshold of 75% with Byrne, 65% with Dietz et al.

Comparing Table 23 and 22, it becomes visible that this new threshold produces exactly the same conclusions as the models do when using the logical operator $\rightarrow$ and the New Model's additional task, in stead of that from the SLDH-framework.

6.3 Summary

In the previous chapter, multiple possible models have been evaluated with relation to the preferred answers given by previous experiments, namely those by [Byrne, 1989] and [Dietz et al., 2012]. Two different thresholds have been evaluated, as well as the difference between using logical operator $\rightarrow$ or $\leftrightarrow$, and the difference between the SLDH-framework's additional task and that of the New Model.

Results of these evaluation are that a threshold of 75% for Byrne's and 65% for Dietz et al.'s results produce the preferred answers that are consistent with the conclusion found in the models with two remarks: (1) only for using the logical operator $\rightarrow$ and (2) for the Additional Task only in the New Model.

(1) The logical operator $\rightarrow$ gives a different result than $\leftrightarrow$ in the Single Task DA and AC configurations and in the Additional Task from SLDH DA and AC configurations. The $\leftrightarrow$ is not used as a logical operator in any of the previous experiments, but only as a symbol for the closed-world reasoning that has been

applied. Therefore, the truth-value assignments are still done as if the operator is a single $\rightarrow$. In this section, the truth-assignments for $\leftrightarrow$ were indeed used, only to clarify the effect that this has on the results. As it has been shown, these effects are rather negative; it becomes impossible to create the same conclusions through the logical models, as the preferred answers that humans give.

Thus this evaluation illustrates that using the logical operator $\rightarrow$ is preferred; not only intuitively (because the double arrow should only represent closed-world reasoning), or because previous experiments have done so, but because the results are undesired.

(2) The Additional Task as in the SLDH-framework neither corresponds to the 50% threshold preferred answers, nor to those of the 75% threshold. The Additional Task in the New Model does not produce the same conclusions as prescribed by the 50% threshold, but it does produce the same conclusions as the threshold of 75% prescribes.

The threshold of 50% produces exactly the same preferred answers for Byrne and Dietz et al., and so does the combination of 65% and 75%. There is no other single threshold than the 50% that produces the same answers for both experiments. However, there is not a single threshold whatsoever that gives the same answers for both experiments *and* corresponds with the results from the logical programs. The combination threshold of 75% for Byrne and 65% for Dietz et al. does produce these results for the Additional Task in the New Model. However, for the Additional Task in the SLDH-framework, there is not even such a combination of thresholds that produces the preferred answers such that they correspond with the conclusions from all subtasks (so including the Single and Alternative Tasks).

The evaluation above has shown two different thresholds and the effects they have on producing preferred answers that correspond with model conclusions. It has illustrated a clear distinction between using $\rightarrow$ and $\leftrightarrow$. Finally, it has shown the difference of performance between the SLDH-framework and the New Model, based on the one different result they produce; the conclusion based on the logical program for the additional task.

7 Hypothesis

The hypothesis is that human reasoners tend to reason according to a notion of commonsense knowledge, more than they reason with abnormality predicates. This hypothesis is so far supported by the fact that the New Model got better results using the more successful threshold of 75%.

To test the hypothesis stated above, an experiment needs to be created where the processes that occur during the reasoning for the Suppression Task are made clear. Finding these processes is only possible through verbally going through the reasoning process with subjects, since the inner workings of their reasoning are not easily made visible with any other type of measurement.

Part IV
Experiment

8 Introduction

To test the model that has been defined in the previous part, an experiment similar to that of [Byrne, 1989] needs to be done with human subjects. This experiment needs to clarify whether human subjects indeed reason more in line with the model we have set up using a *Common knowledge*-notion than with the abnormality predicates as seen in the SLDH-framework.

The goal is to clear the fog that surrounds the reasoning steps humans take in the Suppression Task. However, measuring reasoning steps is a strinkingly inconcrete subject. There is not one clear method such as for example eye-movement tracking. Since the reasoning steps are perhaps even more important than the conclusions of the human reasoners, a suitable method of measurement would be to interview subjects in an extensive matter while they are doing the task. The idea is to create a transcript of the interview, where the transcript of each subject is essentially logging them 'thinking aloud', to eventually be used for analysing the behaviour during the task. To create this transcript, subjects are asked to continue speaking during the entire experiment; they are asked to make each reasoning step they take known to the interviewer.

However, this interview is a rather intensive and possibly exhausting experiment for a subject to go through, especially if the entire Suppression Task in it's original form is to be performed. Therefore, the interview experiment should be focussed on some parts of the Suppression Task that ask for more clarification. For this reason, the experiment is divided into two 'sub-experiments'. The first being a classic Suppression Task procedure with simple yes-or-no questions, and the second an interview procedure. These two experiments are described below.

9 Classic Suppression Task experiment

9.1 Introduction

The aim of this experiment is to find any specific notable focus points and guidelines to make the interview experiment more efficient. This experiment also aims to see if the order of questions that are asked make a difference in the way people answer them.

9.2 Methods

9.2.1 Participants

In the study, 80 participants (37 male, 43 female) took part, whom were recruited through opportunity sampling. All were Dutch-speaking students. Participants should not have followed a logic course, therefore they were recruited at the Faculty for Humanities of University Utrecht. All participants signed an informed consent form which stated that they could end their participation at all times, they were given no financial compensation and their data would be anonymous. This consent form can be found in Appendix B. Each subject performed one subtask, so there are 10 subjects per subtask.

9.2.2 Materials and Task

Participants filled out a survey developed with Qualtrics on an iPad. This survey can be found in Appendix A.

The task is the classic Suppression Task [Byrne, 1989]. As a reminder, below are the same subtask describes as in section 1.2.

Modus Ponens (MP) In this subtask, the premises (simple or otherwise), are given in the combination with proposition p: she has an essay to write. The query to be confirmed then is q: she will study late in the library.

Denial of the antecedent (DA) Here, the given information are the premises and the proposition $\neg p$: she does not have an essay to write. The query to be confirmed or denied is then $\neg q$: she will not study late in the library.

Affirmation of the consequent (AC) For this subtask, the premises are combined with proposition q: she will study late in the library. What is then asked of the subjects is to either confirm or deny the validity of concluding p: she has an essay to write.

Modus Tollens (MT) In this subtask, what is given is the premises and the proposition $\neg q$: she will not study late in the library. Subjects are asked about the validity of $\neg p$: she does not have an essay to write.

For each of these subtask, a combination is made of either only a simple conditional (number 1 below), a simple and an alternative conditional (1 & 2 below) or a simple and an additional conditional (1 & 3 below).

1. If she has an essay to write, she will study late in the library.
2. If she has a textbook to read, she will study late in the library.
3. If the library is open, she will study late in the library.

One full task then consists of 4 subtasks, with each 3 possible combinations, so 12 smaller tasks per participant. Since the influence of the order of questions was to be measured, there are two more configurations added to the full task: either combinations in the classic order (1, 1&2, 1&3), or in a new order (1, 1&3, 1&2). However, because this is a very long task and will most likely cause exhaustion in participants and influence results, each participant will perform only 1 of these 8 configurations:

1 Classic order of combinations, MP.

2 New order of combinations, MP.

3 Classic order of combinations, DA.

4 New order of combinations, DA.

5 Classic order of combinations, AC.

6 New order of combinations, AC.

7 Classic order of combinations, MT.

8 New order of combinations, MT.

9.2.3 Design

The study used a 2 by 4 between-subjects design. The first factor was order of questions (classic or new). The second factor was type of subtask (MP, DA, AC or MT). This gave a total of 8 unique task configurations. All conditions were tested on the same day within a 3-hour window. The first 10 participants completed configuration 1, the second 10 participants completed configuration 2 and so on, until all 8 configurations were answered by 10 participants.

9.2.4 Procedure

Participants first sign the consent form. Then the experimenter explains the task and how it is performed. Participants answer yes if they agree with the conclusion and no if they do not agree or if they are not sure. The ambiguity of the 'no' in the literature (see section 4.1, p. 19) is cleared up here immediately; no is the answer for any answer that is not a yes. Participants are given their configuration and answer all questions. In total, the experiment took less than 3 minutes per participant.

9.2.5 Measurements

Measurements are the amounts of yes's and no's the participants have given for each configuration of the experiment. As will be discussed further in the design section below, a yes is used for when a participant is absolutely sure of their agreement with the conclusion. A no is given either if a participant does not agree with the conclusion, or when they do not know for sure. These measurements will be represented in graphs in the result section, both per subtask per order and in total per subtask (so for both orders together).

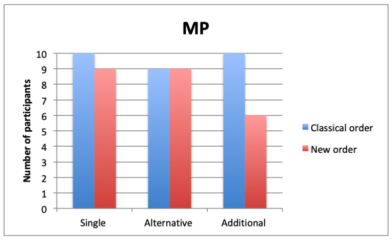
9.3 Results

Figure one shows the results for each subtask. A large difference in the amount of people agreeing with the conclusion of the additional configuration, depending on whether it comes as the third or second question of the task was found in the MP subtask. In the classical order, only one person responded with a 'no', which is close to classical results, whereas in the second order a total of 4 people responded with a 'no'.

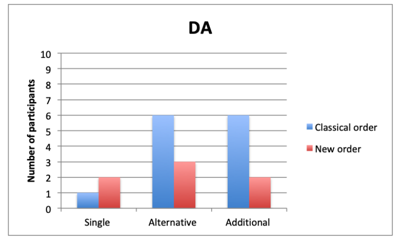
A much larger difference is visible in the DA subtask, where in the classical order people were quite divided between the yes and no answers for both the additional and alternative configuration, in the new order the answers clearly shifted to a lot more 'no' (8 against 10 in the additional task and 7 against 3 in the alternative task).

The AC subtask seems to be the least influenced by this change of question order; the majority still lays at the same side as before, and if anything, participants become less divided and almost always pick 'no'. (In the classical order the additional task scores 7 no's against 3 yes', in the new order this was 9 against 2).

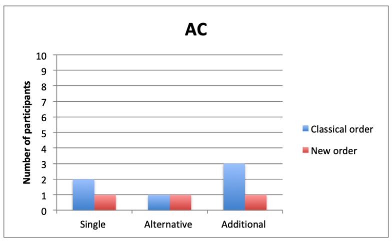
The MT subtask again is very notably affected by this change of configuration order. In the classical task, the majority goes for 'no' in each question, similar to the results in the literature. However, where in the classical order 7 participants chose to answer 'no', in the new order this dropped down to only 4. So, it is no longer a majority that chose the answer that can be found in the literature as a majority answer.



