Social pragmatic factors in reasoning from disjunctions of numerical estimations

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Abstract

The paper presents two studies that investigated how individuals reason from disjunctive statements that use numerical estimations. In the experiments two types of such statements were used. In the first type both constituents of a disjunction could be a logically correct answer. That is, if "The average life time of a fruit fly is either 9 or 27 days", any of those numbers is logically possible. In the second type that truth of one constituent excluded the truth of the other, e.g. "The average time of holidays in the EU is either higher than 9 days or else higher than 27 days". A simple repetition of any of those figures is an illusory inference as it renders both constituents true. The results of Experiment 1 proved that although the participants showed a tendency to repeat one of the disjuncts as their answer, this tendency was smaller when the content of the statements referred to politics and social life in comparison with the general knowledge questions. The results of Experiment 2 showed that individuals reveal the tendency to repeat opinions coming from speakers who are more likeable, even if such opinions are incorrect illusory inferences. The results of both studies show that illusory inferences appear also in the domain of numerical cognition but they may be reduced by pragmatic factors such as the content of the message and the knowledge about its source.

Keywords: reasoning, mental models, persuasion, illusory inferences, social pragmatics

Introduction

Imagine that you heard the following statements from two different politicians:

Politician A: The average number of holiday days in The European Union is lower than 19 days.

Politician B: The average number of holiday days in The European Union is lower than 32 days.

How would you answer a question about the average number of holiday days in the EU, if you were informed that one of the above statements is definitely true and the other is definitely false? If both politicians are equally likely to be speaking the truth, it seems quite reasonable to expect one of their statements to be the correct answer. However, assuming that both options are equally possible would be a logical mistake as the truth of one of them excludes the truth of the other. Therefore, the correct estimate of the number of holiday days in the EU must lie between 19 and 32 days, which comes from the fact that the statement of politician A is false and the statement of politician B is true. This is the only possible answer because an assumption that the statement of politician B is false leads to a contradiction, i.e. the average holiday time is both lower than 19 days and higher than 32 days.

Mental models and the principle of truth

When two statements are presented in the form of a disjunction, one has to represent the fact that if one of them is true, then the other must be false. But naïve individuals seldom do this, as they typically represent only what is true at the expense of what is false. Forgetting about false possibilities is one of the principles of the theory of mental models (the model theory for short, Johnson–Laird, 2007).

The basic assumption of the model theory is that mental representations are iconic and they represent different possibilities as different mental models. Specifically, models represent what is common in all "possible worlds" when a certain type of relation holds. Therefore, the structure of models corresponds to the structure of what they represent (Johnson-Laird, 2006). The same objects may be represented by different types of mental models depending on the relation that was made salient in a given context. For example, if one is informed that the average life of a common fruit fly is three times longer than 9 days, he or she will understand this expression as a multiplication problem and will know that the correct answer is 27, even though an experimenter has not yet started to ask any questions. On the other hand, if a participant of a psychological study was informed that:

> The average life of a fruit fly is either shorter than 9 days or else it is shorter than 27 days.

he or she might see this expression as a disjunction of two possibilities, and represent them as two separate mental models:

shorter than 9 days

shorter than 27 days

As none of those mental models represent false cases (i.e. not shorter than 27 days in the first model and not shorter than 9 days in the second model), the model theory predicts that individuals without training in logic should see both possibilities as equally probable. But choosing any of them as the correct answer is a so-called illusory inference as shorter than 9 means also shorter than 27 and shorter than 27 does not exclude it being shorter than 9.

The model theory predicts such illusory inferences in all those reasoning tasks when models fail to represent what is false (e.g. Johnson-Laird & Savary, 1999). Such illusory inferences have been proved to exist in different domains of the study of reasoning, e.g. conditionals (Barrouillet & Lecas, 2000), probabilistic reasoning (Johnson-Laird & Savary, 1996), quantified reasoning (Yang & Johnson-Laird, 2000), and relations (Mackiewicz & Johnson-Laird, 2012). All those studies prove that illusory inferences are quite compelling and in some of them all the participants succumb to drawing erroneous conclusions.

