Shared Mental Models & Decision-Making

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The Problem: Decision-making among members of a group entails aggregating the opinions of the constituents. If the opinions are unconstrained, then concensus typically fails when any vote is taken. In contrast, when opinions reflect a shared model of the domain, then concensus is likely, assuming members can communicate accurately the reasons for their individual choices. How, then, will concensus degrade if communications or models of the domain are noisy or inadequate?

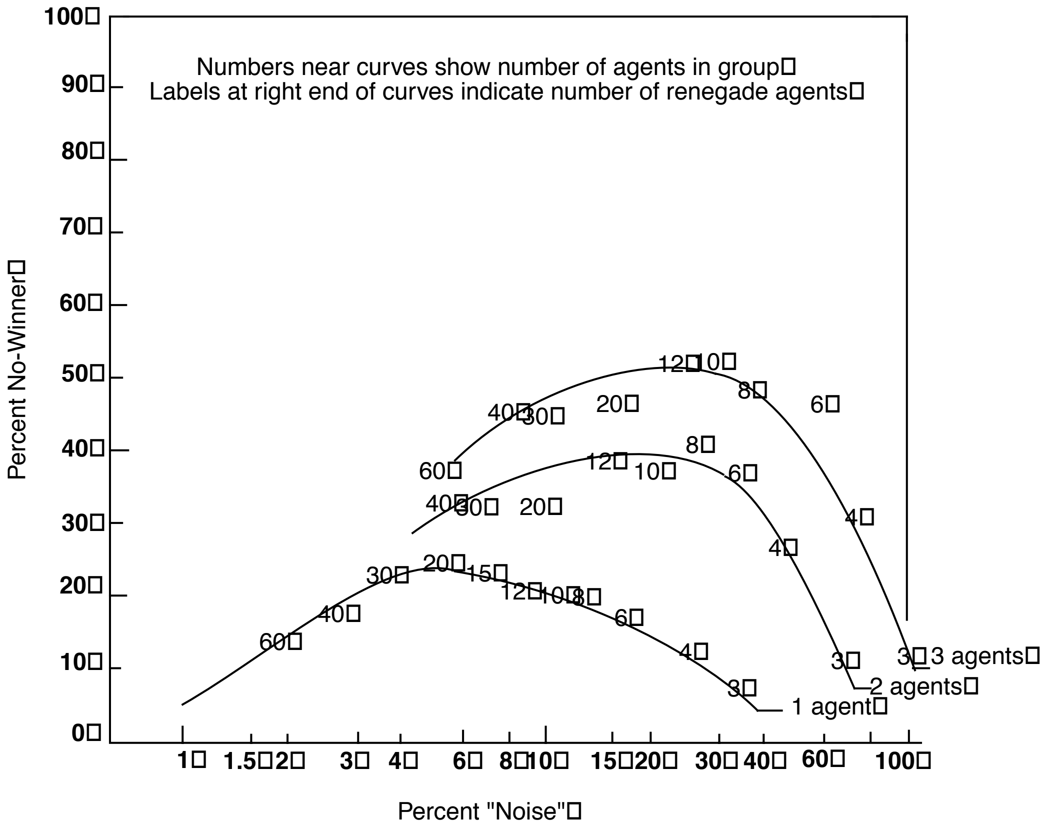
Motivation: Collective behavior based on the aggregation of individual preferences is widespread. The most obvious example is when a group of individuals vote to determine which of many alternatives should be chosen as the group's decision. A less obvious application is understanding how various neural modules of a brain reach agreement in the face of conflicting information [3]; [2]. In both cases, if we assume these kinds of aggregation processes are not subject dictatorial rule (such as a homunculus), then the odds on reaching an agreement are very low, assuming unconstrained voting. Yet most collective decisions, especially our own percepts, are stable, singular and typically compelling. Why?

Previous Work: The key is that an individual's choices should be consistent with a "mental model" that is shared by all members of the group [1]; [4]. This shared model forces all preference orderings for alternative choices to be correlated, rather than being just a random order. Concensus then will be reached better than 95% of the time, assuming faithful communication of preferences.

Approach: The shared "mental model" can be represented as a graph, with the vertices being the alternatives, and the edges specifying the relationships between alternatives. Given the vertex representing an individual's first choice, his second choices will then be those alternatives represented by the adjacent vertices, etc. Weights on the vertices specify the voting power; these are chosen from a uniform distribution. Mental Models were generated as random graphs with edge probability one-half. As shown in the figure, the main variables were the number of alternatives (numbers along the curves) and the number of renegade individuals (agents) who ignored the shared model and voted instead randomly for their second choices. The effect of such renegade voters is a non-monotonic function of the number alternatives, or, equivalently, the size n of the mental model. If only one agent votes at random, then for $n = 3$, one-third of the votes have a random "noisy" component with a no-winner probability of 7%; if $n = 6$, one-sixth of the voting is "noisy", with a no-winner probability of about 15%, etc. The worst case when just one agent votes "at random" is a 20-alternative mental model, which will result in over 20% of the tallies having no winner. The remaining two curves show a similar pattern for two and three renegade voters.

Impact: Although concensus occurs 95% of the time or better when a mental model is shared among individuals, the odds for agreement rapidly become degraded when only a few renegade voters violate the shared model and vote randomly.

Future Work: Mental Models are not arbitrary, and tend to have certain forms such as heirarchical trees or linear orderings. The form of the model can make a huge difference in the success of concensus, even in the presence of noisy communications. In addition, although individuals may vote faithfully, they could have mis-matched mental models. What then will be the odds for concensus? Certain asymptotic conditions still remain unresolved. Finally, we now have insights into the design of a neural net that would perform a pair-wise comparison of weighted alternatives, related by arbitrary graphical forms.



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