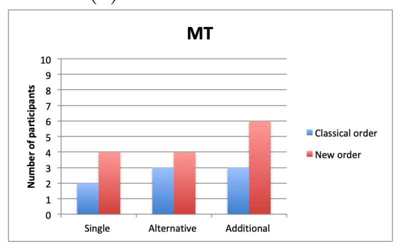
(a) Scores for the MP subtask



(b) Scores for the DA subtask



(c) Scores for the AC subtask



(d) Scores for the MT subtask

Figure 1: Survey scores per subtask

9.3.1 Discussion of Results

The main questions to be answered through the results found in Figure 1 are:

1. Are these results very different from the results in the researched literature? If yes, which factors may have contributed to this?
2. Does the order of combinations have an effect on the given answers?
3. Which results are notable enough so that they could provide new insights if focussed on in the follow-up experiment?

The answer for question 1 is very closely related to that of question 2, which will be the starting point for the evaluation of the results.

These results are evaluated as 'effects from changing the order of configuration', but this experiment most likely has been too small to conclude that this change of order is the definite and single influencer of these results. If the bar shifts up by 2 points, which may seem like a lot on a scale from 1-10, this still only means that just 2 people chose something differently. Therefore, further research on this part is necessary; the first point of interest would be adding the change of order to the interview experiment to see how this affects the reasoning.

This then leaves question 2 answered as well as can be at this point. As was said before, the answers to questions 1 and 2 are closely related. The results in Figure 1 are indeed different from the classical results found in literature on the topic, but part of this can be ascribed to the change of configuration order. It is to be expected that the results for the classical order in this experiment however are very similar to the results from the literature. Therefore it is necessary to evaluate each graph in Figure 1 and compare it to the results in Table 1 (p. 6) and Table 23 (after the evaluation of thresholds) (p. 38).

The first noticeable difference to the literature results in the MP graph is that it was expected that the majority would pick 'no' for the additional subtask. This happens in the new order of configurations, but not in the classical order that was used to get these literature results in the first place. This means that, despite the fact that the change of order has effect on results, something else may have been at play here that makes people decide they do agree with a conclusion, where in the literature participants did not. It would be interesting to see in the follow-up experiment, with new participants, whether these results are found again, and since it is an interview set-up, to discover some reasoning factors that may have influenced these results to become a 'yes' when a 'no' was expected.

This same observation can be made in the graph for the DA subtask. The literature results as seen in table 1 create an expectation for mainly 'no's, especially in the alternative subtask. This is not the case in the classical order, however the alternative configuration's score is much closer to these literature results in the new order. The score for the additional configuration is in the classical order as similar as possible to the literature results, but then in the new order, this shifts totally the other way around: where first they chose 'yes', now the majority leans strongly towards 'no', an unexpected disagreement with the given conclusion.

In the graph for the AC subtask, it is seen that the majority chooses 'no' in each order, and for each configuration. This is not similar to the percentage results in table 1. However, this does correspond to the results for a threshold in table 23. This again shows how the ambiguity of certain results creates gaps to be filled in the research, since there is not just one clear conclusion to be drawn even when there are hard results from a simple survey. Yet again, however, these results may be influenced by other factors apart from the change of configuration order. The experiment being small (in participant amount) could be a large factor that plays in here. These results may however also be given some clarification if researched further in the interview setting.

The percentages given by the literature as results show that a majority would decide to agree with the conclusion (answering with a 'yes') for both the single and alternative configurations in the MT subtask, and disagree in the additional case for the MT subtask. In the graph for this subtask in Figure 1, it can be seen that these results are not found in the survey scores. In stead, in the classical order, the majority chooses 'yes' in each case, so also the additional one. In the new order of configurations, participants suddenly do choose 'yes' with a majority in the additional case only, which is especially the case where it would be expected that the majority would choose 'no'. However, these results may not only be affected by the change of order, the size of the study most likely also again plays a part here.

This counts for the entire survey study; the amount of participants creates a large variability in the graphs since only one person deciding otherwise brings an additional 10% to the results. This, and the change of configuration order are the most important influencers of the results, but apart from this it should be noted that perhaps due to the fact that people only had to answer one subtask and not the entire task could lead to different answers. If a participant has performed multiple subtasks, it may become simpler to reason in a certain way than if a person who generally has not a lot of (semi-)abstract logical reasoning to do suddenly is asked to perform logical reasoning on a selection of premises.

Finally, to answer question 3, the task for the interview experiment would be for each participant to perform one single subtask twice: in the classical order and then in the new order. Talking through the reasoning during this task should shed light on the change in results and how much this is indeed caused by the change in configuration order. This difference in results between orders in Figure 1 is arguably the most notable. Focussing on this by letting participants do the subtask in different orders while explicitly stating their reasoning steps should therefore provide new insights. During this process, all subtasks would be performed again while the reasoning steps are made explicit, so as a byproduct it could become more clear as to why some results differ so much from the results from the literature.

10 Interview Experiment

In this section, the second experiment will be discussed. Firstly by explaining how the experiment will be executed, then by discussing the results. The hypothesis is that these interviews clarify a number of things. First and foremost, this experiment is conducted to research the hypothesis of this entire thesis. Again, this hypothesis is that human reasoners tend to reason according to a notion of commonsense knowledge, more than they reason with abnormality predicates. In Figure 3 it is seen how each part of the experiment plays a role in testing this hypothesis, from most to least important (top to bottom).

Next to this hypothesis that needs to be tested, the previous experiment has brought up some other questions that are to be investigated. Namely why it is that the results differ so much when the order of questions is changed, and, how it is that the results found in this very small study are so different from what is found in the literature.

When this interview experiment has been executed, the results should shed light on the effectiveness of the newly proposed model in Part III. This evaluation will then bring us to the last part of this thesis, being the discussion in Part V.

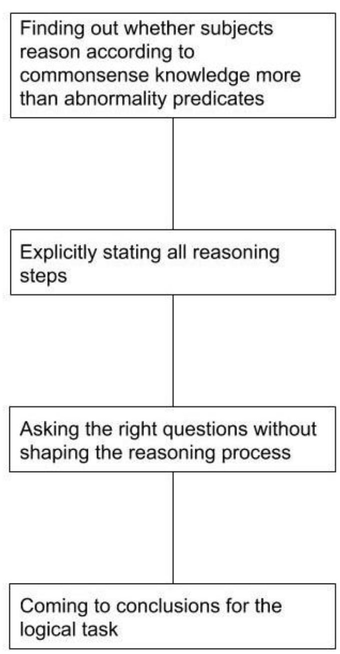


Figure 2: Focuspoints from most to least important for this experiment.

10.1 Methods

10.1.1 Subjects

Subjects are 8 university students (3 male, 5 female) that have never followed a logic course during their studies at university. Since each participant is asked to perform one subtask (in two orders), there will be 2 participants per subtask. Subjects are all between the ages of 18-26 and Dutch-speaking. They signed an informed consent form (Appendix D) explaining that they can stop participating at any moment, their data will be anonymous and they are given no financial compensation for their participation.

10.1.2 Materials and Task

Interviews are recorded by a mobile phone, and the participants are given a sheet of paper which includes all the premisses, conditionals and conclusions they are asked about. These sheets can be found in Appendix C. The task participants are asked to perform is the same as described in section 9.2.2 (p. 41). However, because it is of interest to see what changes the reasoning that participants perform when the order of questions is changed, participants are asked to perform one subtask in two different orders. The experiment starts with the subtask in the new order. Speaking with pilot-experiment participants, who did not take part in the actual experiment, showed that this way participants tend to give more attention to their reasoning in the 'library being open'-combination in both orders. This pilot experiment is discussed more in depth in the design section below. Since all participants perform one subtask in two orders, there are no longer 8, but 4 configurations:

1. New order and classic order of combinations, MP.
2. New order and classic order of combinations, DA.
3. New order and classic order of combinations, AC.
4. New order and classic order of combinations, MT.

10.1.3 Design

This study used a 2 by 4 within-subjects design. The first factor was the order of questions (classic or new). The second factor was the type of subtask (MP, DA, AC or MT). This approach eliminates the between-participants variability. In Appendix C the task sheet can be found that was used during this experiment.

10.1.4 Procedure

Firstly participants signed the informed consent form. The interview starts with explaining the task and how it is performed. Once the participant understands the task and the necessity to continue speaking aloud about their reasoning steps, the task can begin.

Subjects are given a combination of conditionals and asked about the validity of either $q, \neg q, p, \neg p$ (in natural language), depending on the subtask they have been ascribed. This is done for each order of configurations. Firstly in the new order, and then in the classical order. The questions are read aloud by the interviewer, but participants can read the questions on the sheet again if they find this necessary.

The following question was asked in each experiment: 'In what way do the different conditionals (i.e. 'If Mary has to write an essay, she will go to the library', 'If Mary has to read a book, she will go to the library', 'If the library is open, she will go to the library') give you different kinds of information, and how does this difference in the kind of information it gives you influence the way you reason?'. As well as the following:

1. Are you taking any assumptions into account? If yes, what are these assumptions? Are these abnormalities or propositions you always take to be true (commonsense knowledge)?
2. How do these assumptions influence your reasoning and final conclusion?

The total experiment took less than 10 minutes per participant.

10.1.5 Measurements

A transcript is created of each interview, which will be evaluated. These transcripts are found in full in Appendix E. Transcripts are translated in English for the use in section 10.2, but interviews were initially done in Dutch.

10.2 Results and discussion

In this section, the results from the interviews that were part of this experiment will be discussed. The transcribed interviews are visible in full, in Dutch, in appendix E.

The results will first be discussed per subtask, and then some overlapping findings over all subtasks will be discussed. This is because, with the three enumerated questions stated in 10.1.4 in mind, some differences in assumptions were found across all subtasks. The order for discussing these subtasks will again be MP, followed by DA, then AC and finally MT. When all assumption-related results are discussed in detail, the results concerning the order change will be discussed.

