Generating Support: The Influence of Perceived Category Size on Probability Judgments

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Abstract

When assessing the likelihood of an event, human judgment is often inconsistent with the rules inherent in standard probability theory. For example, the judged probability of an event can be heavily influenced by the alternatives that are explicitly presented. Tversky and Koehler (1994) attempted to account for this phenomenon by arguing that probability judgments are made by comparing the amount of cognitive support one holds in favour of the event in question relative to all other possibilities. They suggested that different descriptions of the same event elicit different amounts of support resulting in different probability ratings. In addition to the role played by explicitly considered alternatives, the present paper suggests that people are also sensitive to the influence of alternatives that are not considered explicitly. We present the term 'implied numerosity' in an attempt to indicate that probability ratings are influenced by a general impression of the number of potential alternatives that exist. Systematic differences in probability estimations may result from systematic changes in the perceived size of the category being evaluated.

Introduction

When judging probability or estimating frequency, the numbers raters assign often fail to follow the rules inherent in standard probability theory. For example, Redelmeier, Koehler, Liberman, and Tversky (1995) showed physicians medical case histories and asked them to estimate probabilities for specific diagnoses. Half of the physicians were asked about two diagnoses ("gastroenteritis" and "ectopic pregnancy") and the residual category ("none of the above") while the other half were asked to estimate probabilities for a list of five diagnoses (including "gastroenteritis" and "ectopic pregnancy") and a residual ("none of the above"). Although the case histories shown to both groups were identical, the average probability assigned to the residual in the short list was smaller than the sum of the corresponding probabilities in the long list. In that same paper the authors showed that, not only does the estimated probability of a particular medical diagnosis vary systematically as a function of the number of alternative diagnoses explicitly presented, but that physicians' treatment decisions were also influenced. When sinusitis was the only diagnostic hypothesis given explicitly, fewer respondents recommended a CAT scan than when a longer list of potential diagnoses was offered. Tversky and Koehler (1994) and Rottenstreich and Tversky (1997) have shown this effect using a wide variety of questions and by asking subjects to respond with either probability ratings or frequency estimations.

While these authors have described and modeled these phenomena in impressive detail, much of their focus has been on the influence of alternatives they explicitly gave the raters or alternatives raised by the raters themselves. We now propose that the alternatives that are not considered explicitly may also influence our probability ratings. The present paper introduces the idea of implied numerosity to suggest that one component of probability evaluation involves an assessment of the size of the category to which an event belongs. That is, the context of the questions, including the alternatives offered explicitly, may alter a judge's impression of the number of possible alternatives that have not been mentioned. Although descriptions of the phenomena described in the preceding paragraph might cause humans to appear to be illogical decision makers, the current framework suggests that some part of that appearance might be the by-product of a rational judgment process. We argue that experimental manipulations shown to alter probability ratings may have done so, at least partially, by changing the perceived size of the category being evaluated. This proposal will be argued for in two ways: By an assessment of its ability to explain results already present in the literature and by examining novel predictions that have been tested and are presented here. First, however, we will briefly discuss the need for such a proposal.

I. Implied Numerosity: Seeing the Forest or Counting the Trees?

Support Theory, as presented by Tversky and Koehler (1994) was first developed to explain the finding that different descriptors of the same event give rise to different probability judgments. For example, subjects typically assign a larger probability estimate when asked to evaluate the probability that a randomly selected person will die of natural causes including heart disease, pneumonia, or lung cancer, relative to when the same question is asked without the explicit mention of exemplary instances. Tversky and Koehler postulated that this is so because such judgments are made on the basis of cognitive extensions (hypotheses) rather than physical extensions (events) in the real world. In other words, rather than performing a memorial count of the ways in which people might die of natural causes relative to all other types of death, Tversky and Koehler argued that probability judgments are developed through the consideration of a ratio of cognitive 'support' for the alternative in question (dying of natural causes) relative to all other alternatives (dying of unnatural causes):

