# Cognitive Dissonance Model of Conditional Reasoning based on Truth-making

Dingzhou Fei[1], Dong Zhiwen[2]

1 Wuhan University
2 Peking University

Funding: No specific funding was received for this work.
Potential competing interests: No potential competing interests to declare.

## Abstract

Conditional reasoning (If A, Then B) is a lasting topic in the psychology of reasoning. The experimental paradigm for conditional reasoning is a card selection task using logical rules. Although the models of conditional reasoning have achieved great success, there are still puzzles about the training effect (logical training doesn't improve the correct rate for the tasks in people without formal logic background). For example, ordinary people feel confused with the truth table which is the valid formal rule for conditional reasoning after they have been trained for this rule by logicians. Our work contributes these conflicts to the disposition that ordinary people have, that is, truth-making, a process of making every proposition or judgement true or grounded. Most people may perform better in selection tasks in the pre-test (not training) of the card selection task. This paper tries to solve these puzzles with the cognitive dissonance theory by combing them with the truth-maker theory by proposing that conditional reasoning is a continuous truth-seeking process. We then conducted pre-test and post-test and compared the confidence of their own reasoning in two selection tasks, and the purpose is to examine how the truth-makings of people affect conditional reasoning. Experimental results showed that truth-making is an important factor that governs people's ordinary reasoning processes.

**Dingzhou Fei**[1] and **Dong Zhiwen**[2]

[1] *Department of Psychology, Wuhan University*

[2] *School of psychology and cognitive science, Peking University*

**Keywords**: psychology of reasoning; cognitive dissonance; truth making; suppositive reasoning; conditional reasoning.

## Introduction

Human beings are rational animals, as per a prevailing belief among scientists and philosophers. Reasoning is related to decisions, including deductive reasoning and inductive reasoning, plus kinds of heuristics. In this paper, we investigate the deduction by focusing on conditional reasoning (If A, Then B), which has been also studied in the psychology of management, social psychology, and philosophy. In these studies, the samples are ordinary people without training in formal logic. In daily life, when you judge whether the conditional sentence is true or false and you cannot assure the answer, how will you reason? Will they reason according to logic? Will they reason in line with their old knowledge or their experience? In this article, we call “people solve the problems according to their old knowledge or their experience “as suppositive reasoning. When the suppositive reasoning meets conditional reasoning, people without logical training often begin with the truth of A (If A, Then B) by suppositive thinking and reach into the truth of B also by another suppositive thinking (Johnson-Larid, 1999). This process is complicated but can be generalized to truth-making or seeking truth, and these two notions are borrowed from the philosophy of logic (Armstrong, 2004). The truth-making assumes that ordinary people make logical inferences by making the sentences in reasoning true and these sentences should have truth in the real world or imaginative worlds. The reasoners are then truth-makers.

The selection task as an experimental paradigm in the study of the psychology of reasoning consists of four kinds of conditional arguments, each with the same conditional premise, presented in turn. Two are deductively valid; they are Modus Ponens (MP) and Modus Tollens (MT) and the other two are the fallacies of Affirming the Consequent (AC) and Denying the Antecedent (DA). When the four arguments are presented as a whole set, the task is referred to as "the conditional reasoning task". Psychologists often use conditional reasoning tasks to test their models about conditional reasoning. The selection task probably is the most famous of the tasks devoted to the study of human reasoning, especially outside the psychology community. It would be more appropriate to use the plural, for there are two versions of the task, which have only a superficial resemblance. One is thematic and has been investigated mostly in the deontic domain; it will not be discussed for lack of space. The other version is formal; it was invented by Wason (1966) and has intrigued many philosophers and psychologists interested in human rationality. Participants are presented with a picture of four cards. They are instructed that each card has a letter on one side and a number on the other side. Two of the cards show the letter side up and the other two show the number side up, such as: [A] [K] [4] [7]. The question is: "Indicate those cards and only those cards that need to be turned over in order to decide whether the following rule is true: If there is an A on one side, then there is a 4 on the other side". The results doubted against human rationality aroused by the performance on the abstract task.

There are many theories and models for the explanation of the reasoning of conditional sentences. Among them, there are mental logic, mental rule, optimal data simulation, and paradigmatic reasoning schemas. They are divergent in what is critical factors affecting the subject’s selections in the experiments.

(1) the mental rule explored the syntactic approach to actual human deductive reasoning, and was similar to Fodor's language of thought, which acts on semantic representations. The other is the psychology of proof, which selects patterns of natural deductive logic applied to given premises in order to construct the shortest possible 'chain of reasoning' leading to a conclusion. The reasoning process is partly a universal, early-acquired skill, unaffected by language, culture and education, while the other part is an indirect strategy, which is acquired in external settings. It may be influenced by social and psychological factors. Its use requires heuristics to find successful chains of reasoning. The syntactic core has seven

patterns, a set of reasoning patterns that constitute natural deductive logic (in the sense of Gentzen, 1935), such as double negation and MP, which can be applied routinely. The remaining six are submitted to specific constraints; this group contains elimination, introduction, conditional proof, reduction of absurdity, and the following two modes: p; NOT-p / incompatible; p or q; NOT-p and NOT-q / incompatible. In addition, the model provides an evaluation procedure for a given conclusion. The model has been validated (with arguments that do not involve indirect strategies) in a series of experiments using formal materials (Braine & O'Brien, 1998). Its use requires heuristics to find successful chains of reasoning. The model has been evaluated (with arguments that do not involve indirect strategies) in a series of experiments using formal materials (Braine & O'Brien, 1998). The model employs procedural semantics and includes two modes of reasoning involving only if, namely Modus Ponens and the conditional proof mode (Rips,1994).

(MP) Given if p then q and p, we can infer that q, and

(CP) To deduce if p, then ......, one first assumes p; for any proposition q derived from the assumptions of p and other hypothetical information, one can assert that if p, then q. (CP) is in fact a hypothetical reasoning process, as explored in this paper as a truth-oriented conditional reasoning process.