10.2.1 Results per subtask

MP The MP subtask was the first to be done in this experiment. As was said before, the participants were first asked the three questions in the new order, and then in the classical order. After the first participant finished all the questions, they were asked if they had taken any assumptions into account while answering the questions. The participant then answered the following:

> S: Nou eigenlijk niet, want het is niet alsof ik een assumptie maak of de bibliotheek open of dicht is. Dat laat ik buiten beschouwing in dit geval. Ja in mijn hoofd zit ik dan gewoon, Marie moet een essay schrijven, en je weet dat ze dan naar de bibliotheek gaat. En dan staat er als extra informatie 'als hij open is gaat ze naar de bibliotheek' maar we weten niet of die op en of dicht is, dus in mijn hoofd zeg ik dan 'Marie gaat naar de bibliotheek om te kijken of die open is. Dus ze gaat hoe dan ook. Dus dat is dan een soort van assumptie. Maar niet per se of de bieb open of dicht is.
>
> *S: Well, not really, because I do not assume whether the library is open or closed. I leave this out in this case. In my head I then think, Mary has to write an essay, and you know that she then goes to the library. And then as extra information, 'if it is open, she goes to the library' but we do not know whether it is open or closed, so in my head I say 'Mary goes to the*

> *library to see whether it is open. So she goes nevertheless. That is a kind of assumption. But not really whether the library is open or closed.*

[Appendix E, p. 2]

The participant had made the assumption that she, Mary in this experiment, would go to the library anyway and then check whether the library was open. This assumption was found in a similar sense with the second participant in the MP subtask. This participant made this assumption already when asked for the first time the question that involves the conditional 'If the library is open, she will go to the library'. When asked if Mary would go to the library, this participant answered:

> S: Eerst gaat Marie kijken of de bibliotheek open is en dan gaat ze beslissen, nou ja, dan gaat ze naar de bibliotheek als die open is. Om haar essay te schrijven.
>
> *S: Firstly Mary will go see if the library is open, and then she will decide, well yes, then she will go to the library if it is open. To write her essay.*

[Appendix E, p. 2]

So for this subtask, both participants, independently from eachother, decided that Mary would go to the library to find out whether it was open. This is noteworthy, because this was found with no other subtask or participant during the experiment, whereas here both participants decided this would be the case.

DA In this subtask, the participants both did not immediately grasp the relevance of the information they were given. Both participants, when they were first asked the question that involved the conditional about the library being open, did not think this had anything to do with the question they were asked (whether Mary would go to the library given she did not have to write an essay). The first participant answered as follows:

> S: Nee, ze gaat niet naar de bibliotheek. Ze heeft daar niets te zoeken want ze gaat geen essay schrijven.
> I: Wat zijn je denkstappen, kun je daar nog iets verder op in gaan.
> S: De stelling is, als ze iets moet doen gaat ze iets doen, maar als ze dat niet hoeft te doen, dan heeft ze ook geen reden om naar de bieb te gaan.
> I: Dus dan houd je in principe geen rekening met de andere stelling die gegeven is?
> S: Dat de bieb open is?
> I: Ja.
> S: Nee daar houd ik geen rekening mee. Dat heeft geen verband met het feit of ze wel of niet een essay moet schrijven. Lijkt mij. Toch? (Leest vraag op task sheet) Oh als de bibliotheek open is gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Ja nu kan je hem dubbel zien. Als in, als de bibliotheek open is gaat ze naar de bibliotheek. Dat hoeft niet per se met een doel te zijn. Maar ik was er in eerste instantie vanuit gegaan dat ze alleen naar de bibliotheek gaat om een essay te schrijven.
>
> *S: No, she will not go to the library, She does not have to be there because she won't write an essay.*

I: What are your reasoning steps, can you elaborate on them.
S: The proposition is, if she has to do something she will do something, but if she does not have to do that, then she also has no reason to go to the library.
I: So you do not take the other given proposition into account?
S: The library being open?
I: Yes.
S: No, I do not take this into account. This has nothing to do with whether or not she has to write an essay. Seems to me. Right? (Reads question on task sheet) Oh, if the library is open she will go to the library. Mary does not have to write an essay. Well now you can see it two ways. In the sense that, if the library is open, she will go to the library. That does not have to be with a goal in mind. But I firstly assumed that she would only go to the library to write an essay.

[Appendix E, p. 4]

A similar situation was found with participant 2. When this participant was asked this same question, they answered:

S: Nee, want ze hoeft geen essay te schrijven, en ze gaat alleen naar de bibliotheek als ze een essay schrijft. (Leest de vraag opnieuw) Oh als de bibliotheek open is gaat ze ook naar de bibliotheek. Dan gaat ze wel naar de bibliotheek.
I: Waarom?
S: Er staat hier, als de bibliotheek open is gaat ze wel naar de bibliotheek. Dus als de bibliotheek open is gaat ze naar de bibliotheek. Dus dan gaat ze naar de bibliotheek. Oh maar er staat niet dat de bibliotheek open is. Dus gaat ze niet naar de bibliotheek, want je weet niet of die open is of niet. Dus dan weet je niet of ze naar de bibliotheek gaat of niet.
S: No, because she does not have to write an essay, and she only goes to the library if she writes an essay. (Rereads question on task sheet) Oh, if the library is open she will also go to the library. Then she does go to the library.
I: Why?
S: It says here, if the library is open she will go to the library. So if the library is open she will go to the library. So she goes to the library. Oh, but it does not say whether the library is open. So she does not go to the library, because you do not know whether it is open or not. So you do not know whether she goes to the library or not.

[Appendix E, p. 5]

Both participants in the first place did not see the necessity or relevance of stating the proposition of the library being open. When they did see this relevance, they did not necessarily become less confused about the question they were asked but instead started to sway more between their answers in the follow-up of the experiment. This process of firstly not seeing any relevance to the information and then seeing the added information as a source of confusion was not found so strongly in any other subtask with both participants. However, this is more a general note than a strong assumption as was found in some other individual subtasks.

AC In this subtask there was again an interesting assumption that was made by both participants. Both participants stated this assumption after they already answered all questions and they were asked whether they had used any assumptions when giving the answers. The first participant answered the following:

> S: Nou bij de laatste bedacht ik me dat de assumptie die ik heb gemaakt is dat, ik ging er van uit dat elk ding los zou zijn. Dat was mijn assumptie.
> I: Dat welke dingen los zijn?
> S: Nou bijvoorbeeld daarna dacht ik, ze zou natuurlijk ook een boek kunnen moeten lezen voor haar essay. Dus dan zijn de assumpties aan elkaar verbonden.
>
> *S: Well, at the last one I realized that the assumption I made was that I assumed that each thing was separate. That was my assumption.*
> *I: That what things were separate?*
> *S: Well for example afterwards I thought that she could obviously also have to read a book for her essay. So then the assumptions are connected.*

[Appendix E, p. 8]

Subject 2 had this same assumption of propositions being connected, for they answered the following:

> S: Ja ik krijg nu wel het idee dat ze misschien alleen maar naar de bibliotheek gaat als ze een essay moet schrijven. Misschien alleen maar een boek moet lezen als ze een essay moet schrijven?
>
> *S: Yes well now I am starting to get the idea that perhaps she would only go to the library to write an essay. And maybe only has to read a book if she has to write an essay?*

[Appendix E, p. 9]

Both participants made the assumption that perhaps Mary would only need to read a book for the essay she has to write. This assumption was made by no other participant in no other subtask. Apart from this assumption, only in this subtask the participants decided that perhaps Mary would have other reasons to go to the library apart from what was stated in the information. With the first question to participant 1, they answered as follows:

> I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
> S: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. En dit keer gaat ze naar de bibliotheek en is de vraag, moet ze een essay schrijven.
> I: Ja.
> S: Hoeft niet per se. Want het een slaat het ander niet uit. Want als ze een essay moet schrijven moet ze naar de bibliotheek, maar ze kan in de bibliotheek ook andere dingen doen.

I: Suppose: If Mary has to write an essay, she will go to the library. Mary goes to the library. Does Mary have to write an essay?
S: If Mary has to write an essay, she will go to the library. And this time she goes to the library and the question is, does she have to write an essay.
I: Yes.
S: Does not have to be the case. Because the one thing does not exclude possibility of the other. Because if she has to write an essay, she has to go to the library, but she can also do other things in the library.

[Appendix E, p. 7]

When participant 2 was asked this question for the second time, so in the classical order, they answered the following:

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee, misschien moet ze een boek lezen. Of nog andere redenen om naar de bibliotheek te gaan die niet genoemd zijn. Zoals, socializing. Of koffie drinken.

I: Suppose: If Mary has to write an essay, she will go to the library. If Mary has to read a book, she will go to the library. Mary goes to the library. Does Mary have to write an essay?
S: No, maybe she has to read a book. Or even other reasons to visit the library that weren't named. Like, socializing. Or to drink coffee.

[Appendix E, p. 9]

So in this case, next to the first assumption of reading books for essays, both participants seemed to suddenly let go of the closed-world reasoning that has been found previously and taken as a given for participants performing this task. They seemed to take their other reasons for visiting a library into account, even when there was no information given that these other reasons were relevant for this task.

MT In this subtask, there was again not one assumption that both participants made. The first participant did make a distinction between 'Mary has to write an essay' and 'Mary will write an essay', but this possible deviance on Mary's side was not found in any other participant in other subtask, so will be seen as an outlier perhaps caused by misunderstanding the task. However, in this task, both participants did both come to the valid conclusion that the library had to be closed because Mary did not visit the library. This valid reasoning according to classical logic was not found in the other subtasks with the other participants; if they did make such valid conclusions they could not retrace their reasoning steps in such a sound way as these participants did during this subtask. Subject 1, when they were first asked the question below, they answered as follows:

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Uh, of ze het moet, dat weten we niet, maar ze gaat het niet doen. Omdat de bibliotheek niet open is, dus ze gaat er niet heen, dus ze gaat

het niet schrijven.
I: Hoe weet je zeker dat de bibliotheek niet open is? Is dat een assumptie die je hebt gemaakt.
S: Ja, want als de bibliotheek open is, dan gaat ze er heen.

I: Suppose: If Mary has to write an essay, she will go to the library. If the library is open, she will go the library. Mary does not go to the library. Does Mary have to write an essay?
S: Uh, whether she has to, we do not know, but she will not do it. Because the library is not open, so she will not go there, so she will not write it.
I: How are you sure that the library is not open? Is this an assumption you have made?
S: Yes, because if the library is open, she will go there.

[Appendix E, p. 11]

When participant 2 was asked this same question for the first time, they answered as follows:

S: Misschien wel, maar hij kan ook dicht zijn. Dan weet ik niet of ze een essay moet schrijven.
I: Dus als de bibliotheek dicht is, weet je niet of ze een essay moet schrijven.
S: Nee.

S: Maybe she does, but it can also be closed. So I do not know whether she has to write an essay.
I: So if the library is closed, you do not know whether she has to write an essay.
S: Indeed.

[Appendix E, p. 13]

These two participants, just like all other participants, had no previous education in logic, however they were very clear on the reasons why they gave their answers. This clear logical reasoning was strongest with them in this subtask, but since their previous knowledge on logic was similar to all other participants, the reason for this clear reasoning might firstly be found in the question itself. It is easy to assume that the subtask itself created the opportunity for participants to not get confused by the additional information they were given, when in other subtasks this was more visibly the case. After these discussions on the individual subtasks, below the overlapping findings over all subtasks will be discussed.