Pragmatic modulations of reasoning process

Some researchers have tried to find antidotes to illusory inferences. The typical experimental manipulation in such studies provides some of the participants with an opportunity to learn how to falsify certain premises. For example, in the study of Newsome and Johnson-Laird (2006) the participants were explicitly asked to find conditions that make different statements false. Another method is to make the distinctive character of two premises more visible. Santamaria and Johnson-Laird (2000) used this type of manipulation by informing the participants that they should treat different pieces of information as different physical objects; in this case it was different advertisements cut from a newspaper. All such manipulations are semantic in nature as they aid the process of constructing fully explicit models.

The process of reasoning can be also modulated in a pragmatic way (Johnson-Laird & Byrne, 2002). That is, general knowledge in the long-term memory or some information available from the context may help in forming the expanded representation of a problem (Sperber & Wilson, 1995). In such a case reasoners may go beyond the logical form of the premises presented to them. For example, if you are informed that

> The average time required to fulfill legal requirements necessary to open a new company is *less* than 9 days or else it is *less* than 27 days.

you may invoke from your memory a program recently presented on TV that urged for shortening the period of establishing a new company. Although you may not remember the details of this program, you might think that the whole process is definitely longer than a week and shorter than a month, and you could estimate its length at, say, 14 days. Such an answer is logically correct as it renders the first disjunct false and the second true. However, the process of arriving at this conclusion would be not a result of the analysis of what is true and what is false about the possibilities. Indeed, based on the same kind of recollections one would probably give the same estimation of 14 days, even if the disjunction was presented in the following way:

> The average time required to fulfill legal requirements necessary to open a new company is *less* than 9 days or else it is *more* than 27 days.

In this case 14 days makes both disjuncts false and therefore it is logically incorrect. There is still a possibility that one may know that different types of companies require different legal formalities. Such a person would probably withdraw from giving any estimate of the time necessary to start a new business, claiming that the information given in the premises is incomplete.

As the study of Gigerenzer, Hoffrage, and Kleinbölting (1991) shows, people may use different types of background knowledge in order to arrive at numerical estimations of different facts. For example, they may think that a city that has a soccer team in the first league should be larger than one which team plays in the lower league. We believe that many such cues are available when numerical estimations refer to the domain of social life (e.g. percent of households connected to internet, average time of holiday in the EU) or governmental fiscal policy (e.g. public debt per capita, unemployment rate, percent of the EU funding used in the recent year). We used statements from those domains in our first experiment. As they are frequently mentioned in media coverage of politics, we refer to such statements as political in the rest of the paper. On the other hand, when no pragmatic clues are available, naïve reasoners should more often repeat one of the figures available from the premises as their own answer. We refer to such statements as general knowledge questions and in our studies we included in this group estimations of different facts of natural life (e.g. number of wolves hunting alone, average height of trees) and everyday human activities (e.g. number of words in the average email, number of letters in the average sentence).

We predict that naïve individuals rarely go beyond the principle of truth and in most cases they should err when the correct answer requires envisaging the situations in which some statements are false. However, it should happen less often in the case of political than general knowledge questions because pragmatic knowledge may suffice in recalling correct information from memory in the first type of questions. We verified this prediction in our first experiment.

Pragmatic modulations may also help individuals to see a certain set of premises not as a logical inference but rather as an attempt at persuasion. Recently, Mercier and Sperber (2011) have put forward a hypothesis that the main goal of reasoning is argumentation. Therefore, the main purpose of reasoning is to provide a set of logically related arguments that would support certain thesis. Or, if one is the target of a persuasion attempt, reasoning might be used in order to falsify the statements that other person uses to convince someone to his or her beliefs. Such social pragmatic factors may also include inferences about the intention or credibility of the source of a persuasive message (Bohner, Ruder, & Erb, 2002) or its truthfulness (Eisend, 2006). In the case of reasoning in the political domain, some individuals might even rely on peripheral clues such as personal attractiveness of a politician (Bohner, Moskowitz, & Chaiken, 1995) or potential gains and losses that he might attain (Priester & Petty, 1995). In our second experiment we

wanted to check if reasoners are more likely to choose as their own answer an opinion presented by a person who is more likeable. So in this study we dissociated the content of the problem (politics vs. general knowledge questions) and the source of the message (likeable vs. non – likeable politician).

Experiment 1

The first experiment compared how naïve individuals reason through disjunctions of general knowledge and political statements. We used two versions of both types of such disjunctions. In the first version, repetition of one of the disjuncts led to an illusory inference. We shall call them illusory problems throughout the rest of the paper. Two examples of such problems were given in the introductory section. Apart from the statements of the form

A is lower than X or else A is lower than Y.

we also used statements:

A is bigger than X or else A is bigger than Y.