(2) The mental model theory of deduction developed by Johnson-Laird and collaborators (Johnson-Laird, 1999, 2001; Johnson-Laird & Byrne, 1991) is a semantic -- as opposed to syntactic -- theory. Mental models are representations of situations based on the understanding of discourse (in particular, premises) perception or imagination. "Each mental model represents a possibility and its structure and content capture what is common to the different ways in which the possibility might occur" (Johnson-Laird, 1999). Johnson-Laird, & Byrne (2002) (henceforth JL&B) introduce a distinction between a theory of comprehension which relies on models, and a theory of meaning which relies on possibilities. Possibilities can be either factual or counterfactual (ie., false at the time of the utterance). Another distinction concerns the claims made about a situation which can be either factual or modal. To show how the theory functions, we focus on MP and MT. At the elementary level for MP, combining the model of the minor premise [a] with [a c] straightforwardly yields the conclusion C; but for MT, the combination of [¬c] with [a c] yields the null model and no conclusion follows. At the next levels, for MP whatever the interpretation -conditional or biconditional-- the model of the minor premise eliminates the implicit model and the conclusion C follows from the model [a c]. On the contrary, for MT the minor premise not-C results in a model [¬c]; if the reasoner is focused on the model [a c], this suggests again that nothing follows. For MT to be executed correctly, the reasoner must construct the explicit model [¬a ¬c] from which the conclusion not-A follows. The theory explains performance in a similar manner, mutatis mutandis, for AC (but seems to run into difficulty for DA with the conditional interpretation at the intermediate level). We can see in the mental model theory that the mental models of conditionals play a key role in reasoning processes, and the representations of the sentences in the reasoning can guide the reasoners' attention, which is not the key factor in the selection tasks for AC and DA, in fact, the subjects in experiments think with feasibility during the reasoning processes. The human tendency of seeking ground truth for each sentence in the reasoning process may associate with suppositions (Evans, Over, and Handley,2005).

The optimal data good-of-fitting model was presented by Oaksford and Chater (1991; Chater, & Oaksford, 2000). They argued that logic rules are inadequate to account for performance in reasoning tasks because reasoners use their everyday uncertain reasoning strategies, whose nature is probabilistic. This approach applies in a straightforward manner to the conditional reasoning task (Oaksford, Chater, &Larkin, 2000; Oaksford & Chater, 2009a, 2009b). Reasoners are assumed to endorse the conclusion of a conditional argument in direct proportion to the conditional probability of the conclusion given the minor premise. With the following notations: P(A) = a, P(C) = c, and P(not-C/A) = ε, it follows that the probability associated with the major (conditional) premise is 1-ε (ε is called the exception parameter), which also provides the probability of endorsement of MP. The probabilities of endorsement of the other arguments are: DA: P(not-C/not-A) = 1-c-aε / 1-a AC: P(A/C) = a(1- ε) / c MT: P(not-A/not-C) = 1-c-aε / 1-c .To test the model, the authors ran three experiments (two based on frequency distributions of artificial materials and one with everyday life categories and sentences). Thus, the probability of the truth-making for a sentence in conditionals will be correlated with the probability of truth-making with other sentences, and the difficulty of the truth-making will determine the probability of the truth-making.

Cheng and Holyoak (1985) proposed that the conditional rules that produced facilitation effects on the selection task were subclasses of pragmatic reasoning schemas. These are defined as abstract sets of rules that guide people's expectations about probable outcomes in well-defined categories of situations involving classes of goals and conditions to action. These schemas are learned through experience and possibly social transmission, and allow people to make specific inferences about expected outcomes that reflect the social dynamics involved in specific situations. Each specific form of pragmatic reasoning schema leads to a corresponding pattern of deductions. For example, conditional promises such as "if you do P, then I will give you Q" are commonly interpreted in a way that is consistent with the logic of Biconditionals. Thus, people will commonly infer that if Q is given, then P was done and vice versa. In addition, people will infer that if P was not done, then Q was not given and vice versa. The key class of pragmatic schema is referred to as permission rules. These are sets of rules that govern people's expectations of outcomes in situations that describe required preconditions in order to perform a given action, that is, "if you want to do P, then you must satisfy condition Q". A classic example of such a permission rule is the previously cited one that states that in order to drink alcohol, one must be more than 20 years of age. Cheng and Holyoak specifically claimed that the internal logic of permission schemas was identical to the formal logic of if–then conditionals. Thus, selection task problems that are phrased in terms of permission schemas result in a relatively high level of logically correct responses, while problems phrased in terms of different sorts of pragmatic schemas can generate low levels of correct responses since their internal logic is not appropriate. When people completed pure deductive reasoning tasks, this model seems to lack explanatory power for them.

These models have achieved some degree of success and become the mainstream model for studying conditional sentence inference research. The mental rule explains why MP is more accurate than the other three rules, but why the endorsement of MT is so low, it seems that it is not convincing, why human psychology is like this, and there is no in-depth analysis. The mental model needs to construct a psychological representation psychologically on the premise of reasoning, and also has a representation of the reasoning process. The optimal data fitting method can give a satisfactory explanation for the performance of the subjects, but this is based on the entropy, and its corresponding cognitive mechanism remains unresolved. Paradigmatic schemas examine the mechanism of reasoning in rich contexts. However, there are many different abstract reasoning tasks that are difficult to interpret. In fact, the main question of the reasoning of conditional sentences is still: Why does MP have such a high endorsement, and MT is the opposite? Why are AC and DA changing like this?