10.2.2 Overlapping results for all subtasks

When looking at the transcribed interviews for all tasks, one thing that continues to come forward is that most participants make the derivation that Mary can not visit the library if it weren't open. This derivation comes in different forms and at different moments during the interview. For example, all participants in the MT and AC subtask made this derivation after finishing the task and when they were asked if there were any assumptions they made during the task. Subject 1, AC:

I: Okee. Zit er verschil in de manier waarop je redeneert met de verschillende dingen die worden gezegd. Dus je hebt eigenlijk als eerste 'als ze een essay moet schrijven moet ze naar de bibliotheek', als tweede, 'als ze een boek moet lezen gaat ze naar de bibliotheek' en als derde, 'als de bibliotheek open is gaat ze naar de bibliotheek'. Zit er verschil tussen die drie voorwaardes?
S: Ja, misschien dat, als hij open is en dat van de essay dat dat misschien eerder met elkaar matcht dan een boek lezen en het essay, want een boek daar heb ik meer associaties met je vrije tijd. En met dat de bibliotheek open is is meer zo van, oh ja, dat moet het zijn, anders kun je niet naar binnen zeg maar. Misschien op die manier.

I: Okay. Is there a difference in the way you reason with the different things that are said. So as a first you have 'if she has to write an essay, she will go to the library', secondly, 'if she has to write a book she will go to the library', and thirdly, 'if the library is open she will go to the library'. Is there a difference between these three propositions?
S: Yes, maybe that, if it is open and that of the essay, those are perhaps more matching than writing a book and the essay, because I associate a book more with leisure time. And that with the library being open is more like, oh yes, it has to be, because otherwise you can't go to the library. Maybe like that.

[Appendix E, p. 8]

Subject 2, AC:

I: En is er dan een verschil tussen de informatie kreeg over het boek lezen of het open zijn van de bibliotheek? Heb je daar andere ideen over?
S: Ja, ik denk dat die een verschillende rol spelen in haar besluitvorming om naar de bibliotheek te gaan. Het ene maakt het mogelijk voor haar om naar de bibliotheek te gaan, namelijk het feit dat de bibliotheek open is. En het ander maakt het een doel voor haar om naar de bibliotheek te gaan. Namelijk, het feit dat ze een essay moet schrijven of een boek moet lezen.

I: And is there a difference between the information you got about reading the book or the library being open? Do you have any thoughts on that?
S: Yes, I think these play a different role in her decision making about visiting the library. One of it makes it possible for her to visit the library, namely the library being open. And the other one makes it a goal to visit the library. Namely, the fact that she has to write an essay or read a book.

[Appendix E, pp. 9-10]

Subject 1, MT:

I: Als je je bedenkt dat het uit zou maken of de bibliotheek open of dicht is, hecht je daar dan bepaalde assumpties aan?
S: Nee. Want in de stelling stond dat als de bibliotheek open is dat ze er dan altijd heen gaat. Dan zou het uitmaken of hij open of dicht was. En als hij open is, dan gaat ze er altijd heen, en als ze in de bibliotheek is, dan moet ze een essay schrijven. Of als ze een essay moet schrijven dan

gaat ze naar de bibliotheek?
I: Ja.
S: Okee, als ze een essay moet schrijven gaat ze naar de bibliotheek. Daar kan ze niet heen als de bibliotheek niet open is, neem ik aan.
I: Dat is een assumptie.
S: Ja dat is een assumptie. Misschien dat ze niet naar de bibliotheek kan als hij dicht is.

I: If you think that it matters whether the library is open or closed, do you attach any assumptions to this?
S: No, because in the proposition it said that if the library is open she will always go there. Then it would matter if the library is closed. And if it is open, she will always visit the library, and if she is in the library, then she has to write an essay. Or if she has to write an essay she will go to the library?
I: Yes.
S: Alright, if she has to write an essay she will go to the library. She can't go there if the library is not open, I assume.
I: That's an assumption.
S: Yes, that's an assumption. Maybe that she can't go to the library if it is closed.

[Appendix E, p. 12]

Subject 2, MT:

I: Zit er verschil in de soort informatie die je daar krijgt? Dus zit er verschil in 'als ze een essay moet schrijven gaat ze naar de bibliotheek', 'als ze een boek moet lezen gaat ze naar de bibliotheek', of 'als de bieb open is gaat ze naar de bibliotheek'. Krijg je daar op een andere manier informatie uit?
S: Die met of hij open is wel.
I: Want?
S: Voordat je, zoals bij de eerste opdracht, je die nog niet hebt gezegd, dacht ik gewoon van nee, en toen je dat eenmaal had gezegd dacht ik elke keer van, nou hij kan ook dicht zijn.
I: Dus is er dan een assumptie die je maakt over de toegankelijkheid van de bibliotheek aan de hand van of hij open of dicht is?
S: (...)
I: Alles wat ik niet vertel en jij wel gebruikt in je redenatie, noem ik een assumptie. Dus als jij zegt, ze gaat alleen naar de bieb dat hij open is..
S: Dan ga ik ervan uit dat hij ook dicht kan zijn, en dat ze dan niet kan gaan.

I: Is there a difference in the kind of information you receive there? So is there a difference in 'if she has to write an essay, she will go to the library', 'if she has to read a book she will go to the library', or 'if the library is open she will go to the library'. Do you receive information in a different way from this?
S: With the one about it being open yes.
I: Because?

> *S: Before, like in the first question, you did not say that, I simply thought no, but once you had said it, every time I realized, well it could also be closed.*
> *I: So is there any assumption you make about the accessibility of the library, based on whether it is open or closed?*
> *S: (...)*
> *I: Anything I do not explicitly say, and you do use in your reasoning process, I call an assumption. So if you say, she only goes to the library if it is open...*
> *S: Then I assume it can also be closed, and that then she cannot go.*

[Appendix E, p. 14]

These four participants, independently from each other made a similar conclusion about how she could not visit a closed library. None of these participants in any case spoke of an abnormality, or irregularity concerning a closed library; they simply (partly subconsciously) realized that, if a library is closed, Mary can not visit is, so therefore it is relevant in my reasoning process.

The participants performing the DA task did not both make this derivation in a similar sense. Subject 1 did not make this derivation at all, but reading the transcript it shows that this participant focussed most of their attention on the essay writing part, and did not take Mary visiting the library if it were open as a very relevant piece of information. One could argue that this participant did this because it was so very clear to them that no one could ever visit a closed library so it was not worth stating, however the interview does not give definitive proof that this was the case. Subject 2 also did not come to a conclusion like the participants above did. Therefore, this might have to do with the shape of the task itself. The DA task eliminates Mary having to write an essay, and therefore also rather implicitly (or most implicitly of all subtasks) states that Mary goes to the library if it is open. Therefore, participants arguably do not feel the need to get any more specific about being able to visit the library, and thus do not state a subconscious assumption about only visiting an open library consciously.

The MP participants did come to a similar conclusion again, but as was already noted in the paragraph on the MP task individually (p. 48-49), these participants do it slightly differently; they expect Mary to go to the library to see whether it is open. Mary has to check this, because if the library is closed, she can't go there.

So except for the DA participants, all participants explicitly state in one way or another the following logical relation in natural language: $\neg r \rightarrow \neg q$, *If the library is closed, she can not visit the library.* They use this as an assumption that they only make explicit when asked about it, which makes this a form of commonsense knowledge; the participants use this knowledge despite not being given it during the task, because it is an assumption they always use. Nothing in their reasoning creates the idea that they might think of a library being closed as an 'abnormality', closed libraries is simply a normality that you have to take into account when trying to visit a library. This logical relation is the logical equivalent of the relation that we expected to be in the set of commonsense knowledge $\mathcal{C} : q \rightarrow r$. This seems to show that indeed, this set is both sufficient and complete for replicating the reasoning process real humans perform while doing this task.

10.2.3 Order change results

In the first experiment there were clear differences between the results for each order of questions per subtask. This experiment was in part designed to shed light on these differences. Previous research done on the effect of question order seemed to confirm this expectation:

> Although question order effects seem to be relatively rare (Smith 1988), they appear to occur most when two questions are asked sequentially on the same topic or very similar topics (Tourangeau, Singer, and Presser 2003).

[Stark et al., 2018, p. 28]

It was expected that because participants were asked the same questions in different order sequentially, they would explicitly state their reasoning, including the differences per order.

One participant that showed this difference in answers and reasoning was participant 1, for subtask DA. The difference was the most visible with this participant, because they explicitly gave different final answers for each order. When they were asked the questions first in the new order, they decided both final questions should be answered with a 'yes':

> I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
> S: Ja want ze gaat een boek lezen. Dus ze gaat naar de bibliotheek. (Leest vraag op task sheet) Oh maar dan zou deze ook ja moeten zijn. Als ze naar de bibliotheek open is gaat ze naar de bibliotheek. Wat grappig. Ja, ze gaat bij de laatste twee dus wel naar de bibliotheek.
>
> *I: Suppose: If Mary has to write an essay, she will go to the library. If Mary has to read a book, she will go to the library. Mary does not have to write an essay. Will Mary go to the library?*
> *S: Yes, because she will read a book. So she will go to the library. (Rereads question on Task Sheet) Oh but then this one should also be yes. If the library is open she will go to the library. How funny. Yes, she will go to the library for the two last questions.*

[Appendix E, p. 4]

However, when asked the same questions in the classical order, they shifted to a 'no' for each question:

> I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Ze moet geen essay schrijven. Gaat Marie naar de bibliotheek?
> S: Ja? Want. He?
> I: Vertel alle stappen in je hoofd die je nu maakt.
> S: Okee. Ik raak helemaal verward nu. Omdat ik nu denk. Nu denk ik. Mag ik hem eens lezen? (Leest vraag op task sheet) Nou ze zegt dat ze

geen essay hoeft te schrijven dus ze gaat niet naar de bibliotheek. Want er staat ook niet bij dat ze wel een boek moet lezen.
I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Dit denk ik dezelfde vraag als vorige keer. En als de bibliotheek open is gaat ze naar de bibliotheek. Ja ze gaat naar de bibliotheek.
I: Want?
S: Geen idee, even kijken. Nee, dit is exact dezelfde vraag. Nee ze gaat niet naar de bibliotheek.

I: Suppose: If Mary has to write an essay, she will go to the library. If Mary has to read a book, she will go to the library. She does not have to write an essay. Will Mary go to the library?
S: Yes? Because? Huh?
I: Tell me all reasoning steps you are now making.
S: Alright. I'm getting confused now. Because now I think. Now I think. Can I read it? (Rereads question on task sheet) Well she says she does not have to write an essay so she won't go to the library. Because it also does not say that she has to read a book.
I: Suppose: If Mary has to write an essay, she will go to the library. If the library is open, she will go to the library. Mary does not have to write an essay. Will Mary go to the library?
S: I believe this is the same question as last time. And if the library is open she will go to the library. Yes, she will go to the library.
I: Because?
S: I do not know, let me see. No, this is exactly the same question. No she will not go to the library.

[Appendix E, pp. 4-5]

However despite this difference in answers, the participant was arguably too confused by their own reasoning to explicitly state any specific reasoning steps they had taken. Therefore there was indeed a similar effect of the order change, but no additional information about where this came from.