$$P(A, B) = \frac{s(A)}{s(A) + s(B)} \qquad (1)$$

where P(A, B) = probability of 'A' rather than 'B' and s(A) = support for A. Probability estimates, they suggested, are greater when specific alternatives are "unpacked" (i.e., when exemplary instances are explicitly mentioned) relative to when they remain implicit, because unpacking increases the amount of support in favour of the event in question. They modeled this suggestion in the first two terms in Equation 2:

$$s(A) \leq s(B \vee C) \leq s(B) + s(C) \qquad (2)$$

where $(B \vee C)$ is an explicit disjunction of the implicit disjunction 'A,' and as will be explained shortly, s (B) + s (C) are the ratings of each component made independently. Using the above example, 'A' = death due to natural causes, $(B \vee C)$ = heart disease, lung cancer, pneumonia, or some other natural cause of death. This effect of unpacking has been labeled "implicit subadditivity" since implicitly evaluated diagnoses typically result in a lower probability rating relative to those that are presented as unpacked, explicit possibilities. The latter two terms refer to a phenomenon labeled "explicit subadditivity" by Rottenstreich and Tversky (1997). It is included to illustrate that when probability ratings are assigned to alternatives one at a time by independent subjects, their sum is typically greater than when the same alternatives are explicitly presented, but evaluated as a whole. Again, Rottenstreich and Tversky argued that this is so because the amount of support generated in favour of those alternatives increases when they are evaluated independently.

All in all, Support Theory has had tremendous success; the original formulation as well as the extension published by Rottenstreich and Tversky have provided good explanations for (as well as predictions of) many of the inconsistencies found between subjective probability judgments and standard probability theory. In addition, Support Theory has been used as a tool in attempts to further our understanding of decisions made during the diagnostic process (Eva, Brooks, Cunnington, and Norman, Under Review; Redelmeier, et al., 1995).

There remains, however, another aspect of unpacking which, to our knowledge, has not been addressed by any of the previous writings: the influence held by the alternatives that are not explicitly evaluated. As is evidenced by Equations 1 and 2, much of the work performed in this area focuses on the effect of packing and unpacking specific alternatives. Tversky and Koehler (1994) speculated that the amount of support in favour of any one alternative is constrained by both memory limitations (i.e., the ability to recall possible alternatives) and attentional capture (i.e., an increased salience as a result of an alternative's explicit presentation). Maintaining such a focus on the consideration of specific alternatives leaves one susceptible to the default assumption that only explicitly considered alternatives are influential. Surely, however, there is a more generic, exemplar-free way of performing frequency estimations that should not be ignored. Just as one can estimate the size of a choir by trying to pick out multiple specific voices, the volume of the chorus as a whole must also provide valuable information. The alternatives that are explicitly presented could possibly provide information that can alter a judge's perception regarding the number of potential alternatives that might be generated even without their actual generation. That is, the alternatives themselves imply numerosity.

This possibility is consistent with personal experience as well as with discussion held with experimental participants. Ask yourself the question "How probable is it that Russia hosts the world's largest prison?" While highly capable of generating a long list of countries, many of which would be reasonable alternatives (including China which is, incidentally, the correct answer), most people do not attempt to do so spontaneously. In fact, Eva et al. (Under Review) have found evidence that even the most likely alternatives in a diagnostic decision task may not be generated (or at the very least, are under-appreciated) unless explicitly mentioned. Rather, a more commonly observed pattern is the automatic consideration of the explicitly mentioned alternatives (or at most, 1 or 2 alternatives that are included only implicitly yet come to mind quickly) followed by some vague consideration (i.e., a general impression) of the question as a whole. It seems unlikely that this discounting of alternatives not explicitly mentioned is due to low motivation during the experimental situation given that this strategy has been observed in the most dedicated subjects as well as during natural conversation with other individuals. Rather, when asked to evaluate the likelihood that a given answer is correct, or that a given event might occur, there seems to be a natural tendency to make a decision on the basis of some general impression of its probability rather than through the use of specific comparisons of a number of possible alternatives.

What creates this "general impression" that seems to be driving the responses given by subjects? Given that people do not expend a lot of effort generating additional alternatives to compare with the explicitly given alternatives, what determines the magnitude of the probabilities assigned? We propose that an evaluation of the amount of 'support' one holds in favour of particular alternatives is influenced by a general impression of the size of the category judges are being asked to evaluate. We turn our attention now to an evaluation of whether this framework might still enable the explanation of known phenomena. As implied numerosity is being proposed as one mechanism by which 'support' can be generated, it maintains much of the explanatory power of Support Theory.