In this study, we propose a new idea to treat conditional sentence reasoning as a phenomenon caused by a social cognitive disorder. In daily life, people pay attention to the semantics and context of reasoning. This is a kind of judgment and decision-making for the purpose of truth. This is confirmed by many current models. In this study, we propose a new idea to treat the conditional sentence reasoning process as a phenomenon caused by a social cognitive disorder. In daily life, people pay attention to the semantics and context of reasoning. This is a kind of judgment and decision-making activity for the purpose of truth. This is confirmed by many current models. The best occasion for cognitive dissonance is to explain the truth table or inference rules to a group of people who have not touched the logic, and then conduct a selection task experiment. These subjects will choose between the pattern of daily reasoning and the rules of symbolic logic. For all the subjects, the conflicts between two different rules make choices more uncertain. These subjects will choose between the pattern of daily reasoning and the rules of symbolic logic. We attribute the reason for the conflict to the difference in truth-making between logic and everyday reasoning. In a word, people in daily life make reasoning with truth from reality, not from logical truth. But in select tasks, if they have learnt some rules of the truth table in symbolic logic, they will feel conflict and make choices with uncertainty. The purpose of this paper is to test this hypothesis in later experiments. As for the notion of "truth-making", we will describe it in the next section. This study of the social dissonance model based on truth-making can do relatively precise predictions on how to choose the answers in conditional sentence reasoning. The theories include mental logic, mental model, optimal model and pragmatic model. The theories are different from the logic of deductive reasoning.

This paper will arrange as follows: first basics of the truth table in symbolic logic, second the relation between truth-making and cognitive dissonance, experiments and results followed.

### *Social cognitive dissonance theory and truth-making*

We can reasonably assume that when people are not exposed to formal logic rules, their understanding of conditional sentences is truth-oriented and reasoned according to their suppositive patterns. When people come into contact with formal logic rules, their understanding of conditional sentences conflicts with the rules of formal logic. For example, for the follow truth-table in formal logic, obviously, people's understanding of the true value of conditional sentences is different from the formal logic. Except for MP rules, the other three are contrary to people's intuition. Wason's card selection task verified this observation, and later similar selection experiments (especially experiments with training effects) also proved this conclusion. This paper will use cognitive dissonance theory to explain this phenomenon. Cognitive dissonance theory (CDT) suggests that when individuals hold two or more cognitions that are contradictory, they will feel an unpleasant state—dissonance—until they are able to resolve this state by altering their cognitions (Festinger, 1957).

This paper will use cognitive dissonance theory to explain this phenomenon. Cognitive dissonance theory (CDT) suggests that when individuals hold two or more cognitions that are contradictory, they will feel an unpleasant state—dissonance—until they are able to resolve this state by altering their cognitions (Festinger, 1957). This disorder in the experiment shows that the cognitive state is a trade-off, hesitant, and uncertain. We measure the confidence level of the subject's answer to the chosen answer. When the participant is confident in the answer to the choice, usually the corresponding rule for the answer he chooses is MP. However, when he hesitated repeatedly, his choice reflected that the logical rules contradicted his original cognition. When the participant is confident in the answer to the choice, usually the corresponding rule for the answer he chooses is MP. However, when he hesitated repeatedly, his choice reflected that the logic rules contradicted his original cognition. He chooses AC, DA or MT, which can be carried out from his level of confidence and the original conditional truth test of the conditionals, this is, truth-making processing.

The notions of “truth-making” and “truth-makers” (Mulligan, Simons, & Smith, 1984; Restall,1966; Saenz,2018) are lasting and long issues central to many attempts in contemporary philosophy and formal logic to come to grips with the connection between truth and reality. The intuitive motivation for theories of truthmaking is the idea that truth depends on reality: true propositions (or whatever are the primary truth-bearers, e.g., statements, sentences, or beliefs and judgements) are not true in and of themselves but must be made true by reality. According to M.Dummett, a well-known mathematical logician, the truthmaker theory ”expresses one important feature of the concept of truth . . . that a statement is true only if there is something in the world in virtue of which it is true”(Dummett,1959). Ordinary people without formal logic training are still rational in the meaning of adaption to environments and will be subject to this rationality by a commitment to the truth of sentences (Anderson, 1991). We then will be safe to assume that all sentences in the test have the truthmakers, and reasoning agents make efforts to sustain and support the correspondent truth-making processes, or suppositive processes.

If they feel hard to proceed with the truth-making in reasoning, then they fall in trouble of breaking inference and will be confused by this dissonance.

In the selection task experiment, the subject usually deals with the conditional sentence reasoning task in his own unique truthmaking fashions. If he encounters formal logic, not only does he make all the rules of formal logic into the interpretation of truth-making, but the truth in formal logic is also grounded in the reality. Inevitably, cognitive conflicts arise, except for MP rules. The following diagram (Figure. 1) explains this process very well.