No other participant had such a specific difference in their answers per order of questions. The expectation that this order change within the experiment would create different answers with each participant was not met. Some participants stated that because they were asked what they thought were the same questions, they gave the same answers each time. These statements could be an explanation; if participants recognized the questions too easily, they simply gave the same answers without additional reasoning next to what they did the first time. However, since the questions were indeed the same, not additionally reasoning is not necessarily a bad thing. Certainly it means that there is no sufficient evidence found here for explaining the different results in the previous experiment, but the fact that participants stick to their reasoning process made the first time shows a kind of confidence in their own reasoning process. Especially, because the only participant that did not show this confidence in their reasoning process was the one with the largest difference in answers (participant 2 for DA, discussed above). Since this experiment did not shed the expected light on the different answer per order of questions, this will be discussed futher in the open questions section below (section 12).

11 Discussion of both experiments

In the previous two sections the two experiments were discussed. The first experiment was a questionnaire where every participant was asked to do one of the 8 possible configurations; a subtask (MP, DA, AC, MT) in the new or old order of questions. This was done by 80 people and functioned as an indicator for how the second experiment would be most useful. This consisted of interviews done with participants performing one subtask (MP, DA, AC, MT) first in the new, and then in the old order of questions. This experiment was designed to answer a question that could not be answered with the questionnaire: do human reasoners reason according to a notion of commonsense knowledge, more than they reason with abnormality predicates?

The questionnaire experiment produced some unexpected results; the order change in the questions showed to have a large impact on the answers people gave. This is why it was decided to add this order change into the interview experiment as well, so hopefully participants would explain their reasoning steps well enough that if their reasoning would change, they would say so. However, the design of the experiment seemed insufficient to create a situation where participants changed their reasoning according to the question order change. The interviews produced no explanations for this observed result in the questionnaire, because in the interviews most participants remained consistent with their answers in each question order.

The interviews were however successful in other aspects. Participants were asked about the assumptions they had taken into account while answering the questions. Participants reactions showed that none of them did this is the form of 'abnormalities'; their assumptions were mainly in the form of truths or conditionals they assumed to be valid in any situation. These assumptions could therefore be classified as a form of commonsense knowledge. Apart from this, when participants were asked if the separate conditionals gave them different kinds of information, most participants made explicit the assumption that was expected to constitute the relevant commonsense knowledge for this task: 'she can't visit the library if it is not open'.

The design of the interviews therefore proved successful for answering the questions, apart from the order change-question. This design was produced through the analysing of the questionnaire experiment results, which proved that this was sufficient as an indicator for the interview experiment. The way the results from these experiments can be combined with the theory of the newly produced model is one of the topics that will be discussed hereafter, in Part V, the Discussion.

Part V
Discussion

In the first part of this thesis, the Suppression Task experiment as done by Byrne was discussed [Byrne, 1989]. This experiment had as a main result that classical, two-valued logic is not sufficient for explaining the reasoning humans perform while doing a logical task, in this case the Suppression Task. This finding lead to the necessity of creating new models that are more successful in modelling human reasoning. This success is achieved once this model gets the same results as human reasoners do, but should also have an intuitive aspect that makes it easy to recognize for human reasoners.

The start of this model was found in the research done by Stenning & Van Lambalgen [Stenning and Van Lambalgen, 2012, pp. 173-216]. They created a model of reasoning based on the results found by Byrne in the Suppression Task, which proposed that humans reason according to a notion of 'abnormality predicates'. When humans perform a logical task, they evaluate their options using the value of these predicates; conclusions are made based on whether there is anything 'abnormal' in the situation to be evaluated.

Through a formal theory it was shown that this model consisted of two parts; reasoning towards an interpretation and reasoning from an interpretation. With logical programs created using closed-world reasoning and completion (Definition 2.2 on p. 9), the interpretations were constructed. These interpretations were then evaluated using three-valued logic, which resulted in conclusions that should represent the conclusions made by human reasoners.

This model was extended by Dietz et al. by proposing the use of a different three-valued logic [Dietz et al., 2012]. The reasons for this change were the slight differences in the truth assignments for each logic, which can be seen in Table 4 on p. 13. Since this extension seemed to be an improvement, this extended model was then used again by Hölldobler et al. as a starting point for his extension [Hölldobler et al., 2011]. This extension consisted of adding a notion of abduction, which proved to be useful when reasoning with abnormality predicates.

This trio came together as the SLDH-framework; a framework that created a logical model for human reasoning, based on abnormality predicates. This notion of abnormality however, was exactly the seemingly counter-intuitive part of this framework. The expected recognizability that a human reasoner might feel when reading this theory was arguably lacking. Therefore, the main component of this thesis was the New Model, created to be a more intuitive version of the SLDH-framework. The existing framework was modified and simplified; no longer using a notion of abnormality, but in stead a notion of 'commonsense knowledge'. The hypothesis is that humans reason using a set of truths they consider to be valid at all times (commonsense knowledge), more than they do with abnormality predicates.

For the Suppression Task in it's classical form, a specific set of such truths was designed. This set of commonsense knowledge consisted of just one simple but intuitive conditional: 'If she visits the library, the library is open'. This model was first evaluated with the results from Byrne's experiment as to assure that the resulting logical programs were sufficient. Since this was proven successful, the intuition behind the model and the subtle difference with the SLDH-framework were tested in an experiment.

The most crucial aim of this experiment was to find whether humans reason using the commonsense knowledge as proposed in the New Model. The interviews aimed at uncovering the reasoning steps performed by the participants showed that indeed, participants tend to use some kind of commonsense knowledge in their reasoning, in the form of one simple truth they hold on to; you can not visit a library, if it is not open. This condition is the logical equivalent of the only conditional in the specified set of commonsense knowledge; if she visits the library, the library is open. For this reason, the experiment seemed to validate the hypothesis through which the New Model was designed.

12 Conclusion

The intuition which sparked this thesis is justified by the findings in the experiment, which makes the extension and adaptation of the SLDH-framework into the New Model promising. The creation of the New Model and the experiment in it's current form leave a number of open questions and suggestions for future research, which will be discussed now.

13 Open questions/Future research

This last section will focus on the discussion points that are brought forth by this thesis. These open questions and suggestions for future research can be divided into three categories; firstly, some suggestions on research on the model and theoretical aspects. Then something on the experiment and how it could be improved or conducted differently in the future, and finally one open question on the general topic of this thesis; human reasoning in logical tasks.

Theoretical aspects In Section 4.1 (p. 19), the ambiguity of the results of 'successful models' were discussed. Two ways were found to deal with this ambiguity; deciding that answers could be 'yes', 'no', and 'not sure', as well as analysing some possible thresholds later in the thesis (Section 6.2, pp. 26-38). These solutions were created because the ambiguity found in the literature was problematic for further research. Mainly if this future research wanted to be less vague in their results, which was indeed an aim of this thesis. However, this way of dealing with this ambiguity was only one of multiple options and can be solved in different ways that might also be worth researching; other thresholds could be used, as well as another interpretation of the possible answers that participants could give.
In Section 2.1.2 (pp. 8-10), a notion of 'minimal models' is described, as used in S&L. Not all models that are constructed using their method are minimal, however only minimal models are of interest for the step of 'reasoning from an interpretation'. A fixed point operator is used to assure finding the minimal models. This approach is a useful addition in their model, because otherwise too many possible models would have to be evaluated. This step is however not used in the New Model proposed in Part III. This is because adding this step in a useful manner would be too big of a task on top of creating the model, however it is an interesting extension to be evaluated in future research.

On the experiment With the experiment there were some separate aspects that came up. First and foremost, in the first part of the experiment, it became clear that when the Suppression Task is done in the form of a questionnaire, the order of questions makes a big difference in the answers people give. In the literature that was studied, all Suppression Task experiments were done in the form of a one-on-one interview, and nothing was stated about any order changes of any form. In the interview part of the experiment, the order changes did not result in different answers with the participants. Therefore, no in-depth analysis of the different reasoning processes were found for each order of questions. This could however be solved by doing the interview experiment in a different way; in stead of doing the order change during one interview, each interview should consists of one subtask in one order. This would lead to an in-depth evaluation of the reasoning processes used for one order of a subtask, which could then be compared to the other order of the same subtask.

Next to this, it was found in the interview experiments that participants seemed to use their own experiences and knowledge about a specific situation to come to conclusions within the given task. The Suppression Task is designed to analyse the logical reasoning that humans use in such logical tasks, but these results indicate that this logical reasoning is more complicated to analyse individually than expected. The closed-world principle assumed in the literature, as well as in our New Model, might not be as applicable as previously thought. Therefore, separating the logical reasoning part of one's mental processes seems not quite as obvious. This finding (the apparent absence of closed-world reasoning) needs more research in itself before an experiment on the Suppression Task could be designed in such a way that it could deal with this phenomenon.

However, I propose that one way of designing the experiment in a successful way (as to ensure somewhat more closed-world reasoning) is to make the conditionals less recognizable. When students at a university are asked about 'going to the library', they are quick to use their own day to day experience with the matter. If the questions are less recognizable content-wise, it might be easier for participants to separate their own experiences from the logical reasoning necessary for the task, and based on only the given information. I argue that this would still lead to an intuitive set of commonsense knowledge propositions, since these propositions are based on truths participants always believe to be relevant, which would occur even if the information is not about a library.

General Lastly, a general open question and a topic to be further researched is how the models such as the one proposed in this thesis relate to existing theories of mind as found in philosophy. The focus of this thesis, as previously explained, was not on the philosophical part, but more theoretical. However, linking the theoretical (and successful) practical theories with the more abstract theories found in philosophy of mind should lead to a greater understanding of the general notion of reasoning, mind and cognition. Especially when looking at Philosophy of AI, many sceptics of (strong) AI believe that there are some parts of human reasoning that are simply not reproducable in computersystems.

The theory of mind claiming that humans are purely rational reasoners becomes less likely when looking at research on human reasoning in logical tasks alone [Sloman, 1971]. But the fact that a formal model can be created that simulates this reasoning inspires the idea that even the 'irrational' (i.e. not according to classical logical inference) parts of human reasoning could be formalized in a way that computersystems could understand. This has two significant effects for philosophical theories of mind and AI: firstly, if computersystems are capable of performing a recognizable part of human reasoning, another step in the direction of the realization of a strong AI is made, and strong AI as a philosophical theory and vision becomes more plausible. Secondly, if such a computersystem would indeed become more human-like through this reasoning process, this should inspire philosophers of mind to re-evaluate the link between reasoning and rationality in general [Mercier and Sperber, 2011], which is significantly beneficial to developing future theories and technologies within the field of Artificial Intelligence.