II. Explaining Known Phenomena

Subadditivity

As described earlier, Support Theory predicts that unpacking the Focal hypothesis will result in an increase in its judged probability whereas unpacking the alternative hypothesis should result in a decrease in the judged probability of the Focal. That is, implicit subadditivity requires that the explicit presentation of "pneumonia, cancer, and myocardial infarction (MI)" cause the Focal hypothesis 'natural causes of death' to be assigned a higher probability rating. An implied numerosity framework would make the same predictions, but for a different reason. The argument would be that unpacking the Focal hypothesis causes the category 'natural causes of death' to seem larger within the superordinate category 'causes of death' relative to when the disorders remain implicit. If a category is perceived as being larger, then assigning it a greater probability as a whole is a perfectly rational action; an action that is consistent with standard probability theory as well as with the empirical results found throughout the literature. The converse of this, and the latter half of the above prediction, is that unpacking the alternative hypothesis by explicitly naming auto accidents, fires, or drowning as unnatural causes of death should reduce the probability assigned to 'natural causes of death' (Tversky and Koehler, 1994). Again, we would argue that such an unpacking causes the category 'unnatural causes of death' to appear larger within the superordinate category 'causes of death' relative to when these alternatives remain implicit. As a result, the probability assigned to 'natural causes of death' as a whole should be smaller.

The second type of unpacking, explicit subadditivity, suggests that the sum of disjoint components, when judged independently, receive a probability rating greater than or equal to the rating assigned to all components when evaluated as an explicit disjunction. To extend the above example, being asked to assign a probability to dying of pneumonia, cancer or MI, should result in a lower probability rating than the sum of pneumonia, cancer and MI when each are evaluated independently. Supportive empirical evidence was presented by Rottenstreich and Tversky (1997). Using the current framework, the explicit presentation of pneumonia, cancer, and MI together should cause the category 'natural causes of death' to appear larger relative to when pneumonia is presented by itself. So, any one alternative within the category 'natural causes of death' should receive a lower probability rating in the former case relative to the latter. As a result, we would expect pneumonia, cancer, and MI to receive larger probability ratings when presented independently and summed, relative to when all are presented together.

Binary Complementarity

Tversky and Koehler (1994) argued that the sum of probabilities assigned to alternatives that are judged in a binary manner (i.e., when a given alternative is judged in relation to its complement) should sum to one. That is, these types of judgments should be additive rather than subadditive. For example, when asked the week before Super Bowl XXXIII if Denver will win or if Atlanta will win, independent judgments should sum approximately to 1.0. This would also be predicted using the implied numerosity framework outlined here as every instance of the category being evaluated is explicitly known regardless of whether one is asked to assign a probability to Denver or Atlanta. Evaluating one or the other can not change the perception of category size and so estimates are fairly stable and consistent with standard probability theory. Preliminary evidence has been gathered in support of this claim and will be described briefly in section III.

Strength of Alternatives Effect

An issue not addressed by any of the preceding work on subjective probability is the role played by the prevalence / plausibility of the unpacked alternatives themselves. While Support Theory does not make any specific predictions regarding this factor, manipulating the probability of the alternatives has the potential to yield three very different results. (1) If memory and salience are the sole causes of the subadditivity phenomenon, one might expect that the more likely the alternatives, the least effect they should have on people's probability judgments. Highly probable alternatives are the ones that should come to mind most readily and that should be considered with the greatest care. As a result, the most likely alternatives should influence probability judgments even when not mentioned explicitly. (2) If there is relative constancy in the degree to which the salience of an item increases upon its explicit presentation, then we would expect the same amount of subadditivity regardless of the unpacked item's prior probability. (3) An inversely proportional relationship might be found in which the decrease in probability assigned to the Focal diagnosis (i.e., the size of the unpacking effect) increases with the plausibility of the alternatives. The latter possibility would be predicted if implied numerosity is playing a role in our probability judgments; the more likely any given alternative is, the larger influence it should have on perception of category size (i.e., making it seem that a greater number of potential alternatives could be plausible) and hence the smaller the probability should be assigned to any single alternative.