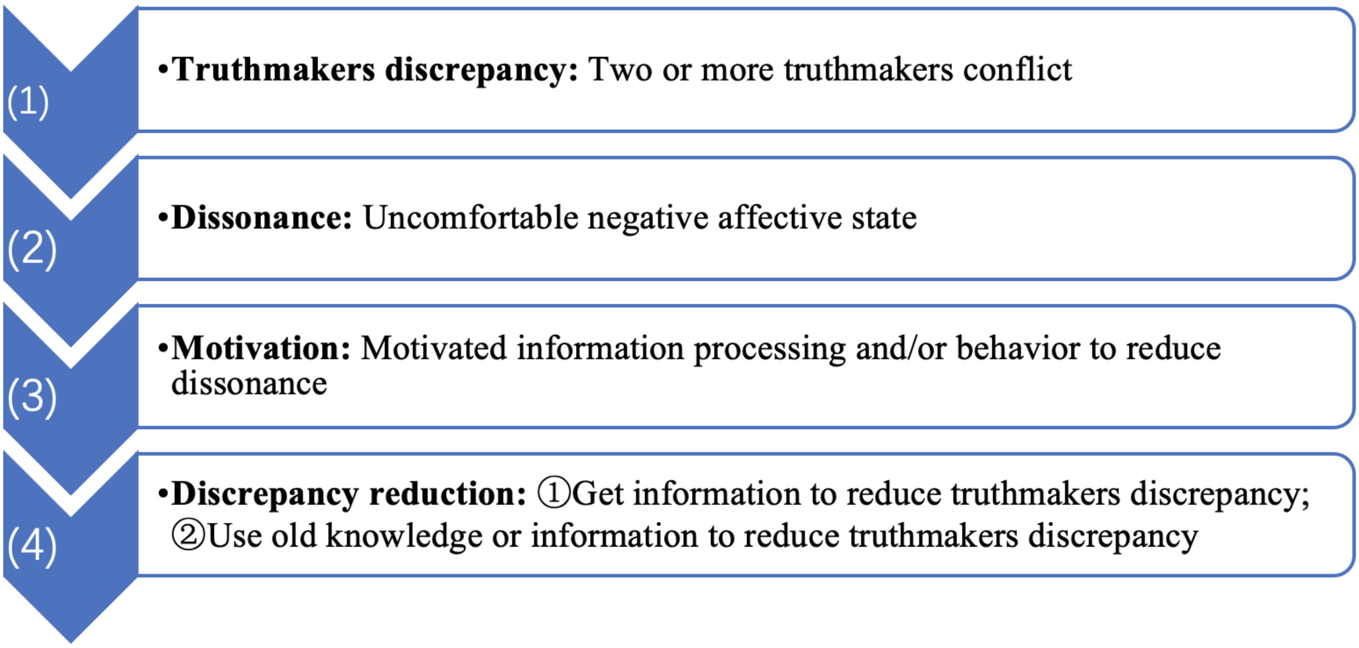



**Figure 1**. *The cognitive dissonance based on truth-making*

### *The study hypotheses*

The study herein investigates the cognitive dissonance model in the reasoning of conditionals. That means that when people cannot judge whether the conditional sentence is true or not, they will be in cognitive dissonance. And the main task of the study is to investigate the dissonances in reasoning through the effect of logical training in conditional sentence reasoning. The following hypotheses will be necessary for tests by comparing the rate of correct and the confidence of subjects in reasoning experiments.

- H1: there is no statistical relationship between suppositive reasoning and deductive reasoning, because people reason with truth-making in a different and independent way with formal logic rules in the conditional reasoning
- H2(truth-making hypothesis): people are not exposed to formal logic rules, their understanding of conditional sentences is truth-oriented and reasoned according to their suppositive patterns,
- H3: When people encounter formal logic rules, their understanding of the truth of conditional sentences conflicts with the rules of formal logic (cognition dissonances)
- H4: Except for MP rules, the other three are contrary to people's intuitions about truth-makings.

Moreover, based on these hypotheses, we can predict that (1) When the subjects' confidence levels of deductive reasoning are greater than that of suppositive reasoning, the task accuracy rate is high. (2) When the subjects' confidence levels of suppositive reasoning are greater than that of deductive reasoning, the error rate is high. (3) When the subjects 'confidence levels of deductive reasoning are equal to that of suppositive reasoning, the error rate tends into high and they will reason in the way of suppositive reasoning. (4) The training effect of deductive reasoning is not significant because of cognitive dissonances.

## Methods

### *Participants*

We recruited 112 undergraduate students in various majors from a national university and 100 observational data (48% male; mean age=19.70, SD=1.60) were valid because 11 students did not complete the questionnaire. 47 students learned science, 40 students learned liberal arts in high school and others did not write their major in high school. In addition, there are 61 students with a major in the humanities and social sciences, 33 in engineering, 3 in management, 1 in science, 1 in medicine, and 1 did not write his major in university. They all don't learn formal logic courses.

### *Procedure and Experimental Materials*

In the experiments of conditional reasoning, there are many traps in designs. If the authentic logic rules (logic books formally express) are directly told to the subjects during the experiments, they often suppose that the rules in the material are the true logical rules, and then may apply these rules without any deliberations in the experiment regardless of the true or false of the conditionals being tested (so that our original experiment design will not work.)

We have noticed that quite a lot of logic major students, in order to pass the logic course, simply apply the truth table rules and directly use formulas and axioms to solve logic problems in conditional sentences without considering truth values, even if they have cognitive discomfort. We tried to avoid this make-up-to effect in our experiments with ordinary people. To this end, we designed two experimental materials, one called strong logic, which told the subjects that these rules must be followed, but did not tell them that these are logic textbook rules (so the subjects were more likely to use it as a reminder than a necessity). The other is called weak logic, giving subjects an example of a familiar conditional sentence, and then explaining it with real logic rules, making them feel that they can do logical reasoning problems without using those rules (the familiarity effect makes them forget the cognitive discomfort temporarily).

Procedure: Participants were randomly assigned to one of the two conditions of the reasoning (strong logic vs. weak logic). Then, they would complete the questionnaire (there are 3 parts in the questionnaire: pre-test, the measurements of confidence levels of the suppositive and deductive reasoning and post-test). Finally, we collected their demographic variables (sex, age, and majors in their high school and university). When the experimental material makes the artificially constructed conditional sentence, the ordinary person adopts the suppositive reasoning strategy

Experimental Materials: Strong deductive logic questionnaire:

The pre-test experimental material is Wason's card selection task (Wason, 1966):

The rule: If there's a vowel on one side, there's an even number on the other.

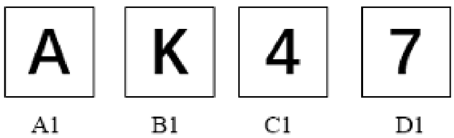



**Figure 2**. *The pre-test material*

Select those cards that you need to turn over to determine whether the rule is true or not.