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Appendices

A Survey Experiment 1

Enquete

Enquêteflow

Block: Blok 1 (2 Vragen)

Branch: New Branch
If
Als Volgorde 1 is geselecteerd

Branch: New Branch
If
Als Type MP is geselecteerd

Block: Blok 2 (3 Vragen)

Branch: New Branch
If
Als Type DA is geselecteerd

Block: Blok 3 (3 Vragen)

Branch: New Branch
If
Als Type AC is geselecteerd

Block: Blok 4 (3 Vragen)

Branch: New Branch
If
Als Type MT is geselecteerd

Block: Blok 5 (3 Vragen)

Branch: New Branch
If
Als Volgorde 2 is geselecteerd

Branch: New Branch
If
Als Type MP is geselecteerd

Block: Blok 2, volgorde 2 (3 Vragen)

Branch: New Branch
If
Als Type DA is geselecteerd

Block: Blok 3, volgorde 2 (3 Vragen)

Branch: New Branch
If
Als Type AC is geselecteerd

Block: Blok 4, volgorde 2 (3 Vragen)

Branch: New Branch

If

Als Type MT is geselecteerd

Block: Blok 5, volgorde 2 (3 Vragen)

Pagina-einde

Start van blok: Blok 1

Q20 Volgorde

- 1 (1)
- 2 (2)

Q1 Type

- MP (1)
- DA (2)
- AC (3)
- MT (4)

Einde blok: Blok 1

Start van blok: Blok 2

Q4
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

- Ja (1)
- Nee (2)

Q9 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q10 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Einde blok: Blok 2

Start van blok: Blok 3

Q11
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q12 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q13 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Einde blok: Blok 3

Start van blok: Blok 4

Q14
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

○ Ja (1)

○ Nee (2)

Q15 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

○ Ja (1)

○ Nee (2)

Q16 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

○ Ja (1)

○ Nee (2)

Einde blok: Blok 4

Start van blok: Blok 5

Q17
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

○ Ja (1)

○ Nee (2)

Q18 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Q19 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Einde blok: Blok 5

Start van blok: Blok 2, volgorde 2

Q21
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

- Ja (1)
- Nee (2)

Q23 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q22 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Einde blok: Blok 2, volgorde 2

Start van blok: Blok 3, volgorde 2

Q24
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q26 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Q25 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?

○ Ja (1)

○ Nee (2)

Einde blok: Blok 3, volgorde 2

Start van blok: Blok 4, volgorde 2

Q27
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

○ Ja (1)

○ Nee (2)

Q29 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Q28 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Einde blok: Blok 4, volgorde 2

Start van blok: Blok 5, volgorde 2

Q30
Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Q32 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Q31 Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.
Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?

- Ja (1)
- Nee (2)

Einde blok: Blok 5, volgorde 2

B Informed Consent Form Experiment 1

Toestemmingsformulier

Betreft:

Onderzoek naar het logisch redeneren van mensen tijdens het uitvoeren van een logische taak, in de vorm van het beantwoorden van drie logische vragen in een online enquete. Doel van het onderzoek is het verwerven van data voor een master scriptie.

- Ik heb de informatie gelezen. Ik kon vragen stellen. Mijn vragen zijn voldoende beantwoord. Ik had genoeg tijd om over deelname te beslissen.
- Ik weet dat meedoen vrijwillig is en dat ik mijn toestemming kan intrekken op ieder moment van het onderzoek. Daarvoor hoef ik geen reden te geven.
- Ik weet dat als ik mij terugtrek, mijn gegevens tot dat moment gebruikt kunnen worden, tenzij ik ook vraag om de reeds verzamelde gegevens te wissen. Dit kan enkel als het onderzoek daardoor niet wordt geschaad.
- Ik geef toestemming voor het verzamelen, bewaren en gebruiken van mijn gegevens voor de beantwoording van de onderzoeksvraag in dit onderzoek.
- Ik weet dat ik geen vergoeding krijg voor deelname aan dit onderzoek.
- Ik ben op de hoogte van de risico's van deelname aan dit onderzoek.
- Ik weet dat alleen ter controle van de wetenschappelijk integriteit van het onderzoek sommige mensen toegang tot mijn verzamelde gegevens kunnen krijgen.
- Ik kan mijn gegevens inzien en volledige inzage krijgen in de wijze waarop mijn gegevens worden verwerkt en bewaard.
- Ik geef **wel/geen** toestemming om mij na dit onderzoek opnieuw te benaderen voor vervolgonderzoek aansluitend op deze studie.
- Ik heb **wel/geen** logica vakken gevolgd tijdens een universitaire studie. - Ik wil meedoen aan dit onderzoek.

Naam deelnemer:

Handtekening:

Datum:

C Task Sheet Experiment 2

1 MP 1

1.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

1.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

1.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

2 MP 2

2.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

2.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

2.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet een essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

3 DA 1

3.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

3.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

3.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
○ Ja
○ Nee

4 DA 2

4.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
◦ Ja
◦ Nee

4.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
◦ Ja
◦ Nee

4.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
◦ Ja
◦ Nee

5 AC 1

5.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

5.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

5.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

6 AC 2

6.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

6.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

6.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

7 MT 1

7.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

7.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

7.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

8 MT 2

8.1

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

8.2

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

8.3

Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek.

Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
○ Ja
○ Nee

D Informed Consent Form Experiment 2

Toestemmingsformulier

Betreft:

Onderzoek naar het logisch redeneren van mensen tijdens het uitvoeren van een logische taak, in de vorm van het beantwoorden van twee keer drie logische vragen, tijdens welke het verwacht wordt dat de proefpersoon elke denkstap hardop vertelt. Doel van het onderzoek is het verwerven van data voor een master scriptie.

- Ik heb de informatie gelezen. Ik kon vragen stellen. Mijn vragen zijn voldoende beantwoord. Ik had genoeg tijd om over deelname te beslissen.
- Ik weet dat meedoen vrijwillig is en dat ik mijn toestemming kan intrekken op ieder moment van het onderzoek. Daarvoor hoef ik geen reden te geven.
- Ik weet dat als ik mij terugtrek, mijn gegevens tot dat moment gebruikt kunnen worden, tenzij ik ook vraag om de reeds verzamelde gegevens te wissen. Dit kan enkel als het onderzoek daardoor niet wordt geschaad.
- Ik geef toestemming voor het verzamelen, bewaren en gebruiken van mijn gegevens voor de beantwoording van de onderzoeksvraag in dit onderzoek.
- Ik weet dat ik geen vergoeding krijg voor deelname aan dit onderzoek.
- Ik ben op de hoogte van de risico's van deelname aan dit onderzoek.
- Ik weet dat alleen ter controle van de wetenschappelijk integriteit van het onderzoek sommige mensen toegang tot mijn verzamelde gegevens kunnen krijgen.
- Ik kan mijn gegevens inzien en volledige inzage krijgen in de wijze waarop mijn gegevens worden verwerkt en bewaard.
- Ik weet dat dit interview/experiment opgenomen wordt d.m.v. een audiorecorder in een mobiele telefoon.
- Ik geef **wel/geen** toestemming om mij na dit onderzoek opnieuw te benaderen voor vervolgonderzoek aansluitend op deze studie.
- Ik heb **wel/geen** logica vakken gevolgd tijdens een universitaire studie.
- Ik wil meedoen aan dit onderzoek.

Naam deelnemer:

Handtekening:

Datum:

E Transcribed Interviews Experiment 2

1 MP

1.1 Subject 1

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Okee, dus de informatie die ik heb is dat ze als ze een essay moet schrijven naar de bibliotheek gaat. Ze moet nu een essay schrijven, dus het antwoord op de vraag is ja.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Okee, als ze een essay moet schrijven gaat ze naar de bibliotheek. En de voorwaarde, nee, wacht. Als de bibliotheek open is gaat ze naar de bibliotheek. Ze moet een essay schrijven. Nou in dit geval maakt het niet zoveel uit of de bibliotheek open is, want ze moet een essay schrijven en dan gaat ze naar de bibliotheek. Dus ja.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Dit is zoveel onnodige informatie erbij.
I: Waarom?
S: Omdat ze, als ze een essay moet schrijven, naar de bibliotheek gaat. Dus ze gaat sowieso naar de bibliotheek. Dus ja.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Hoe is dit anders dan de eerste vraag? Laat eens zien? (S bekijkt de task sheet) Dit is toch niet anders? Dan ja. Weer.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ik raak erg gefrustreerd omdat ik het idee heb dat het allemaal hetzelfde is. Omdat het de hele tijd gewoon 'als-dan' is. En in dit geval moet ze weer een essay schrijven en dan gaat ze naar de bibliotheek. Dus ja.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Deze vraag heb ik ook al gehad. Nou het zijn twee als dan dingen, maar er staat dat als ze een essay moet schrijven ze naar de bibliotheek gaat. En daarbij is niet echt inbegrepen of die open is ja of nee. En in de vraag zeg je niet of de bibliotheek open of dicht is. Dus eigenlijk kun je niet met zekerheid

een antwoord geven, tenzij je zegt van, als ze een essay schrijft gaat ze sowieso naar de bibliotheek. Dus in dat geval zou het ja zijn. Maar we don't know if it's open or closed. Maar in principe zou ik bij deze vraagstelling ja zeggen. I guess.

I: Zijn er dan bepaalde assumpties die je maakt bij het beantwoorden van deze vraag?
S: Nou eigenlijk niet, want het is niet alsof ik een assumptie maak of de bibliotheek open of dicht is. Dat laat ik buiten beschouwing in dit geval. Ja in mijn hoofd zit ik dan gewoon, Marie moet een essay schrijven, en je weet dat ze dan naar de bibliotheek gaat. En dan staat er als extra informatie 'als hij open is gaat ze naar de bibliotheek' maar we weten niet of die op en of dicht is, dus in mijn hoofd zeg ik dan 'Marie gaat naar de bibliotheek om te kijken of die open is. Dus ze gaat hoe dan ook. Dus dat is dan een soort van assumptie. Maar niet per se of de bieb open of dicht is.
I: Dat ze er ter plekke achter zou komen?
S: Ja.
I: En dat dat dan invloed heeft?
S: Ja, want ze gaat een essay schrijven en ze weet dan van zichzelf 'okee als ik een essay moet schrijven ga ik naar de bieb', dus als je zegt 'als de bibliotheek open is gaat ze naar de bieb' is eigenlijk contrasterend omdat je bij de eerste zin denkt 'ze gaat sowieso naar de bibliotheek' en daarna staat er 'als hij open is gaat ze naar de bibliotheek'. Maar als je dus niet weet of die open of dicht is, zou ik afgaan op die eerste zin en zeggen, ze moet een essay schrijven dus ze gaat sowieso. Dus ik zou hier op ja zeggen.
I: En als er dan later informatie bij komt, zou je je antwoord op basis van die latere informatie aanpassen?
S: Ja.

