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Are Logicians Logical?

Abstract

The relationship between formal logic and language is highly contested historically. As recently as sixty years ago, both logicians and linguistics believed language to be too complex, and messy, to be modeled successfully by formal logic. More recently, though, logic has been accepted to underlie language in some way. Language and cognition more generally do not always obey logic, however. In the case of scalar implicatures, classic interpretation of language and formal logic diverge. Scaled terms have both a logical interpretation, that which is literally true given the information provided, and a scaled interpretation, that which depends on the assumption of a speaker being maximally informative. Previous studies (source) have shown adults to use the scaled interpretation more frequently. This current pair of studies considers the effect of logic experience on the interpretation of scalars, to see whether a logic background actually causes one to be more logical with language. Experiment 1 is a demographic survey investigating whether professional logicians use logical interpretations more frequently than English professors. Experiment 2 builds on this theme to consider whether a brief logic lesson can cause a participant to interpret scalars more logically.

Background

"It is a commonplace of philosophical logic that there are, or appear to be, divergences in meaning between, on the one hand, at least some of what I shall call the formal devices- ~, ^, v…- and, on the other, what are taken to be their analogues or counterparts in natural language" (Grice Logic and Conversation, source).

While the clear symbols of formal logic are today seen as the foundation of the messy and complicated structure of natural language, this relationship has not forever been so clear. Before Professor H.P. Grice's 1968 lecture series at Harvard University, logic and language were taken to be two different domains. The logical "languages" of Principia Mathematica and W.V. Quine were taken to be of a different kind entirely from that of the everyday world. Grice flipped this convention by arguing that logical symbols and everyday language connectives do not diverge in function or meaning, and that any possible divergence in meaning can be explained by a larger linguistic context within which an utterance is given. This hypothesis has been accepted generally for the most part, with formal semantics heavily using logic to understand the structure of language.

The two fields diverge enough, however, to make this conclusion questionable. Certain logical inferences, such as modus tollens, have been shown to be substantially harder cognitively

than others, despite them being similarly logically valid (source). Peter Cathcart Wason's *Selection Task* exhibit's this divergence. Wason presented subjects with a set of four cards, and they were told that each card has a number on one side and a letter on the other and that "Every card which has a D on one side has a three on the other" (Source). The faces visible to the participants read D, K, 3, and 7. The subjects were asked which cards were required to turn over to verify the rule. The correct answer, using both modus ponens and modus tollens, would be the cards reading D and 7. However, participants were substantially more likely to turn over the cards reading D and 3. Turning the card reading 3 does nothing to verify the conditional however, since it is not necessarily true that every card reading 3 on one side has D on the other. Despite modus tollens being as logically valid, and simple, as modus ponens, participants were vastly less likely to use it. This makes it seem as though logic may not underlie cognition, since if it did simple logical truths should be readily available. And with language being a byproduct of cognition, this result puts in question the possibility of language being founded in logic.

The frequently studied example of the divergence between language and logic, the interpretation of scaled terms, will be the focus of the following study. Terms such as some/all exist in a scale, with the terms higher on the scale entailing those lower on the scale. So "I have all of the cookies" logically entails "I have some of the cookies." However if I have all of the cookies, it seems strange to assert that I have some of them. This interpretation, with the normal entailment relation not holding, is called a scalar implicature. It has been argued (source) that scalar implicatures arise from the Gricean Maxim of Quantity, which requires a speaker to be just as informative as possible. In the cookie example, by using "some" when in fact "all" is true, the speaker is withholding information, and thereby violating the Maxim of Quantity.

The disjunction "or" is also a scaled term, since it can take an inclusive and exclusive interpretation. Gennaro Chierchia et al investigated differing interpretations of the disjunction

between children and adults in both downward and upward entailing linguistic environments. In downward entailing environments, almost all adults and children cancelled a possible scaled reading, and interpreted the disjunction as being inclusive. In upward entailing environments, where "and" was a suitable alternative to the disjunction, adults used the scaled interpretation of the disjunction and therefore denied the disjunctive statement much more frequently than children. This showed the increased likelihood of adults to be "illogical" (scaled) than children. Chierchia et al then used a follow-up Felicity Judgment task to determine whether children are able to interpret the scaled usage at all. In that test, children were asked which usage, "and" or "or," was better in the context in which "and" is possible. The children demonstrated a preference for the "and" statement, despite both statements being true. Chierchia et al concluded that children are unable to access the scaled interpretation when the "and" alternative is not specifically given. Essentially, for children to deny the disjunction in favor of the conjunction, children would be required to envision the conjunction as a viable alternative. This is only possible when that alternative is readily present in their mind, something Chierchia believes to require more conceptual resources than the children are successfully able to access. Putting the important conclusions about children's conception of scaled terms aside, Chierchia et al showed adults to greatly disprefer the logical interpretation of scaled terms in upward entailing environments, despite them being true.