The measurement of confidence of the suppositive and deductive reasoning: in this part, we did the pre-test and concluded three suppositive reasoning and deductive reasoning. And the reasoning is to express why to choose the answers. There were three types of answers: the first answer is "A", the second is "A" and "4" and the others chose "A", "4" and "7". So, the suppositive reasonings are made according to the results of the pre-test. The strong deductive reasoning material is the rule of deductive logic (truth-table, see Table1). For example, "To test the rule is correct, the logic should be followed: the rule: if p (a vowel on one side), then q (an even number on the other side). To test whether the rule is correct, the following logic should be followed: If p is true and q is true, then the rule is true (MP)." To exclude the other independent variables, we made the reasoning the same in form (see the Appendix).

**Table 1**. Truth-table.

| | p→q | Conditional rule |
|---|---|---|
| **MP** | T→T | T |
| **AC** | T→F | F |
| **DA** | F→T | T |
| **MT** | F→F | T |

The post-test experimental material is made by us. It is like the pre-test:

The rule: If there's a letter on one side, there's a round on the other.

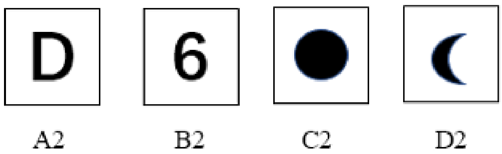



**Figure 3.** *The post-test material*

Select those cards that you need to turn over to determine whether the rule is true or not.

Weak deductive reasoning questionnaire: It is like the strong deductive reasoning questionnaire. And the pre-test, the post-test and suppositive reasonings are the same as the strong deductive reasoning questionnaire. The weak deductive material is a daily example: "If a person is drinking beer, then they must be over 18 years old." (See the Appendix, Griggs, & Cox, 1982).

## Results

All the data were calculated by SPSS Statistic 24.

To identify the relationship between suppositive reasoning and deductive reasoning, we calculated the correlation between them and drew scatter diagrams. The correlation between suppositive reasoning (average scores of three types of suppositive reasoning) and deductive reasoning is not significant: r=0.076, p=0.454. And the scatter diagrams between deductive reasoning and suppositive reasoning present Random distribution in Figure 4. It turns out that there is no statistical relationship between suppositive reasoning and deductive reasoning.

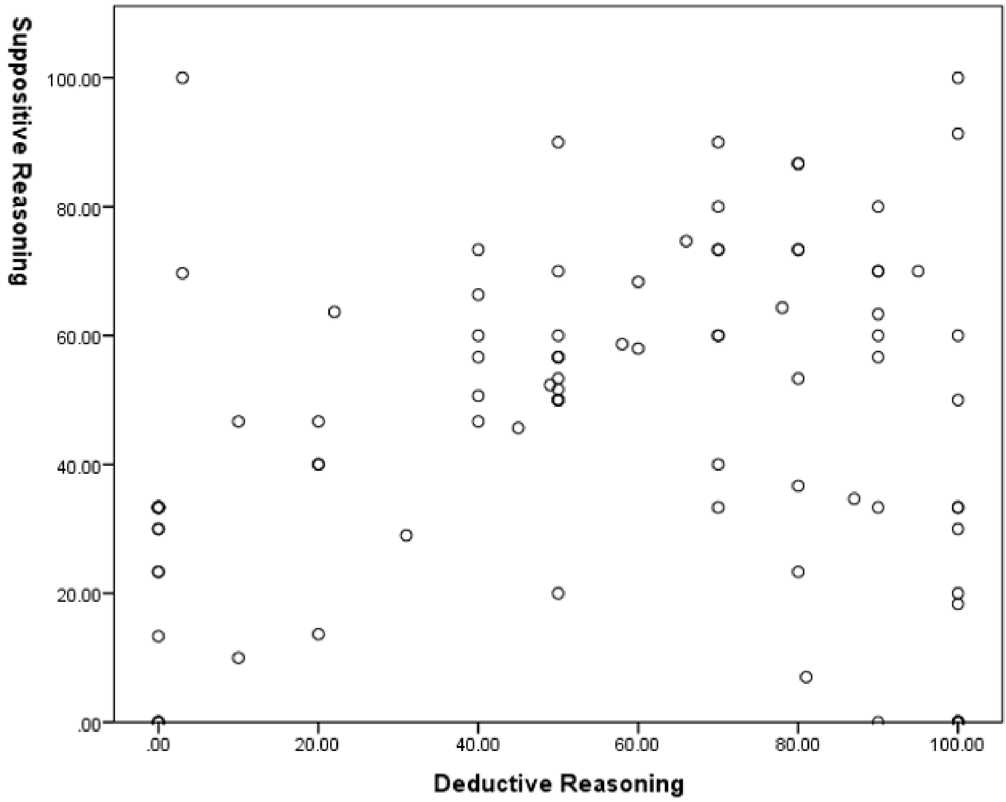



**Figure 4**. *The scatter diagrams of deductive reasoning and suppositive reasoning*

When the confidence of deductive reasoning is greater than that of suppositive reasoning (a total of 44 people), 14 people are correct in the post-test, while 16 people are correct in the pre-test, so the accuracy rate is 14/16(=87.5%). When the confidence of suppositive reasoning is greater than that of deductive reasoning (a total of 45 people), there is only 1 person is correct in the post-test results, so the error rate is 44/45, which is close to 100%. When the confidence of deductive reasoning is equal to that of suppositive reasoning (a total of 11 people), there is only 1 person was correct in the post-test, so the error rate is 10/11, which is also close to 100%.

To identify the training effect of deductive reasoning, we calculated the rate of each option in the pre-test (Figure 5) and the post-test (Figure 6). We can see that in the pre-test, the rate of option A is 94% and the rate of option D is 42%, while in the post-test, the rate of option A is 95% and the rate of option D is 39%: Chi-square: $\chi^2$=0.102, p=0.750. Then the training effect of deductive reasoning is not significant.