This latter pattern is indeed what was observed by Eva, Brooks, Cunnington, and Norman (Under Review). Medical students and Motive Technology Students were shown brief case histories relevant to their field of study and asked to evaluate the probability of that case being representative of each diagnosis in the presented list. On average, the rating of the Focal hypothesis decreased when the Residual alternative was unpacked even when the unpacked alternatives were considered Implausible by expert raters - a finding consistent with Support Theory. Also consistent, but not predicted by Support Theory was the finding of the "strength of alternatives effect." It was found that the magnitude of the probability assigned to the Focal diagnosis was inversely proportional to the probability of the alternatives explicitly presented.

Other Effects of Context on Judgments

Within this framework, biases in probability judgments become consistent with numerous other findings in Psychology - those that have revealed that a change of context can alter the way in which we perceive and evaluate a problem. Studies of hindsight in both psychology (see Hawkins and Hastie, 1990 for a review) and medicine (Arkes et. al., 1981) have revealed that people who know an event occurred tend to believe falsely that they would have predicted the reported event. Teigen (1983) presented subjects with mystery stories and varied the number, and the role, of characters who may have committed the murder. His results suggested that the degree of suspicion drawn against one person had profound implications for the evaluation of the other characters - probability estimation was seemingly not done in isolation from the alternatives themselves. Similarly, Norman, LeBlanc, and Brooks (In Press) have shown that the features noticed by medical students in classic patient photographs are highly dependent on the diagnosis students have in mind. With knowledge of these prior studies, it seems reasonable to believe that context would play a role in our perception of category size as well. This being the case, implied numerosity is consistent with the unpacking effects described by Support Theory. In addition though, this framework makes novel predictions regarding the magnitude of the unpacking effect - predictions that are supported by the data presented here as well as another data set that will be outlined cursorily, but presented in detail elsewhere.

III. Testing Novel Predictions

Magnitude of the Unpacking Effect

The first prediction tested by the current study is that the size of the category required to include all unpacked alternatives should systematically alter the magnitude of the unpacking effect. This will be illustrated by the use of an example. Consider again the question "what country hosts the largest prison in the world?" If subjects are sensitive to implied numerosity, then the decrease in the probability assigned to the Focal alternative (Russia) should be greater if the Residual is unpacked into alternatives which include countries from all over the world (United States and Australia) relative to when the unpacked alternatives are all Asian countries (China and Japan). The category size (i.e., the number of possible alternatives) in the latter is smaller, so any individual country should receive a larger probability rating, creating less of a drop in the rating of the Focal hypothesis relative to when the Focal hypothesis is presented on its own (i.e., the packed condition).

The second prediction is that if the alternatives which are unpacked are held constant, then there should be a greater unpacking effect the smaller the packed category is perceived to be. The smaller a category is perceived to be, the greater should be the probability assigned to any one alternative, and so the greater the effect should be upon unpacking additional alternatives. Providing a hint that the country which hosts the largest prison in the world is in Asia should serve to reduce the size of the category of focus in the packed condition. Therefore, when a hint is given, Russia should receive a larger probability rating -- and unpacking into China and Japan should result in a greater difference in probability ratings -- relative to when no hint is given.

Methodology 25 undergraduate Psychology students were presented with 50 trivia questions and asked to evaluate what percentage of people they thought would generate particular answers in response to being asked each question. Participants were asked to assign a number between 0 and 100 to each alternative and told that the inclusion of an "all other alternatives" option should result in the numbers summing to 100 for each question. They were also told that the correct answer was not necessarily presented, so not to make that assumption. Finally, for the purpose of a manipulation check, subjects were asked on each question to assign a number estimating how many potential alternatives might possibly be generated.