With this general theoretical context in mind as well as the previous study considering disjunction as a scalar, this pair of proposed studies will investigate the effect of a type of priming on adults' interpretations of the disjunction. As with the Chierchia et al study, participants in each study will be presented with stimuli in which the conjunction is true and will be asked about the truth-value of the disjunction in different environments. Also as in Chierchia et al, if participants interpret the disjunction as being exclusive (the scaled interpretation) they will deny the disjunctive statements. I predict the control groups for each study, which will not receive any priming, to

respond similarly to Chierchia et al's original results. Building on this initial work, these studies will be considering the difference between these control groups and groups that have backgrounds with the disjunction in a formal logic context.

Experiment 1 is a demographic survey that will test whether Logic professors and English professors differ in their interpretation of the disjunction. I predict that the English professors will respond similarly to Chierchia et al's adult subjects. I also expect Logicians to reply similarly to Chierchia et al's subjects when the disjunction is placed in downward entailing environments. In upward entailing environments, if Logic professors reply using the logical interpretation much more frequently than English professors, this signals that logic experience has a direct priming effect on the logical interpretation of scalars. Put simply, logicians would be more logical. However, if no such pattern exists, then it will signal that logical background has little priming effect on general language learning. This could point to significant implications on the relationship between formal logic and language. If an increase in formal logic does not sway speakers toward logical interpretations, then logic and language may not be as paired as we once thought.

Experiment 2 builds on Experiment 1 by considering the effects of more short-term logic learning on the computation of implicatures in adults. A control group will complete the survey as in Experiment 1. Another group of participants will endure a lesson on the truth conditions of the disjunction symbol 'v' in formal logic. Once these participants exhibit their understanding of the material, they will be given the same survey. A final group will be taught a similar lesson, but will also be told that 'v' and 'or' can be treated in the same way. This Experiment utilizes priming related to but distinct from the actual task ultimately presented in the survey. For Group 2, instead of teaching the participants to respond to a similar survey question in the affirmative, Experiment 2 will involve a language lesson that is only connected to the survey if participants are able to transfer their

knowledge from the logic lesson to the survey. This therefore poses a compelling push forward in priming studies methodologically.

I predict that Experiment 2 will have parallel results to Experiment 1, with the logically experienced participants responding more logically than the control groups. If this is the case, then we can conclude that logicians are in fact more logical. If the results of the two experiments diverge, this will reveal a time delay or acceleration in the effect of logic understanding on the computation of implicatures. In the Future Experiments section, I will present several follow up studies that will investigate this possible temporal difference.

Experiment 1

Participants:

We will distribute this survey until ten Logic faculty members and ten English faculty members have responded. These faculty members will be found at Boston colleges or universities through the respective Philosophy and English department contact pages. We will first be contacting faculty members at the following universities: Harvard University, Massachusetts Institute of Technology, Boston University, and Boston College.

Procedure:

Participants were given the following survey, and asked to not discuss it before sending it out. They then returned the survey by mail.

Survey:

Respond to the following statements by circling **T** or **F**, using the provided image of Sally as reference:

Sally has an apple. T/F

If Sally has an apple or a pear, she will win a prize.

Sally will win a prize. T/F

Sally has an apple and a pear. T/F

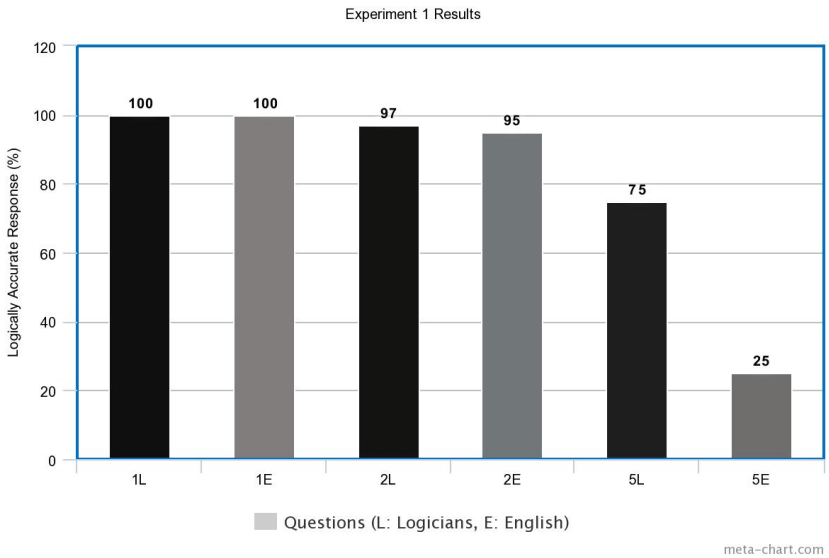
Sally has a pear. T/F

Sally has an apple or a pear. T/F

Predictions:

The two critical sentences are clearly the second and fifth. Any respondent who replies **T** to all of the sentences is using the logical interpretation of disjunction throughout. Considering the fifth sentence first, being an upward entailing environment, Chierchia et al (source) leads to the expectation that adults will use the scaled interpretation and respond in the negative. If formal logic experience influences the interpretation of scalars, then logicians will reply **T** more than English professors. Now considering the second sentence, Chierchia et al leads me to predict that both Logicians and English professors will reply **T**, since downward entailing environments, like the antecedent of a conditional, have been shown to cancel scalars.

Mock Results:



Questions 1, 3 and 4 were controls, so I did not include each of them in the above graph. I would expect each of them to result in 100% T responses (these I take as the logically accurate

responses for question 1 above). The 2E results are similar to those given in Chierchia et al (source), with the downward entailing environment cancelling the implicature and leading to adults responding in a logical manner. I do not predict 2L to differ greatly, if at all, from 2E, since the scaled interpretation is already cancelled by the environment, enough for the participant's logical background to likely not have much of an effect. If there were any effect, however, I would expect it to be an increase in logical interpretation.

The predicted result in 5E comes from (source), where the scaled interpretation is used vastly more frequently than the logical in upward entailing environments by adults. I expect 5L to be a substantially higher percentage than 5E, since I predict logical experience to have a large effect on in these upward entailing environments. I would predict logicians to interpret Question 5 must as being **T** less than Question 2, but I would still expect 5L and 2L to be more similar than 5L and 5E.

Experiment 2

Participants:

Sixty Harvard University undergraduates will participate in this study, after an initial screening process.

Initial Screening:

Prospective participants will be asked whether they have experience with the following logical symbol: 'v'. Any student who has experience with this symbol will not participate further. This screening will continue until sixty eligible participants are selected. These participants will be taken randomly from different academic departments, but they will be asked to identify their department, highest level of mathematical or logic course material, and experience in computer science after the study.

Procedure:

The participants will be split into three groups, each of twenty. Group 1 (the control group) will be given the same survey as in Experiment 1, and then asked the demographic questions given above once the survey has been collected. Group 1 will then be dismissed. Then Groups 2 and 3 will go through their logic lessons.

Group 2 Logic Lesson:

The experimenter will read the following lesson to the participant, with sections in italics signaling questions asked of the participants to test understanding and the sections in bold signaling the items that will be written on a whiteboard in the room for emphasis. If a participant answers incorrectly to a teaching question, the experimenter will clarify. If the participant then answers incorrectly to the next question, the participant is excluded from the study. Any participant who gets to the final question and answers it correctly will continue to the experimental phase. The lesson goes as follows:

In logic, normal sentences can be represented by letters like **'p' and 'q'**. For the purpose of this lesson, take 'p' to be the sentence 'it is raining' and 'q' to be 'it is Thursday'. Sentences can be joined by connectives, like 'and'. *So if I were to write, **'p and q'** what would that new sentence represent?* (Answer: It is raining and it is Thursday. If the participant gets this answer incorrect, then give the answer and ask: *If I were to write **'q and p'** what would that new sentence represent?* Answer: It is Thursday and it is raining. If they answer incorrectly, they are dismissed.) In logic, there is a symbol **'v'** (read vee). Statements using vee are true under certain conditions. **'p v q' is true when p is true, when q is true, and when both p and q are true**. *When would the following statement be true: **"it is raining v it is Thursday"**?* (Answer: When it is raining, it is Thursday, and it is Thursday and it is raining.)

Experimental Phase:

Participants will then be given the same survey as was given to Group 1, and in Experiment 1.