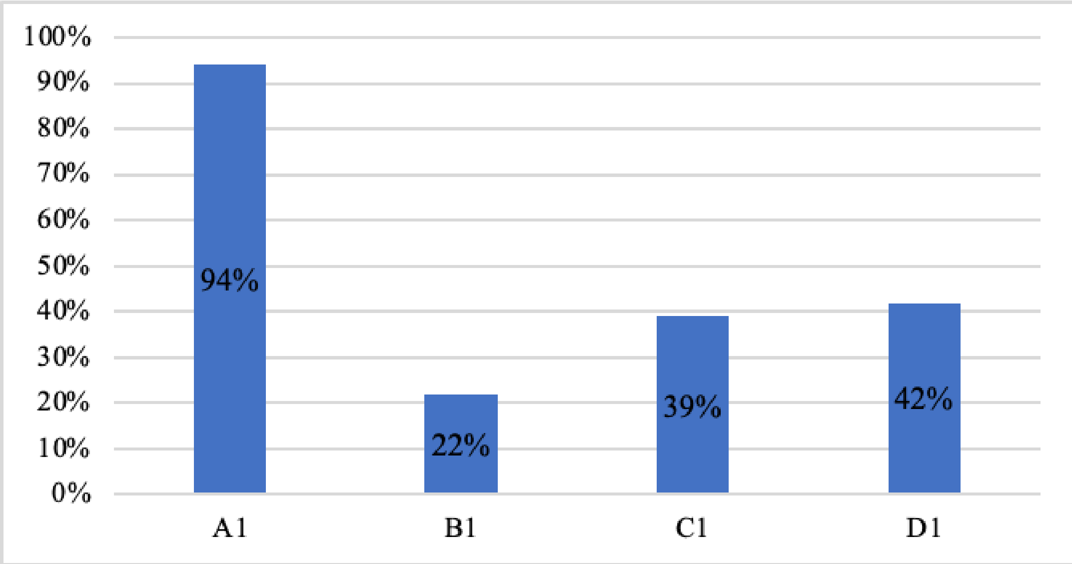



**Figure 5**. *The rate of each option in the pre-test*

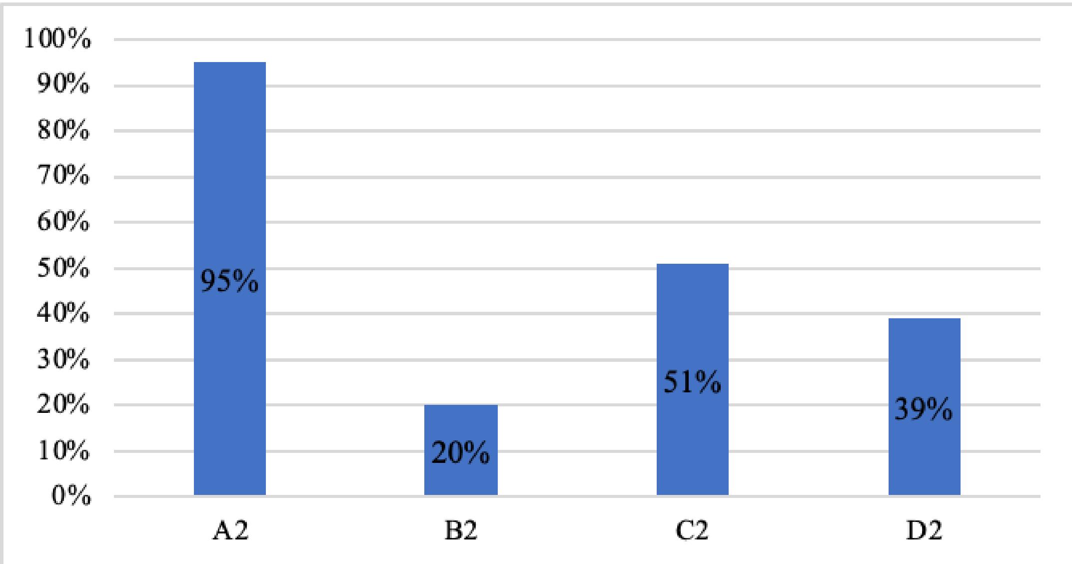



**Figure 6**. *The rate of each option in the post-test*

Regarding correct rates in these experiments, we have similar interpretation strategies. We compared the means of the confidence of the suppositive reasoning and the deductive reasoning (see Table 2), people's confidence in deductive reasoning is significantly greater than the confidence in suppositive reasoning: $t(99)=-2.502$, $p<0.05$. In addition, to identify the training effect of strong deductive reasoning, we listed the number of correct and incorrect answers for both the condition of strong deductive reasoning and weak deductive reasoning, respectively (Table 3). We can see that the numbers of the correct answers in both conditions are not much different: $\chi^2=0.173$, $p=0.687$. So, neither the training of strong deductive reasoning nor weak deductive reasoning works.

**Table 2**. Means comparison between confidence in suppositive reasoning and confidence in deductive reasoning.

| | N | M | SD | t | *p* |
|---|---|---|---|---|---|
| **Suppositive reasoning** | 49 | 46.57 | 37.79 | -2.502 | 0.014 |
| **Deductive reasoning** | 51 | 64.43 | 33.53 | | |

**Table 3**. Number of the correct and incorrect for both the condition of strong deductive reasoning vs. weak deductive reasoning.

| | Correct | Incorrect |
|---|---|---|
| **Strong deductive reasoning** | 7 7.8 | 42 41.2 |
| **Weak deductive reasoning** | 9 8.2 | 42 42.8 |

## Discussions

In this section, we discuss each result and meantime associate them with our study hypotheses, which are based on the cognitive dissonance theory combing with the truthmaker theory, a theory from the philosophy of logic. According to which a proposition is true just in case it corresponds with a fact. The Truth is grounded. Grounding is a relation. Relations link entities. This means that when the content of the conditional sentence exceeds the actual world or the artificial construction example, the subject's truth-making process will break, and he will call what he can imagine to reason (suppositive reasoning). Usually, this process is inevitably cognitive discomfort, and in the selection tasks, we were able to observe the performance of these cognitive discomforts.