In all such statements the correct answer is any number that lies between X and Y as the principle of truth excludes all other possibilities.

The second set of disjunctions used pairs of statements that could not be both true at the same time but the falsity of one of them did not exclude the other as a possibly correct answer. We used two types of such statements:

A is lower than X or else A is higher than Y.

A equals X or else A equals Y.

An example of the second type would be:

Either the average life time of the fruit fly equals 9 days or else it equals 27 days.

Given that one of those statements is true and the other is false, one cannot give any precise estimate of the average life time of the fruit fly. If the first disjunct is true than the other is false and vice versa. Such statements are typically tagged as control problems in the model theory research and so we will use this label throughout the rest of the paper.

Method

Participants. 27 undergraduate psychology students from the Warsaw University of Social Sciences and Humanities took part in the study in exchange for a course credit. Although none of them had participated in a higher – level course in logic, it must be noted that an elementary course in this subject is obligatory at all higher education institutions in Poland. Participating in such a course should not, in fact, influence the results of our studies as it provides only basic level knowledge.

Design and materials. Participants acted as their own controls and were asked to give their own numerical estimations for twelve problems presented in the form of disjunctions "Either *X* or else *Y*". Half of them were illusory, as in the examples described in the introduction to this experiment, and the other six were the control inferences. Three of the illusory inferences used "higher" relations in both disjuncts and the other three used the predicate "lower". Three of the control inferences used "higher" – "lower" relations and the other three used exact numbers. Our main independent variable: general knowledge or political content was manipulated as a between group factor. Therefore, half of the participants were presented with general knowledge problems and half with political ones.

We used different contents for each of 12 general knowledge problems and for each of the political statements. Examples of both types of content are provided in the introductory section. The pairs of numbers presented in each of those problems were different. Nevertheless, each pair from the political domain matched one pair of numbers from the list of those presented with the general knowledge questions.

All problems were presented in the form of a small booklet. The instructions informed that the experiment was not a test of either intelligence or the personality of the participants. The instructions informed the participants that they would see different pairs of statements and that in each pair one of the statements is true and the other is false, but it is not possible to say which is true and which is false. The participants were also informed that they should give their own estimations only on the basis of the content that was used in each pair of statements. The two key instruction sentences were phrased in the following way: "Try to give your own estimate in each of the situations described below only on the basis of the information provided here. (…) Please write a number that reflects your estimation or, if you are not able to give your own answer, write "X" in the answer line".

Results and discussion

Our main concern was to investigate how often the participants repeat the figures provided in the disjunctive statements. In all control problems such repetitions should be considered as possibly correct answers, while in illusory problems a simple repetition was considered as an incorrect answer. Table 1 presents percentages of different types of answers for illusory and control problems with the general knowledge and the political content.

Similarly to all studies investigating illusory inferences, we obtained a strong effect of the type of disjunction. In general, the participants were more often correct on control than on illusory problems: 73% and 14%, respectively (Wilcoxon test $z = 4.02$, $p < .001$). As we predicted, the participants were more likely to repeat numerical estimates from the general knowledge statements than from those pertaining to the world of politics. As repetitions were correct in the control problem, this resulted in a bigger number of correct answers in the control problems with the general knowledge content in comparison with the political ones (Wilcoxon test $z = 2.43$, $p = .008$, one tailed). However, in the case of illusory inferences repetitions were logically incorrect and so there were more such answers

with the general knowledge questions than with the political content (Wilcoxon test $z = 2.16$, $p = .015$, one tailed). The participants did not show any regular tendency to choose the first or the second disjunct as their answer. However, the first one was chosen slightly more often in abstract (47% choices of the first vs. 39% choices of the second disjunct) than in political problems (24% for the first one and 34% for the second one).

Table 1. Percentages of answers repeating and not repeating the numbers provided in disjunctive statements in Experiment 1. (The column for the correct non repetitions in control problems is empty, as only repetitions could be considered as correct answers; the percentages of logically correct answers are marked by italics.)