Group 3 Logic Lesson:

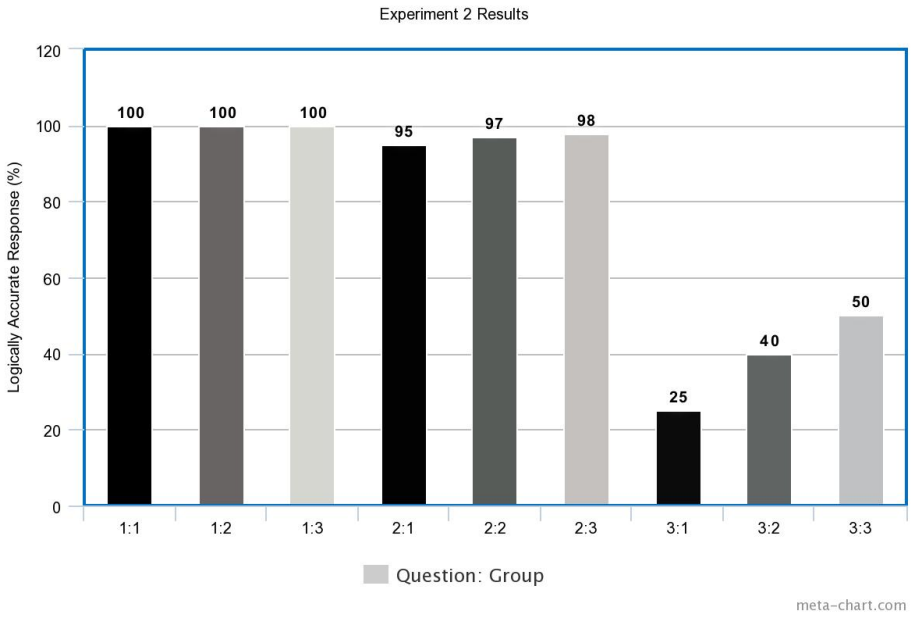
The procedure for Group 3 is identical to that of Group 2, except this is added to the original logic lesson:

Vee can be read as the English word "or." To convince you of this, consider the sentence **"Whenever it is Thursday or it is raining, we go to the store."** If 'or' is like vee, then we should go to the store when it is Thursday, when it is raining, and when it is both Thursday and raining. And that seems true! So 'or' and vee can be seen as the same.

Predictions:

I expect Group 3 to respond substantially more logically than Group 1, and Group 2 to respond more logically than Group 1 but less logically than Group 3. If this is the case, then a brief logic lesson will be shown to cause logical interpretations of the disjunction. Also, these results will reveal that priming that is more closely related to the experimental phase (Group 3) has a greater effect than that more abstractly related to the experimental phase (Group 2). Therefore, these results would have combined import, revealing both the variety of possible priming effects and the influence of short-term logic experience on scalars. It will also be important to note the presence of any outliers. I expect people with deeper mathematics or computer science backgrounds to respond more logically than those without them, though I will present a specific future study that would test for this explicitly.

Mock Results:



As with Experiment 1, I am only including one control in the above graph. Also as with Experiment 1, predictions for 2:1 and 3:1 come from Chierchia et al. For Question 2, I expect the logic lesson to have negligible effect on the responses. If there is any effect, I expect recent logic exposure to only cancel scalars more. I would similarly be surprised if Groups 2 and 3 have much difference in responses, but if there were a difference I would expect Group 3, whose lesson was more directly connected to the survey and therefore were more heavily taught to interpret the disjunction logically, to reply more logically.

For Question 5, I predict Groups 2 and 3 to both reply more logically than the control. Group 2 will likely have a noticeable increase in logical responses compared to control, but for Group 3 to have a higher logical response rate than Group 2, since their lesson was more directly connected to the survey questions. I do not expect either Group 2 or Group 3 to reply as logically as the logicians in Experiment 1, since their logical experience is substantially less ingrained. However, as I will soon discuss, the possible difference on Question 5 between the logicians and Groups 2 and 3 need to be addressed.

General Possible Results

It is important to note that scalar implicatures are hugely susceptible to even inadvertent linguistic influences. While the design of this survey tries to control for such influences, by testing multiple linguistics environments and turning the question into a T/F, it is still possible that the specific wording of the survey may have skewed results in a certain direction.

Generally, I would expect Group 1 to respond to the survey similarly to English faculty members, and Groups 2 and 3 to respond similarly to the Logic faculty members. If this is the case and if Group 2 responds to question 4 more logically than Group 1, this would signal that the logical interpretation is more likely for those with experience using the logical symbol relevant to the implicature. If this is the case but Groups 2 and 3 and Group 1 do not have a notable difference in responses, the logical interpretation is likely not able to be primed using logical experience specifically.

If Groups 2 and 3 responds less logically than Group 1, then it is possible that participants processed logical learning as being a different domain from language, and therefore hyper-corrected when considering actual English disjunction. This seems like a hugely unlikely result however.

I do not expect a large effect of logic experience in downward entailing environments, since the scalars will likely be cancelled almost always no matter a participant's experience.