The first experimental result is about the relation between two different reasoning: deductive and suppositive. Our claim is that there is no statistical relationship between supportive and deductive reasoning, because people use truth-making in real-world and formal logic rules in conditional reasoning in a different and independent way. The truth-making requires people to put conditionals in the real world and see if they are true or false, but valid reasoning requires people to imagine a truth value for the conditionals even though the conditionals do not have a truth value in the real world. Figure 3 describes the scattering diagram between these two scores of the confidences in suppositive and deductive reasoning, and shows that they distribute There is no obvious correlation between these two methods of reasoning, and the points are irregularly scattered in all directions of the graph, and the correlation coefficient is low (r=0.067). There are many pitfalls in the experimental design of conditional reasoning. If the subjects are directly told during the experiment that the logical rules are formally expressed in the logical textbooks, they usually think that these rules are highly trustworthy while giving lower confidence in their own suppositive reasoning. Our experimental design strives to avoid this situation. Mental logic has a very similar conclusion in this aspect: mental logic supposes that there are very distinct reasoning systems.

Although these two systems (Formal logic vs. mental logic) have the same MP rule, there still are different and independent rules.

We noticed that the participants who had higher confidence in deductive logic were very stable in the pre-test and post-test, and remained basically consistent, while the suppositive reasoning in daily life was very unstable. When the confidence of deductive reasoning is greater than that of reasoning (44 in total), 14 people are correct in the post-test, while 16 people are correct in the pre-test, so the accuracy is 14/16 (=87.5%). When the confidence in reasoning is greater than that of reasoning (45 people in total), only one person in the post-test results is correct, so the error rate is 44/45, close to 100%. This shows that 14 people are aware of the valid deductive rules (the other 34 people do not correctly understand the valid deductive rules). These people accounted for 14% of the total number of participants. A correct understanding of logic can promote people's level of confidence and reduce dissonances. The training effect is not obvious for these people, but is very significant for people with lower confidence in deductive logic.

To analyse the second experimental result (see Figure 5), we first watch the training effect of deductive reasoning. We calculated the ratio of each option in the pre-test (Figure 5) and post-test (Figure 6). We can see that in the pre-test, the ratio of selecting A is 94%, the ratio of selecting D is 42%, and in the post-test, selecting A is 95%, and the ratio of selecting D is 39%: Chi-square: $\chi^2 = 0.102$, $p = 0.750$. Then the training effect of deductive reasoning is not obvious. This shows that our design for avoiding the make-up-to effect is well done. The choice of A is the highest of all choices for the tests, and suggests that the MP rule is not sensitive to truth-making, and does not spark cognitive dissonances in reasoning to almost people. However, the other valid reasoning rule MT (choice D) is as lucky as MP, and the correct rate is much less than 50%. This fact suggests that there is a systematic bias in these subjects in the experiments and maybe people do not tend to understand this rule in unfamiliar occasions, and in familiar cases, because people select D not for logical reasoning, but for suppositive reasoning with truth-making, which does not work in artificial abstract experimental materials in the experiments. The choices of B, C, D are usual as other selection task experiments by psychologists.

Table 2 and Table 3 suggest that although the number of people with a higher level of confidence in deductive logic is slightly dominant, the correct rate has not increased as a result. The reason may be that the participant's understanding of the deductive rules is not correct as they supposed. Their previous knowledge interferes with the correct understanding of these rules. We speculate that this may be because they use suppositive reasoning to understand these rules, because the materials in the experiments are unfamiliar, and they appeal to the familiar materials even though deductive logic has a higher level of confidence. Due to cognition conflicts, they try to imitate suppositive reasoning in familiar scenes, and they are hesitant. According to our hypothesis H1, this case often gets the wrong answer.

Across the study, we found again and again that when people’s confidence in deductive reasoning is equal to that of suppositive reasoning, they tend to reason according to suppositive reasoning. In addition, the training of deductive reasoning (suppositive reasoning vs. deductive reasoning) does not work and there is no statistical relationship between suppositive reasoning and deductive reasoning.

According to the results, we can use cognitive dissonance to describe the way people reason when they can't guarantee the correct answer. This means that when their confidence in deductive reasoning is close to or equal to their confidence in reasoning, their cognition will not appear harmonious, which makes them choose suppositive reasoning. In fact, they use the mechanism of truth-making to reason. In addition, to a certain extent we can use cognitive dissonance to predict how people reason. We can use the theory of truth-makers to discuss why when their minds have cognitive dissonance, people usually reason by reasoning.

Compared with other models of reasoning psychology, cognitive dissonance theory has its obvious advantages: it can find out the cognitive roots of people's errors in conditional sentence reasoning, that is, ordinary people (including college students) without formal logic training understand the rules based on truth values, and these truth values must be grounded on their real experiences. The kind of grounding is different for different individuals, so we can understand the individual difference in people's reasoning performance. The MP rule is an exception because in whatever way we make the sentences true in reasoning processes, people almost do right inference with MP, how to explain this exception is a challenge (Over, & Baratgin, 2017; Politzer, Over, & Baratgin, 2010).

In our study, there are still some important questions that need to be further explored: Is it true that all reasoning requires truth-makers, and whether there is a more reasonable explanation for the relative level of confidence in level of confidence in these two types of reasoning? However, it must be pointed out that our analysis suggests that the understanding of reasoning psychology may be promising from the perspective of social cognition and philosophy. Our work overlaps with other models in reasoning but has better explainable power than them, partially, in predictability in participants' selections.

## Appendix

1. The suppositive reasoning materials:

- To test that the rule is correct, the logic should be followed:
- If one side is a vowel and the other side is an even number, then the rule is true.
- If one side is not a vowel and whatever the number on the back is, then the rule is false.
- If the back is an even number and whatever the letter on the back is, then the rule is false.
- If the back is not an even number and whatever the letter on the back is, then the rule is false.
- So when you turn over A, and only on the other side is an even number, then the rule is true; When you turn over K, and on the other side is an even number or not, then the rule is false; When you turn over 4, and the other side is a vowel or not, then the rule is false; When you turn over 7, and the other side is a vowel or not, then the rule is false.
- So the answer is "A".

