Psychological Review
1992, Vol. 99, No. 1, 188-190

0033-295X/92/$3.00

In Defense of Reasoning: A Reply to Greene (1992)

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Greene (1992) argued that assertions of the form "None of the A are in the same place as some of the C" are difficult for subjects to generate and that this phenomenon explains the results of our study of multiply quantified reasoning without having to invoke mental models or deductive reasoning (see Johnson-Laird, Byrne, & Tabossi, 1989). The present article shows, first, that the phenomenon fails to explain most of our principal results; second, that, far from undermining the theory of mental models, it can actually be explained by the theory; and, third, that the best available account of our results is that subjects both reason and rely on mental models to do so.

In a study of reasoning with quantifiers such as *some, all,* and *none,* we presented evidence that subjects make deductions, not by using formal rules of inference, but by imagining the relevant states of affairs, formulating a putative conclusion from such a mental model, and then searching for alternative models that might refute the conclusion (Johnson-Laird, Byrne, & Tabossi, 1989). We argued that, for example, premises of the form

None of the A are in the same place as any of the B
All of the B are in the same place as all of the C

readily elicit a valid conclusion: "Therefore, None of the A are in the same place as any of the C," because they yield only one model, in which the *A*s are in one place and the *B*s and *C*s are all together in another place. For example,

|aaa|bbbccc|,

where the number of tokens for each set is arbitrary. In contrast, premises of the form

None of the A are in the same place as any of the B
All of the B are in the same place as some of the C

only rarely elicit a valid conclusion: "Therefore, None of the A are in the same place as some of the C," or equivalently, "Some of the C are not in the same place as any of the A," because they support more than one qualitatively distinct model. For example,

|aaa|bbbcc|c|

or

|aaac|bbbcc|.

Greene (1992) made two points about this study. First, he claimed that the crucial factor is the difficulty of generating the respective conclusions to the problems rather than generating the number of models. In particular, he argued that subjects have difficulty in generating "crossed-scope" assertions of the form "None of the A are in the same place as some of the C," where the scope of *some* includes *none;* that is, the sentence can be paraphrased as "Some of the C are not in the same place as any of the A." Greene reported studies in which subjects judged which diagrams in a set were described by such sentences and a study in which subjects generated descriptions of diagrams. "The evidence is overwhelming," Greene wrote, "that subjects simply do not generate statements of the form 'None are related to some' (p. 186)." And he drew a radical conclusion: "Johnson-Laird et al.'s major results can be explained without invoking mental models or, in fact, deductive reasoning at all" (p. 184).

Greene's (1992) second point is subsidiary. The effect of reversing the order of the quantifiers in a sentence, such as "Some of the A are in the same place as all of the B," may produce a sentence, "All of the B are in the same place as some of the A," that is both more ambiguous and difficult to comprehend.

Greene's (1992) conclusions go far beyond what his findings warrant. In what follows, we show that the alleged difficulty of none–some assertions does not refute the theory of mental models, that the theory elucidates the phenomenon, and that the theory is compatible with the effect of reversing the order of quantifiers.

Does the Difficulty of a None–Some Conclusion Imply That Subjects Neither Reason Nor Rely on Mental Models?

Greene's (1992) principal argument is a non sequitur. Suppose, for the sake of argument, that none–some assertions are genuinely difficult to generate. It does not follow that our major results are thereby accounted for and that subjects can carry out our task without reasoning. Greene considers only the difference in difficulty between the two sorts of problem, and he overlooks five other major phenomena that we reported.

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First, our logically untutored subjects generated their own valid conclusions to one-model problems at a much greater rate than chance. The subjects coped with each of the following forms of premise pair. For example,

1. All of the A are in the same place as some of the B.
   All of the B are in the same place as all of the C.
2. Some of the B are in the same place as all of the A.
   All of the C are in the same place as all of the B.
3. All of the A are in the same place as some of the B.
   All of the B are in the same place as some of the C.
4. None of the A are in the same place as any of the B.
   Some of the B are in the same place as all of the C.

There are 12 logically distinct possible conclusions interrelating *A* and *C* and so if the subjects produced the valid conclusions by some procedure other than reasoning, then Greene owes us an account of this process.

Second, this alternative process should explain the most frequent responses to the multiple-model problems, that is, erroneous conclusions. Why should these conclusions happen to correspond to just one of the possible models of the premises? Greene may say that it is easy to generate a conclusion of the form "None of the A are in the same place as any of the C," which corresponds to the first of the two models for the multiple-model example in the Introduction; but why do some subjects draw the conclusion "All of the A are in the same place as some of the C," which corresponds to the second of the two models? Why don't subjects produce the negative conclusion to affirmative premises? Greene does not describe an alternative mechanism, and, as we showed, the hypothesis that subjects are making guesses that correspond to the "atmosphere" of one (or both) of the premises fails to account for performance. If they had done so, then, for example, they should have drawn the correct none–some conclusion to the multiple-model premises

None of the A is in the same place as some of the B
All of the B are in the same place as some of the C

Third, the subjects sometimes draw modal conclusions, such as "All of the A could be in the same place as some of the *C*." The model theory predicts that such conclusions should occur more often with multiple-model problems than with one-model problems because a modal conclusion characterizes what may be the case, that is, what holds in one possible model. This prediction was corroborated by our experiments. Again, it is hard to see why modal responses would be guessed more often with multiple-model problems than with one-model problems.