	Control problems		
Content	Correct repetitions	Correct non-repetitions	Incorrect non-repetitions
Political	*49%*		51%
General knowledge	*85%*		15%
	Illusory problems		
	Incorrect repetitions	Correct non-repetitions	Incorrect non-repetitions
Political	61%	*23%*	16%
General knowledge	88,5%	*4%*	8%

As all illusory problems were of the form: "A is higher (lower) than X or else A is higher (lower) than Y, the correct answers to all of them were estimates that fell between those two numbers provided in the statements. We called all such answers "correct non – repetitions" in Table 1. Very rarely did the participants gave such estimates in the general knowledge problems but they did it more often in the political ones (Wilcoxon test $z = 1.72$, $p = .043$, one tailed).

In sum, the results of Experiment 1 proved our hypotheses. The participants were less likely to repeat numbers from the statements referring to broadly defined political issues than in the general knowledge problems. Although, generally there were more correct answers in control than in illusory problems, the caution evoked by the political content resulted in a smaller number of incorrect repetitions in illusory problems and more logically correct answers in those problems.

Experiment 2

The previous study examined the influence of social pragmatic modulation on the tendency to repeat numbers provided in the form of a disjunction. Our Experiment 2 investigated whether it was possible to convince the participants to use the statements provided by some speakers as participants' own estimations. As many of the studies from persuasion research show, one of the key factors that makes a message more persuasive is the attractiveness of its source (Petty & Wegener, 1998). Following that, we hypothesized that participants would more often repeat the statements provided by more than less likeable speakers, even though endorsing the conclusions of such speakers may be logically incorrect.

Method

Participants. We recruited a group of 27 participants from the same population as those described in Experiment 1. They were tested in small groups in exchange for a course credit.

Design and materials. We used the same two sets of 12 general knowledge and 12 political problems as those in Experiment 1. The design of this study was exactly the same as that of Experiment 1 with one exception. Both in political and general knowledge settings we wrote in the instructions that all the statements came from two different politicians. We manipulated their likeability by informing our student participants that one of them said in a television interview that "students are more mature than it is commonly believed", while the other said that "students are spoiled and do not know the true life". We assigned those two descriptions at random to both politicians, so the statements within each pair were assigned once to a likeable and once to a non – likeable politician. We also measured the sympathy for those two politicians by asking the participants to rate their likeness on a five-point scale with higher numbers meaning higher liking. The key instruction sentences were the same as in Experiment 1, so the participants were asked to give their own estimates only on the basis of the information provided in the experiment, and write "X", only if they were not able to figure out their own answers.

Results and discussion

Again, we proved that there is a strong tendency to repeat numerical estimations provided in the form of disjunctions. As in Experiment 1, this led to correct answers in the control problems (57%) and incorrect in the illusory problems (31%). Only in 14% of their answers to illusory problems did the participants gave correct estimations that fell between two figures provided by the politicians depicted in the instructions (Wilcoxon test for comparison with correct answers in control problems yielded a significant result: $z = 3.4$, $p = .001$). In comparison with the previous experiment the difference between the repetitions in general knowledge and political problems was not significant, though it was in the predicted direction: 69% versus 52% (Wilcoxon test $z = 1,49$, $p = .07$, one tailed). And also there was no difference between numbers of correct answers in illusory problems concerning general knowledge (18%) and those connected with the world of politics (10%).

As our main objective was to see if the participants tended to repeat the statements from a likeable politician more

often than from a non – likeable one, we first checked the effectiveness of our manipulation. Indeed, a politician presented as a person who liked students scored on average 3.96 on a five-points sympathy scales. This number was significantly higher than the average for a person who did not seem to be fond of students: 2.04 (Wilcoxon test $z = 3.97$, $p < .001$). To check our main prediction for this experiment we calculated the Spearman correlations between the attractiveness scores of a likeable politician and the tendency to repeat his statement as the correct answer. The correlation coefficients are given in table 2.

Table 2. Correlations between the ratings of likability of a politician and the frequency of choosing his answer by the participants in Experiment 2. Correlations marked with an asterisk are significant at $p < .05$.

	Type of relation between disjunctions	
Inference content	Control problems	Illusory problems
General knowledge	.62*	.63*
Political	.53*	.39

As Table 2 reveals, we observed significant positive correlations between the sympathy ratings of a politician who was presented as likeable and the frequency of choosing his statements as answers in both control and illusory problems that required some general knowledge. However, the participants were more skeptical about the expertise of a politician in illusory problems that used the content for the political domain. Only in this case the results did not follow our prediction but it was mainly due to a bigger frequency of participants' refraining from giving any estimates. From the logical point of view, this is also an incorrect answer but we counted the correlations only for answers that repeated the opinion of one of the politicians described in the instructions to this experiment.