1.2 Subject 2

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ja.
I: Want?
S: Er is gezegd dat als ze een essay moet schrijven gaat ze naar de bibliotheek. Dus als die opdracht komt gaat ze ook naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Eerst gaat Marie kijken of de bibliotheek open is en dan gaat ze beslissen, nou ja, dan gaat ze naar de bibliotheek als die open is. Om haar essay te schrijven.
I: Maak je daarbij dan bepaalde assumpties als je dit hoort? Zijn er dingen die je al weet?
S: Je gaat ervan uit dat zij sowieso naar de bibliotheek gaat voor haar essay.

Niet ergens anders. Dat is toch een assumptie? Je gaat er ook van uit dat hij op een gegeven moment sluit. Dus dan gaat ze er niet naartoe. En je gaat er ook van uit dat er een bibliotheek is berhaupt.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ja.
I: Want?
S: Of ze een boek moet lezen of niet is onafhankelijk van dat ze haar essay moet schrijven. Dus ze gaat haar essay schrijven in de bibliotheek. Mits er een bibliotheek is. En hij is open. Maar dat is onafhankelijk daarvan volgens mij. Dus ja.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ja, want we gaan ervan uit dat er een bibliotheek is, en dat die open is en dat ze geen boek hoeft te lezen dus vervolgens gaat ze naar de bibliotheek om haar essay te schrijven.
I: Dus nu houd je ook nog rekening met het boek?
S: Ja omdat dat eerder is genoemd, maar niet per se, dat kwam niet voorbij in mijn denkwijze. Het is meer dat ik het wil benoemen omdat ik meer inhoudelijk wil reageren dan alleen maar 'ja'.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ja, want ze moet nog steeds dat essay schrijven. Dat is nog steeds haar taak en het boek staat daar helemaal los van voor zover ik weet.

I: Stel: Als Marie een essay moet schrijven gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet een essay schrijven. Gaat ze naar de bibliotheek?
S: Ja, ze gaat naar de bibliotheek als hij open is en als er dus een bieb is die open is.
I: Zijn er nog bepaalde dingen die in je opkomen als ik de 'als dan' aan je vertel; dus de 'als ze een essay moet schrijven gaat ze naar de bibliotheek' maar ook 'als de bibliotheek open is gaat ze naar de bibliotheek'. Komt er dan een assumptie in je op, of is er iets waar je zelfs voordat ik de vraag stel over na denkt?
S: Niet per se, je gaat er van uit dat die bibliotheek regelmatige openingstijden heeft.

2 DA

2.1 Subject 1

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee, ze gaat niet naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee, ze gaat niet naar de bibliotheek. Ze heeft daar niets te zoeken want ze gaat geen essay schrijven.
I: Wat zijn je denkstappen, kun je daar nog iets verder op in gaan.
S: De stelling is, als ze iets moet doen gaat ze iets doen, maar als ze dat niet hoeft te doen, dan heeft ze ook geen reden om naar de bieb te gaan.
I: Dus dan houd je in principe geen rekening met de andere stelling die gegeven is?
S: Dat de bieb open is?
I: Ja.
S: Nee daar houd ik geen rekening mee. Dat heeft geen verband met het feit of ze wel of niet een essay moet schrijven. Lijkt mij. Toch? (Leest vraag op task sheet) Oh als de bibliotheek open is gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Ja nu kan je hem dubbel zien. Als in, als de bibliotheek open is gaat ze naar de bibliotheek. Dat hoeft niet per se met een doel te zijn. Maar ik was er in eerste instantie vanuit gegaan dat ze alleen naar de bibliotheek gaat om een essay te schrijven.
I: Waarom ga je dan alleen daarvan uit?
S: Weet ik niet eigenlijk.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Ja want ze gaat een boek lezen. Dus ze gaat naar de bibliotheek. (Leest vraag op task sheet) Oh maar dan zou deze ook ja moeten zijn. Als ze naar de bibliotheek open is gaat ze naar de bibliotheek. Wat grappig. Ja, ze gaat bij de laatste twee dus wel naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Ze moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Ja? Want. He?

I: Vertel alle stappen in je hoofd die je nu maakt.
S: Okee. Ik raak helemaal verward nu. Omdat ik nu denk. Nu denk ik. Mag ik hem eens lezen? (Leest vraag op task sheet) Nou ze zegt dat ze geen essay hoeft te schrijven dus ze gaat niet naar de bibliotheek. Want er staat ook niet bij dat ze wel een boek moet lezen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Dit denk ik dezelfde vraag als vorige keer. En als de bibliotheek open is gaat ze naar de bibliotheek. Ja ze gaat naar de bibliotheek.
I: Want?
S: Geen idee, even kijken. Nee, dit is exact dezelfde vraag. Nee ze gaat niet naar de bibliotheek.
I: En waarom ga je nu van ja naar nee?
S: Volgens mij is het hetzelfde als hiervoor. Geen aanleiding waarom ze nu wel zou gaan. Dus daarom denk ik dat het antwoord nee is, want dat denk ik eigenlijk. Kun je hier wat mee?
I: Ja. Bedankt.

2.2 Subject 2

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee, ze gaat niet naar de bibliotheek, want ze hoeft geen essay te schrijven.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat Marie naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee, want ze hoeft geen essay te schrijven, en ze gaat alleen naar de bibliotheek als ze een essay schrijft. (Leest de vraag opnieuw) Oh als de bibliotheek open is gaat ze ook naar de bibliotheek. Dan gaat ze wel naar de bibliotheek.
I: Waarom?
S: Er staat hier, als de bibliotheek open is gaat ze wel naar de bibliotheek. Dus als de bibliotheek open is gaat ze naar de bibliotheek. Dus dan gaat ze naar de bibliotheek. Oh maar er staat niet dat de bibliotheek open is. Dus gaat ze niet naar de bibliotheek, want je weet niet of die open is of niet. Dus dan weet je niet of ze naar de bibliotheek gaat of niet.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nou nee, want er staat ook niet dat ze een boek moet lezen. Want dan zou ze wel naar de bibliotheek gaan. Ze moet geen essay schrijven, dus dan gaat ze niet naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee. Want ze moet geen essay schrijven.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Nee want ze hoeft geen essay te schrijven en je weet ook niet of ze een boek moet lezen, dus ze gaat niet naar de bibliotheek.
I: Dat weet je dan zeker?
S: Dat weet je niet zeker, of ze een boek moet lezen.
I: Maar je weet wel zeker dat ze niet naar de bibliotheek gaat?
S: Met de informatie die je hebt, weet je zeker, eigenlijk vrijwel zeker, dat ze niet naar de bibliotheek gaat.
I: Maak je daar dan bepaalde assumpties?
S: Ja, want dan ga je er ook vanuit dat ze geen boek hoeft te lezen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie moet geen essay schrijven. Gaat Marie naar de bibliotheek?
S: Dat ligt er dus aan of de bibliotheek open is. Als de bibliotheek open is gaat ze wel naar de bibliotheek, als de bibliotheek dicht is niet.
I: Heb je bij deze dan weer bepaalde assumpties die je maakt?
S: Nou ja, je maakt de assumptie of ie open is of niet. Als je die informatie hebt kan je zeggen of ze naar de bibliotheek gaat of niet, maar dat weet je niet.
I: En is er verder iets met de proposities die je gekregen hebt, de 'als dan', brengt dat andere assumpties in je naar boven als je die hoort.
S: Ik had het wel bij de tweede, maar ik had het bij de derde weer door.
I: Wat was het verschil qua assumpties?
S: Ik weet niet meer precies het verschil, maar bij die tweede wist je het meer zeker ofzo dan toen je het de eerste keer zei.
I: Bij de eerste taak bedoel je?
S: Ja.

3 AC

3.1 Subject 1

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. En dit keer gaat ze naar de bibliotheek en is de vraag, moet ze een essay schrijven.
I: Ja.
S: Hoeft niet per se. Want het een slaat het ander niet uit. Want als ze een essay moet schrijven moet ze naar de bibliotheek, maar ze kan in de bibliotheek ook andere dingen doen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Okee als ze een essay moet schrijven gaat ze naar de bibliotheek en als de bibliotheek open is gaat ze naar de bibliotheek, maar dan is het nog steeds niet dat als ze naar de bibliotheek gaat dat optie 1 ook moet uitkomen.
I: Dus dat ze een essay moet schrijven?
S: Ja precies, dus ze hoeft niet per se een essay te schrijven.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Misschien wel, misschien niet. Ja kan wel, hoeft niet. Nu ga ik twijfelen omdat ze alledrie hetzelfde zijn en daardoor zo opbouwend zijn. Dan denk ik, ik heb ergens een fout gemaakt. Het kan niet zo simpel zijn. (Leest vraag opnieuw) Ik zou nog steeds zeggen van ja misschien. Hoeft niet per se.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Zijn dit precies dezelfde vragen nog een keer? Dit is heel naar. Okee. Misschien wel, misschien niet. Maakt niet uit, kan allebei.
I: Okee dus je vindt dat je niet genoeg informatie hebt om de conclusie te trekken.
S: Ja.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Misschien wel, misschien niet, hetzelfde antwoord als de vorige. Eigenlijk heb je niet genoeg informatie, want het kan allebei zijn en het kan ook zijn dat ze voor haar essay een boek moet gaan lezen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als

de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Oh zo. Maar je zou natuurlijk ook nog kunnen denken dat als allebei waar is, dat alleen dan ze naar de bibliotheek gaat. Ik hou het op hetzelfde antwoord, ik ga consistent zijn.

I: Heb je verder, in hoe je deze vraag hebt beantwoord, assumpties gemaakt waar je rekening mee hebt gehouden?
S: Nou bij de laatste bedacht ik me dat de assumptie die ik heb gemaakt is dat, ik ging er van uit dat elk ding los zou zijn. Dat was mijn assumptie.
I: Dat welke dingen los zijn?
S: Nou bijvoorbeeld daarna dacht ik, ze zou natuurlijk ook een boek kunnen moeten lezen voor haar essay. Dus dan zijn de assumpties aan elkaar verbonden. Niet dat het een soort van 'and/or' is maar dat het een 'and' is. Dat had ik me nog niet bedacht.
I: En bij de laatste, met als de bibliotheek open is, heb je daar andere assumpties bij gehouden?
S: Ik denk het niet. Niet wat ik me nu realiseer, maar vast wel want zo werkt je hoofd.
I: Is er iets wat je daar is opgevallen aan de vraagstelling, of iets waarvan je denkt 'dat geeft mij meer informatie, dat geeft mij niet per se heel veel informatie'?
S: Nee niet echt. Want volgens mij zijn dit soort vragen altijd bedoeld met dat je elke kant op kan denken. Dus op het moment dat je meer informatie krijgt denk je alleen maar 'waar ligt het addertje, wat zie ik verkeerd'. Dus misschien is dat ook een soort assumptie, dat je gaat denken dat er iets verborgen ligt.
I: Dat je niet te makkelijk mag denken?
S: Ja.
I: En als je wel makkelijk mag denken, had je dan iets anders gedaan?
S: Dan was het overal waarschijnlijk gewoon, ah essay.
I: Okee. Zit er verschil in de manier waarop je redeneert met de verschillende dingen die worden gezegd. Dus je hebt eigenlijk als eerste 'als ze een essay moet schrijven moet ze naar de bibliotheek', als tweede, 'als ze een boek moet lezen gaat ze naar de bibliotheek' en als derde, 'als de bibliotheek open is gaat ze naar de bibliotheek'. Zit er verschil tussen die drie voorwaardes?
S: Ja, misschien dat, als hij open is en dat van de essay dat dat misschien eerder met elkaar matcht dan een boek lezen en het essay, want een boek daar heb ik meer associaties met je vrije tijd. En met dat de bibliotheek open is is meer zo van, oh ja, dat moet het zijn, anders kun je niet naar binnen zeg maar. Misschien op die manier.