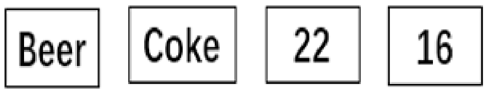
2. The strong deductive reasoning materials:

- To test that the rule is correct, the logic should be followed:
- The rule: if p (a vowel on one side), then q (an even number on the other side)
- To test that the rule is correct, the following logic should be followed:
- If p is true and q is true, then the rule is true.
- If p is true and q is false, then the rule is false.

- If p is false and q is true, then the rule is true.
- If p is false and q is false, then the rule is true.
- So when you turn over A (p is true), and only the other side is an even number, then the rule is true;
- when you turn over K (p is false), and on the other side is an even number or not, then the rule is false; When you turn over 4 (q is true), then the other side is a vowel or not, then the rule is true; When you turn over 7 (q is false), then the other side is a vowel or not, then the rule is true.
- So the answers are "A" and "7".

3. The weak deductive reasoning materials (Griggs & Cox, 1982):

- You can make an analogy with the following example:
- The rule: If a person is drinking beer (If there’s a vowel on one side), then they must be over 18 years old (there’s an even number on the other).




- To test that the rule is correct, the logic should be followed:
- If you turn over the “Beer” and the number on the back is 18 or greater, the rule is true.
- If you turn over the “Coke” and whatever the number on the back is, it cannot prove that the rule is true.
- If you turn over “22”, and whatever the wine on the back is, it cannot prove that the rule is true.
- If you turn over the “16” and the information on the back is not wine, the rule is true.
- So you don’t need to turn over the “Coke” and the “16” and you need to turn over the “Beer” and the “16”. Similarly, the answers are “A” and “7”.

## References


- Anderson, J. R., Is human cognition adaptive? *Behavioral and Brain Sciences,* Vol14 (3), 1991,471 - 485
- Armstrong, D. (2004). Truth and Truth-makers. Cambridge: Cambridge University Press.
- Braine, M. D. S., & O’Brien, D. P. (Eds.), (1998). *Mental logic*. London: Erlbaum.
- Chater, N., & Oaksford, M. (2000). The rational analysis of mind and behavior. *Synthese*, *122*(1-2), 93-131.
- Cheng, P. W., & Holyoak, K. J. (1985). Pragmatic reasoning schemas. *Cognitive psychology*, *17*(4), 391-416.
- Cox, J. R., & Griggs, R. A. (1982). The effects of experience on performance in Wason’s selection task *Memory & Cognition*, *10*(5), 496-502.
- Dummett, M. (1959). Truth. Reprinted in his *Truth and other enigmas*. Cambridge, MA: Harvard University Press.
- Evans, J. S. B. T., Over, D. E., & Handley, S. J. (2005). Suppositions, extensionality, and conditionals: A critique of the

mental model theory of Johnson-Laird and Byrne (2002). *Psychological Review*, 112(4), 1040–1052.

- Festinger, L. (1957). *A Theory of Cognitive Dissonance*. Stanford, CA: Stanford University Press.
- Gentzen, G. . (1935). Untersuchungen über das logische schließen. i. *Mathematische Zeitschrift, 39*(1), 176-210.
- Johnson-Laird, P. N. & Byrne, R.M.J. (1991). *Deduction*. Hove: Erlbaum.
- Johnson-Laird, & P., N. (1999). Deductive reasoning. *Annual Review of Psychology, 50*(1), 109-135. Johnson-Laird, P. N. (2001). Mental models and deduction. *Trends in Cognitive Sciences, 5*(10), 434-442.
- Johnson-laird, P. N. & Byrne, R. M. J. . (2002). Conditionals: a theory of meaning, pragmatics, and inference. *Psychological Review, 109*(4), 646-78.
- Mulligan, K. Simons, P., & Smith, B. (1984). Truth-makers. *Philosophy and Phenomenological Research, 44*(3), 287-321.
- Oaksford, M. & Chater, N. (1991). Against logicism cognitive science. *Mind & Language, 6*(1), 1-38.
- Oaksford, M., & Chater, N. (2009a). Précis of Bayesian rationality: The probabilistic approach to human reasoning. *Behavioral and Brain Sciences*, *32*(1), 69-84.
- Oaksford, M., & Chater, N. (2009b). The uncertain reasoner: Bayes, logic, and rationality. *Behavioral and Brain Sciences*, *32*(1), 105-120.
- Oaksford, M., Chater, N., & Larkin, J. (2000). Probabilities and polarity biases in conditional inference. *Journal of Experimental Psychology Learning Memory & Cognition, 26*(4), 883.
- Over, D. E., & Baratgin, J. (2017). The 'defective' truth table: Its past, present, and future. In N. Galbraith, E. Lucas, & O. D. E., Abingdon (Eds.), *The thinking mind: A Festschrift for Ken Manktelow* (pp. 15–28). London: Wiley.
- Politzer, G., Over, D. E., & Baratgin, J. (2010). Betting on conditionals. *Thinking & Reasoning*, *16*(3), 172-197.
- Restall, K. (1996). Truth-makers, entailment, and necessity. *Australasian Journal of Philosophy, 74*(2), 331-340.
- Rips, L., *The psychology of proof: deductive reasoning in human thinking* MIT Press, Cambridge, MA, 1994
- Saenz, N.B. (2018), An account of truthmaking, Synthese (2020) 197:3413–3435
- https://doi.org/10.1007/s11229-018-1894-5
- Wason, P. C. (1966). Reasoning. In B. M. Foss (Ed.), *New horizons in psychology I* (pp. 106–137). Harmondsworth: Penguin.