Table 1 illustrates, using an example, the 5 experimental conditions described below. Trivia questions were presented in 1 of 5 conditions all of which had a Focal hypothesis consistently presented: (1) a Large Category (i.e., no hint) Packed condition (LP), (2) A Small Category (i.e., hint given) Packed Condition (SP), (3) a Large Category Unpacked Similar Condition (LUS) in which the alternatives that were unpacked were all from a relatively small category, (4) a Large Category Unpacked Dissimilar Condition (LUD) in which the unpacked alternatives came from a wide range of possible alternatives, and finally, (5) a Small Category Unpacked Condition (SU) in which the alternatives were the same as in the LUS condition. Only the Focal alternative was presented in the Packed conditions while three alternatives, including the Focal, were presented in all unpacked cases.

Table 1: Example question illustrating five conditions

"Which country saw the invention of the bicycle?"

Condition	Hint	Alternatives
Large Packed		France, "All other countries"
Small Packed	It's in Europe	France, "All other European countries"
Large Unpacked Similar		France, England, Germany, "All other countries"
Large Unpacked Dissimilar		France, U.S.A., Taiwan, "All other countries"
Small Unpacked	It's in Europe	France, England, Germany, "All other European countries"

Results Figures 1 and 2 illustrate the scores assigned to the Focal diagnosis in each condition averaged across 49 questions - one question was dropped from analysis as an error was found in the alternatives list presented.[1] Figure 1 shows that, as predicted by Support Theory, the probability

[1] Error bars represent Standard Error of the Mean

assigned to the Focal diagnosis was higher in the Packed Condition than in either Unpacked conditions. Furthermore, as the implied numerosity framework predicted, the decrease in the probability assigned to the Focal is greater when the alternatives are Dissimilar (i.e., taken from a large category) relative to when the unpacked alternatives are Similar (i.e., from a smaller category). The difference scores (LP - LUS vs. LP - LUD) are statistically significant ($p < 0.03$) using a repeated measures, two-tailed t-test with question as the unit of analysis.

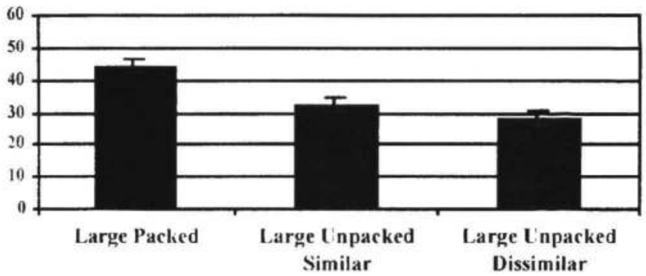

Figure 1: Mean estimated Pr (Focal alternative)

Figure 2 reveals that the second prediction made by the current framework was also observed. Keeping the unpacked alternatives constant, but varying the size of the category of focus in the Packed condition resulted in a larger unpacking effect when the category size in the Packed condition was small (SP – SU) relative to when the category size of the Packed condition was large (LP – LUS). This difference was significant ($p < 0.05$) using the same analysis as above. It can also be observed in Figure 2 that the difference in the two unpacking effects resulted from an increase in the probability assigned to the Focal diagnosis in the Small category Packed condition. This was also predicted by the impled numerosity framework, because the similarity of scores in the two Unpacked conditions is to be expected if the manipulation of unpacking into similar alternatives had the same effect as providing a hint while asking the question. That is, it appears to be true that the alternatives presented lead the judge to focus on a category of sufficient size to encompass all explicitly mentioned alternatives and nothing more. In addition to this being viewed as a manipulation check, the similar ratings in these two conditions also rules out the possibility that the higher probability assigned to the Focal diagnoses in the Small Packed condition relative to the Large Packed condition resulted solely from an increase in confidence as a result of having been given a hint.

The Ratio Rule

As described in the section entitled "Binary complementarity," the implied numerosity framework suggests that probability judgments will show additivity when every alternative is known before estimates are provided. If all alternatives are known, then changing the alternative presented can not influence the contextually determined perception of number of potential alternatives. Although the results are preliminary and as such will not be presented in any detail, the authors have used the Ratio Rule espoused by Tversky and Koehler (1994) and elaborated on by Rottenstreich and Tversky (1997) as a measure of the consistency of subjects' probability ratings. As predicted by the current framework, it appears that the critical determinant in whether or not the behavioural data satisfies the rule is whether or not judges have an appreciation of the size of the entire sample set before evaluating the probability of any pair of alternatives. That is, only when there is no change in the number of potential alternatives are probability ratings consistent with the rules inherent in standard probability theory. This will be expounded upon at a later date - it is mentioned here simply to foreshadow further support for the implied numerosity framework.