3.2 Subject 2

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Ik denk niet dat dat per se zo hoeft te zijn. Want je kan ook om andere redenen naar de bibliotheek gaan? Ja, dus nee.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee. Om dezelfde reden als net.
I: Om ze ook voor andere redenen naar de bieb zou kunnen gaan.
S: Ja, dat.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Uh, nee, ik denk het niet, want misschien wil ze ook een boek lezen. En ik heb niet het gevoel dat alle informatie die verder wordt gegeven per se relevant is?
I: Waarom zou die niet relevant zijn?
S: Het staat voor mij los van de eerste opmerking. En van de vraag.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee. Ik denk het niet. Omdat, voor mijn gevoel is het heel vaak dezelfde vraag. En daarom geef ik ook telkens hetzelfde antwoord.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee, misschien moet ze een boek lezen. Of nog andere redenen om naar de bibliotheek te gaan die niet genoemd zijn. Zoals, socializing. Of koffie drinken.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee, misschien is de bibliotheek open.
I: Zijn er verder nog assumpties die je gemaakt hebt tijdens het beantwoorden van deze vragen?
S: Ja ik krijg nu wel het idee dat ze misschien alleen maar naar de bibliotheek gaat als ze een essay moet schrijven. Misschien alleen maar een boek moet lezen als ze een essay moet schrijven? Dus ondertussen betwijfel ik ook mijn eerdere antwoorden.
I: Dus je denkt nu dat er een verband zit tussen de informatie die je kreeg, waarvan je eerst dacht dat het niet relevant was?
S: Ja.
I: En is er dan een verschil tussen de informatie kreeg over het boek lezen of het open zijn van de bibliotheek? Heb je daar andere ideen over?
S: Ja, ik denk dat die een verschillende rol spelen in haar besluitvorming om naar de bibliotheek te gaan. Het ene maakt het mogelijk voor haar om naar de bibliotheek te gaan, namelijk het feit dat de bibliotheek open is. En het ander

maakt het een doel voor haar om naar de bibliotheek te gaan. Namelijk, het feit dat ze een essay moet schrijven of een boek moet lezen.

4 MT

4.1 Subject 1

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Het klinkt als een syllogisme. Als ze het gaat schrijven. Dan gaat ze naar de bibliotheek. Dat ze naar de bibliotheek gaat, betekent niet dat ze per se een essay gaat schrijven, noch betekent het dat als ze niet naar de bibliotheek gaat dat ze wel of niet een essay gaat schrijven. Er staat geen 'altijd' in de stelling, dus ik zou zeggen nee, ze gaat niet naar de... Het is onzeker of ze wel of niet een essay gaat schrijven. Het zou best kunnen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Uh, of ze het moet, dat weten we niet, maar ze gaat het niet doen. Omdat de bibliotheek niet open is, dus ze gaat er niet heen, dus ze gaat het niet schrijven.
I: Hoe weet je zeker dat de bibliotheek niet open is? Is dat een assumptie die je hebt gemaakt.
S: Ja, want als de bibliotheek open is, dan gaat ze er heen.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet ze een essay schrijven?
S: Ik ga er nog steeds van uit dat... Het klinkt in deze set-up dat als de bibliotheek open is ze erheen gaat en dat ze of een boek gaat lezen, of niet een boek gaat lezen, of een essay gaat schrijven of niet een essay gaat schrijven. Dus dat ze een van de drie dingen gaat doen. Of eigenlijk vijf dingen. Vier dingen. Of wel een boek lezen en een essay schrijven. Of een essay schrijven maar geen boek lezen. Of een boek lezen en geen essay schrijven. Of geen van beiden. En gezien het feit dat ze niet naar de bibliotheek gaat gaat ze geen van de vier dingen doen. Dus ik zou zeggen nee, ze gaat niet per se een essay schrijven. Kan.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet ze een essay schrijven?
S: Als ze een essay moet schrijven, gaat ze naar de bibliotheek. Als ze geen essay moet schrijven, gaat ze dus niet naar de bibliotheek. Ze gaat niet naar de bibliotheek, dus ze gaat niet een essay schrijven. Of het wel of niet moet, dat weten we niet.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Nog steeds hetzelfde. Ze gaat niet naar de bibliotheek. Als ze naar de bibliotheek zou gaan dan zou ze een essay schrijven of een boek lezen. Of allebei,

of geen van beiden. Dat doet ze niet, maar we weten niet of ze een essay moet schrijven. Of ze het wel of niet gaat doen weten we ook niet.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Ze gaat niet naar de bieb, dus we weten niet of de bieb open is of dicht. We weten ook niet of ze een essay moet schrijven. Hieruit weten we volgens mij ook niet of ze het gaat schrijven. We weten alleen dat ze niet naar de bibliotheek gaat. Het is niet zo dat het uitsluitend is dat ze alleen maar essay schrijft in de bibliotheek.
I: En als we wisten of de bibliotheek wel of niet open zou zijn, op wat voor manier zou dat verschil hebben gemaakt?
S: Geen, want we weten niet of ze een essay gaat schrijven als ze het moet. Of was de vraag of ze het moet doen?
I: Ja.
S: Dus de vraag is of ze het gaat doen.
I: Nee, de vraag is moet ze een essay schrijven. Want als ze een essay moet schrijven gaat ze naar de bibliotheek. Maar ze gaat niet naar de bibliotheek, dus moet ze een essay schrijven?
S: Uh, ze moet een essay schrijven, ze gaat niet naar de bibliotheek. Als ze naar de bibliotheek gaat, moet ze een essay schrijven. Okee, ze moet een essay schrijven als ze naar de bibliotheek gaat. Ze gaat niet naar de bibliotheek. Dan kan ze nog steeds een essay moeten schrijven. En of de bibliotheek open of dicht is, dat doet er dan niet toe.
I: Zijn er verdere assumpties die je hebt gemaakt tijdens het beantwoorden van deze vragen?
S: Nee ik heb geen assumpties gemaakt, ik weet namelijk niet of de bibliotheek open of dicht is. Nou misschien heb ik wel een assumptie gemaakt. Dat weet ik niet helemaal zeker.
I: Als je je bedenkt dat het uit zou maken of de bibliotheek open of dicht is, hecht je daar dan bepaalde assumpties aan.
S: Nee. Want in de stelling stond dat als de bibliotheek open is dat ze er dan altijd heen gaat. Dan zou het uitmaken of hij open of dicht was. En als hij open is, dan gaat ze er altijd heen, en als ze in de bibliotheek is, dan moet ze een essay schrijven. Of als ze een essay moet schrijven dan gaat ze naar de bibliotheek?
I: Ja.
S: Okee, als ze een essay moet schrijven gaat ze naar de bibliotheek. Daar kan ze niet heen als de bibliotheek open is, neem ik aan.
I: Dat is een assumptie.
S: Ja dat is een assumptie. Misschien dat ze niet naar de bibliotheek kan als hij dicht is. Maar ze gaat niet naar de bibliotheek. Dus eigenlijk, of hij open of dicht is, dat doet er niet toe. Dus vandaar, weet ik niet of ze een essay moet schrijven.

4.2 Subject 2

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee.
I: Want?
S: Want anders ging ze naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Misschien wel, maar hij kan ook dicht zijn. Dan weet ik niet of ze een essay moet schrijven.
I: Dus als de bibliotheek dicht is, weet je niet of ze een essay moet schrijven.
S: Nee.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet ze een essay schrijven?
S: (Herleest vraag op task sheet) Dat weten we nog steeds niet want misschien is de bibliotheek dicht.
I: Dus je houdt nu ook nog rekening met de informatie uit de vorige vraag?
S: Ja.
I: En als je alleen maar redeneert met de informatie uit deze vraag?
S: Dan nee.
I: Want?
S: Want ze gaat niet naar de bibliotheek. Dan zou ze een essay moeten schrijven als ze wel naar de bibliotheek ging.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet ze een essay schrijven?
S: Nee. Want anders ging ze naar de bibliotheek. Tenzij die dicht is.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als Marie een boek moet lezen, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee. Tenzij de bibliotheek dicht is. Anders ging ze wel naar de bibliotheek.

I: Stel: Als Marie een essay moet schrijven, gaat ze naar de bibliotheek. Als de bibliotheek open is, gaat ze naar de bibliotheek. Marie gaat niet naar de bibliotheek. Moet Marie een essay schrijven?
S: Nee. Tenzij de bibliotheek dicht is.
I: Zijn er bepaalde assumpties die je hebt gemaakt bij het beantwoorden van deze vragen?
S: Dat ze naar de bibliotheek gaat als die open is en als ze een essay moet maken.

I: Zit er verschil in de soort informatie die je daar krijgt? Dus zit er verschil in 'als ze een essay moet schrijven gaat ze naar de bibliotheek', 'als ze een boek moet lezen gaat ze naar de bibliotheek', of 'als de bieb open is gaat ze naar de bibliotheek'. Krijg je daar op een andere manier informatie uit?
S: Die met of hij open is wel.
I: Want?
S: Voordat je, zoals bij de eerste opdracht, je die nog niet hebt gezegd, dacht ik gewoon van nee, en toen je dat eenmaal had gezegd dacht ik elke keer van, nou hij kan ook dicht zijn.
I: Dus is er dan een assumptie die je maakt over de toegankelijkheid van de bibliotheek aan de hand van of hij open of dicht is?
S: (...)
I: Alles wat ik niet vertel en jij wel gebruikt in je redenatie, noem ik een assumptie. Dus als jij zegt, ze gaat alleen naar de bieb dat hij open is..
S: Dan ga ik ervan uit dat hij ook dicht kan zijn, en dat ze dan niet kan gaan.