The results of Experiment 2 repeated our findings from Experiment 1: the participants were more likely to repeat one of the statements as their own answers. This led to illusory inferences in those problems where the truth of one statement excluded the truth of the other. As our correlations show, there was quite a strong tendency to choose more often the estimates given by a more likeable politician. Our manipulation could seem somehow suspicious to the participants of the study: it is hard to believe that a politician knows anything about the life span of a fruit fly. We observed a smaller tendency of repetitions in illusory problems in this experiment than in the previous one. But possible skepticism did not lead to a bigger number of correct answers in illusory problems in comparison with Experiment 1. It seems as the participants in Experiment 2 more often refrained from giving any numerical estimates in comparison with those taking part in Experiment 1.

General Discussion

The main purpose of the current study was to investigate how naïve individuals solved problems that used a pair of numerical estimations presented in the form of a logical disjunction. We used two versions of such problems. In the first version, one example being *A is lower than X or else A is higher than Y*, the verbatim repetition of any of the statements had to be considered as a logically correct answer. However, in the second set of trials, including for *example A is lower than X or else A is lower than Y*, the correct answer fell between X and Y and simple repetition of one of the disjuncts did not take into account that in such a case both disjuncts are true at the same time. Following the tradition in the psychological study of reasoning (Johnson-Laird & Savary, 1996) we referred to such problems as illusory inferences.

A number of researches have tried to find an antidote to illusory inferences. Most of the previous research used direct exemplifications of situations in which logical statements are false. We used a different approach and manipulated the pragmatic factors that led our participants to look for alternative possibilities. In Experiment 1 we compared frequencies of illusory answers for disjunctions in which the statements referred to the general knowledge questions (e.g. the average life of a fruit fly) with the problems referring broadly to social life and politics (e.g. the average time necessary to open a new company). We assumed that social and political issues trigger more cues from the long term memory that participants could use to arrive at their own answers. Our predictions were confirmed. In Experiment 1 the participants were significantly more often correct in illusory problems from the political domain than the general knowledge problems that did not induce pragmatic cues. The "illusory effect" was also present in our Experiment 2 in which we wanted to cue the participants to repeat an opinion presented by a more likeable politician. In this experiment the difference between the proportions if illusory answers in political and the general knowledge questions was lost but indeed we observed a significant tendency to repeat an opinion of a more likeable politician. Our manipulation of the likeability that we used in Experiment 2 might seem suspicious to our student participants, so they more often avoided direct repetitions of opinions coming from a politician who may know nothing about the subject matter of a given question. We guess, however, that it is possible to design a manipulation that would more directly cue the participants to choose one of the provided opinions. Therefore the current results of Experiment 2 provide a useful stepping stone for future research.

Both experiments showed that illusory inferences can be elicited in the domain of numerical cognition. Although there are many studies in the cognitive psychology of reasoning that explicitly use numbers in experimental materials (cf. Oaksford, Chater, & Larkin, 2000), they mainly use them as labels of probabilities or frequencies. Our study differs from such accounts as we investigated

how individuals reason from relational predicates such as "higher than X" or "lower than X". As it seems they do not only treat numbers as the representations of abstract numerical quantities, but are also able to treat numerical statements as entries into logical arguments.

Our study also differed from those typical for the area of persuasion research. Such studies normally measure the change of attitudes between and after the presentation of a persuasive message (e.g. Bohner, Einwiller, Erb, & Siebler, 2003). In our research we asked the participants to draw logically valid conclusions taking into account only the information given in the premises. As it turned out, the reasoners were more likely to go beyond the logical form of the problem when its content provided pragmatic cues that triggered the search for available facts in the long term memory (Exp. 1). Although they tended to repeat more often an opinion from a person who was presented as more likeable, it did not help them when it came to finding the logically correct answers (Exp. 2).

As asserted by Gilbert (1991), understanding the message entails believing that it is true at least until it is falsified by some other clues or statements. The results of our experiments show that indeed people believe that two statements that are not overtly contradictory can be both true at the same time. Individuals do not assume that one of them can be false and, what is more, they do not follow the consequences of such assertions. Such an attitude may have an important influence on the world of politics and the role of democratic institutions. It is quite likely that during election campaigns voters do not analyze the relations between statements of different politicians but they rather choose those they would like to believe on the basis on pragmatic factors, such as the likeability of the source of the message.

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