Fourth, one-model problems are harder when the middle term has two different quantifiers in the two premises, for example,

All of the A are in the same place as some of the B
All of the B are in the same place as all of the C

than when both quantifiers are the same. The model theory predicted the difference. When one premise asserts that a set is in the same place as all of the members of a second set and another premise locates only some of this second set, then to construct a unified model reasoners have to overrule the premise containing *some* and to interpret the quantified noun phrase as concerning the whole set.

Fifth, there is a reliable effect of the *figure* of the premises on the difficulty of problems. This phenomenon was predicted on the grounds that it is hard to construct a model when the occurrences of the middle term are not contiguous in the premises (see Hunter, 1957).

In short, it is all too easy to assert that an inferential task can be carried out without deductive reasoning, but until such a claim is backed up with an alternative procedure that accounts for the inferential phenomena, the claim lacks substance.

Are Multiple-Model Problems Hard Because Their Conclusions Are Difficult to Generate?

Greene claimed that multiple-model problems are hard because of the difficulty in generating their conclusions. To establish this point, however, he needs to show that subjects have difficulty in framing conclusions both of the form "None of the A are related to some of the C" and of the logically equivalent form "Some of the C are not related to any of the A." He has not produced definitive evidence that meets this demand. He has shown that subjects have difficulty in choosing or generating assertions of the form "None of the A are connected to some of the C" to describe diagrams. However, his first 2 studies say nothing about the difficulty of generating "Some of C are not connected to any of the A," because they did not include such sentences in the experimental materials. Greene's third study permitted any verbal formulation that the subjects cared to use, but unfortunately the task of describing the relevant pair of diagrams seems to have been beyond the subjects' competence: Only just over a fifth of the subjects managed to produce a sentence that said anything true of the relevant diagrams.

Why should it be apparently so hard to cope with crossed-scope none–some sentences? Greene is silent on the matter. The answer is implicit in the procedure that we described for constructing models from quantified assertions. Each quantified noun phrase calls for a loop that plays a part in the construction of the model, and the loops are ordered according to the scope of the quantifiers. Hence, the loops are relatively easy to set up when their order corresponds to the order of the quantifiers in the sentence, but they have to be mentally re-ordered when their scope differs from the order of the quantifiers in the sentence. Conversely, it will be easier to formulate a conclusion (on the basis of a semantic representation containing the loops) where the sentence maintains the same order of quantifiers than where it does not maintain the same order.

The Effects of Reversing the Order of Quantifiers

Greene's (1992) subsidiary point concerns the scope ambiguities of such sentences as "Some of the A are in the same place as all of the B" and "All of the B are in the same place as some of the A." According to Greene, "Johnson-Laird et al. (1989) claimed that all–some and some–all premises should be equally ambiguous and equally difficult for subjects to understand" (p. 3). He goes on to argue that the all–some premises should be more ambiguous, and harder to understand, than the some–all premises. We agree. Indeed, as Greene acknowledges, Johnson-

Laird (1969) had anticipated this prediction and obtained corroboratory evidence for it. We never claimed that the premises should be equally ambiguous or easy to understand. We wrote as follows: "both of these premises are, in principle, ambiguous in scope" (see Johnson-Laird et al., 1989, p. 667). Even though one is more ambiguous than the other, we can be certain that this factor is not responsible for the difference in difficulty between one-model and multiple-model problems. Both sorts of premise occur in one-model problems, and the presence of an all–some premise does not lead to a drop in performance to the level of a multiple-model problem.

Conclusions

In summary, Greene (1992) is correct in pointing out that certain quantified assertions may be difficult to frame, but his conclusions go too far beyond his results. He has not shown that other equivalent assertions, such as "Some of the A are not in the same place as any of the C," are difficult to generate. We doubt that they are, though the figural bias may have inhibited subjects from drawing them in our particular problems. Even so, some theory of deductive reasoning is necessary unless one can establish that logically untutored individuals are unable to make quantified deductions. Claims of this sort have been made in the past, and they continue to exert their attractions (M. Levine, personal communication, January 10, 1991). Such hypotheses need to be able to explain why intelligence tests of syllogistic ability predict academic performance, why natural language allows us to construct quantified assertions from which we can draw deductively valid conclusions, and how logic was invented in the first place. Last, if untutored individuals cannot reason with multiple quantifiers, then what exactly are they doing in our experiments? We believe that they make deductions from models of the premises. They are deductively competent, but they err in performance when they have to construct more than one model. In other words, some people—logicians, perhaps—may reason validly all of the time, all people reason validly some of the time, and no one reasons invalidly all of the time. An alternative account must explain why one-model problems tend to elicit valid conclusions (in all the domains of deduction that have been tested, including propositional, relational, and quantificational inferences; see Johnson-Laird & Byrne, 1991), why erroneous conclusions with multiple-model problems tend to correspond to one of the possible models, and why modal conclusions are more frequent with multiple-model conclusions than with one-model problems. Greene does not attempt to explain these phenomena. The alleged difficulty of framing a conclusion does not really impugn our subjects' ability to reason or a model theory of that ability.

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Received March 18, 1991
Accepted March 18, 1991 ■