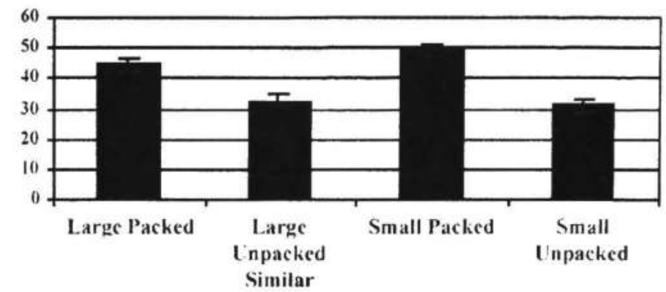

Figure 2: Mean estimated Pr (Focal alternative)

Discussion

Like Cosmides and Tooby (1995), we propose that humans may be good intuitive statisticians after all. It is a rational act to assign a probability on the basis of the number of potential alternatives -- all else being equal, the more alternatives there are, the lower the likelihood that any one alternative will be correct. Unlike Cosmides and Tooby, we do not feel that the phenomena observed in much of the judgment under uncertainty literature is simply a numbers game that results from a poor conceptualization of probabilities. Rather, we argue that the systematic variations found in probability judgments arise as a result of conceptions being altered by the way in which questions are asked or by the number of alternatives that one is explicitly asked to evaluate. The presentation of specific alternatives not only influences the support in favour of those alternatives, but can also drive people's impressions of the number of potential alternatives that they have not considered explicitly. A physician who is asked to evaluate a medical case for the presence of two specific infectious disorders might perceive the problem differently than one who is asked to evaluate the same problem via the consideration of an infectious disorder and a genetic defect. Even if additional alternatives are not explicitly considered, the two physicians' senses as to the number of plausible alternative diagnoses that exist is likely very different, but nonetheless potentially influential in both cases.

As has hopefully been made clear, we are not arguing that implied numerosity is the only factor influencing our probability judgments. On the contrary, Support Theorists have shown that a more explicit consideration of specific alternatives is very influential. In addition, using a Process Dissociation Procedure, Begg, Faulkner and Jacoby (Unpublished Manuscript) have demonstrated to our satisfaction that frequency discriminations are affected by both automatic and controlled processes such as availability and memory for frequency, respectively. We speculate that implied numerosity acts in a more automatic way in that it is not expected that judges consciously evaluate the number of alternatives that might be considered plausible before transforming the result into a probability judgment or frequency estimation. Regardless of whether or not this is the case, there remain at least two possible mechanisms through which judges might be sensitive to implied numerosity.

It has been argued throughout this paper that the alternatives explicitly mentioned create a context through which judges gain a general impression of the number of possible alternatives that exist. A second possible interpretation of the results presented is that the explicit mention of examples that constitute a relatively large category cue more additional alternatives than do examples that constitute a smaller category. The latter possibility seems unlikely for two reasons. First, as mentioned earlier, Eva et al. have presented evidence which suggests that even judges who have been trained to generate lists of differential diagnoses may fail to bring to mind even highly likely alternatives if they are not explicitly mentioned. Second, researchers examining concept formation (e.g., McRae, de Sa, and Seidenberg, 1997) often opt to use larger category decision tasks (e.g., superordinate descriptors such as "is it a living thing") so as to avoid cueing specific exemplars. Jared and Seidenburg (1992) found that narrower decision tasks (e.g., "is it a bird") were inappropriate, because they were more likely to cue specific exemplars. If this is the case, then a greater amount of spontaneous unpacking would have been expected in the "small category" condition relative to the "large category" condition, thereby resulting in predictions opposite to the ones verified in this paper. Furthermore, in observing experimental participants, it appears unlikely that frequency estimations consist of a systematic search through multiple possible alternatives. Rather, we argue that the information gained through implied numerosity consists of the creation of a general impression of the size of the category under consideration, thereby modulating the perceived probability.

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