The current mock results would mean that logicians, with their ingrained logic background, use the logical interpretation more than participants who had a brief logic lesson before taking the survey, but every group with logic experience replies more logically than control groups without such experience. However, this effect is substantially larger in upward entailing contexts than in downward entailing contexts, since I do not predict much of an effect of logic experience on the interpretation of scalars in downward entailing environments.

If Groups 2 and 3 and the Logic professors diverge significantly, it would signal time effect on logic learning on implicatures. If Logic professors and English professors differ more than Group 2 and Group 1, as I am predicting, it would signal that short-term logic learning does not ultimately have as large of an effect on language interpretation as long term, a more engrained logical background. If Logic professors and English professors differ less than Group 2 and Group 1, this would signal that short term logic learning changes the interpretation of scaled terms, but that this change reverts back to the normal, scaled interpretation over time.

General Discussion

Experiments 1 and 2 investigate the effects of logic teaching on the interpretation of scaled terms. I had hypothesized that a background in formal logic makes one more likely to have the logical interpretation of scalar implicatures. To investigate the effect of formal logic on the interpretation of scalars, Experiments 1 and 2 considered both professional logicians and those who have less extensive logic experience. As was discussed in General Possible Results, it seems likely that Experiments 1 and 2 will both result in the more logically educated of the two groups having a more logical interpretation of scaled terms, with the difference particularly apparent in upward entailing environments. The most compelling result, as was explained above as well, would result from the two experiments diverging. This would result in a series of new experiments, as will be introduced in the next section.

Future Experiments

Dependent on the differences between results in Experiments 1 and 2, future experiments should target the possible time delay in the effect of logic learning on scalar implicatures. If Logic professors use the logical interpretation more often than Groups 2/3, this will signal that logic learning needs a more long-term immersion into ones life before it takes full hold of scalar

implicature interpretation. If this is the case, I would want to alter the experiment to include a series of lessons, and delay between the final survey and the teaching process, to see whether quantity of logic teaching or time devotion to logic have effects on implicature computation. Similarly, it would be interesting to find the point at which, after a certain amount of learning, Groups 2/3 become drastically similar to Logic professors.

If Logic professors use the logical interpretation less often than Groups 2 and 3, this would signal a short-term effect of logic learning on scalar implicatures that ultimately fades with time. Future experiments could address the timing of this expiration by delaying the survey by different times from the actual logic lesson, to see if there is a point at which logic learning no longer interferes into language interpretation. It would be important, though, to ensure that the participants in question are able to exhibit continued understanding of the logical symbol 'v', while simultaneously returning to the scaled interpretation. This would ensure that general forgetfulness about the logic curriculum is not interfering, since this forgetfulness would not exist for the Logic professors.

Unlike previous research on the topic, Experiment 2 considered the effect of a different but directly related domain on scalar implicature computation. Experiment 2 investigated the effect of the formal logic domain on the language domain. Differing results between Groups 3, 2 and 1 will show the effect of logic priming directly connected to the relevant task in comparison to logical priming not overtly connected to the relevant task. If Experiment 2 provides interesting results, future experiments should consider the effects of different types of priming on logical interpretations of scalars, moving even farther from the specific task in question. It would be compelling to expand this current line of inquiry, which considers the effects of logic explicitly on logical interpretations, to see whether other mathematical or precise domains could have priming effects on scalar interpretations, and whether these priming effects would differ from those resulting

from some sort of artistic practices. A follow up study could involve three groups, Group 1 as in Experiment 2, and then one group that completed multiplication tables for a period of time, and another group that painted before taking the survey. This type of study could test the extent to which generally precise domains have effects on language, beyond explicit translation between the two tasks as in Experiment 2. In Experiment 2, the lessons taught about 'v' are explicitly translatable to the survey for Group 3 and for Group 2 they are directly relevant to the survey question, while this modified experiment would have substantially less overt connection to the task at hand. This would also raise interesting questions about the effects of nonlinguistic tasks on language more generally. This follow-up study would be particularly motivated by Experiment 2 if the students who self reported as having mathematics or computer science experience replied more logically than those who did not.

Examples of language, and even cognition more generally, diverging from logic do not inherently show language not to be founded in logic. They do reveal, though, a lack in our current understanding of the ways in which the two domains are bridged together. If logic does in fact underlie cognition, then there must be a structure that bridges the logical foundation across to the non-logical everyday usage. Scalar implicatures are a rich point of research, since much analysis has been devoted to finding the mechanics that bring out the scaled interpretation from the initial logical interpretation using exhaustification. The potential of future studies seems to be founded in the search for a more complete bridge between logic and language, used beyond simple scalar implicature cases. This presented pair of studies may act as a template for future work on priming effects and the effect of logic on language more generally, which could very well help identify these bridges.