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### **Perspectives on Preference Aggregation**

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# Perspectives on Preference Aggregation

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## Abstract

For centuries, the mathematical aggregation of preferences by groups, organizations or society has received keen interdisciplinary attention. Extensive 20th century theoretical work in Economics and Political Science highlighted that competing notions of “rational social choice” intrinsically contradict each other. This led some researchers to consider coherent “democratic decision making” a mathematical impossibility. Recent empirical work in Psychology qualifies that view. This nontechnical review sketches a quantitative research paradigm for the behavioral investigation of mathematical social choice rules on real ballot, experimental choice, or attitudinal survey data. The paper poses a series of open questions.

Some classical work sometimes makes assumptions about voter preferences that are descriptively invalid. Do such technical assumptions lead the theory astray? How can empirical work inform the formulation of meaningful theoretical primitives? Classical “impossibility results” leverage the fact that certain desirable mathematical properties logically cannot hold universally in all conceivable electorates. Do these properties nonetheless hold in empirical distributions of preferences? Will future behavioral analyses continue to contradict the expectations of established theory? Under what conditions and why do competing consensus methods yield identical outcomes?

Key Words: Behavioral Social Choice, Borda, Condorcet, Instant Runoff, Voting Paradox.

Social choice procedures (aka voting or consensus methods) have a long tradition in Economics and Political Science, but have also received limited attention in Psychological Science. Economics and Political Science have perfected the mathematical analysis of “what is possible” and “what is not universally possible.” Scientists in these fields have highlighted a number of voting “paradoxes” and “impossibility” theorems. This mathematically sophisticated literature has drawn a complex picture. Two essential, and widely endorsed, conclusions can be paraphrased in simple terms as follows: 1) Competing notions of “rational social choice” appear intrinsically irreconcilable. 2) Universal “democratic decision making,” based purely on aggregation of voter preferences, may be a mathematical impossibility.

Theoretical and empirical work in Psychological Science takes a more optimistic perspective. Psychologists have found little empirical evidence for voting paradoxes, and, so far, little behavioral support for the famed incompatibility of social choice methods. These findings suggest that technical assumptions or theoretical problem formulations in social choice theory might bias our understanding. I discuss a number of major open theoretical and empirical questions about how to reconcile “rational social choice” theory with empirical data. Resolving these questions requires the interdisciplinary development of a comprehensive descriptive theory of social choice behavior, with Psychological Science plausibly in a leadership role.

Social choice procedures are mathematical tools. Here, I introduce key mathematical notions via examples, not formal definitions. For full fledged technical treatments, see Regenwetter et al. (2006) and its predecessor papers, or Regenwetter et al. (2007a) and Regenwetter and Rykhlevskaia (2007).

### **Mathematical Representation of Individual Preferences.**

Throughout the paper, our mathematical representation of individual preferences consists of “preference relations.” Consider four choice alternatives,  $A, B, C, D$ , and suppose a decision maker strictly prefers  $A$  to  $B$ , strictly prefers  $B$  to  $C$ , and strictly prefers  $A$  to  $C$ , but has no other strict preferences. I will denote such a decision maker’s preference as a *preference relation*  $\mathcal{R}$ , namely as a collection of ordered pairs  $\mathcal{R} = \{(A, B), (B, C), (A, C)\}$ . For simplicity, I only consider *strict* preference: If a person prefers  $X$  to  $Y$ , then they cannot also prefer  $Y$  to  $X$ . In the example above, the decision maker has no strict preference among  $C$  and  $D$ . This is captured by the fact that  $\mathcal{R}$  contains neither  $(C, D)$ , nor  $(D, C)$ .

Consider  $n$  many choice alternatives. I refer to these also as objects, candidates, competitors, or options.

For any preference relation  $\mathcal{R}$ , one can, for each object  $X$ , derive a (*generalized*) *rank* of  $X$  in  $\mathcal{R}$ , as follows: First, start with the number  $n + 1$  and add to it the number of choice alternatives that are strictly preferred to  $X$  in  $\mathcal{R}$ . Now, subtract how many choice alternatives  $X$  is strictly preferred to in  $\mathcal{R}$ . The (generalized) rank is this quantity divided by two (Regenwetter and Rykhlevskaia, 2004). For example, if there are  $n = 3$  choice alternatives,  $A, B, C$ , and the preference relation is the collection  $\mathcal{R} = \{(A, B), (B, C), (A, C)\}$ , then  $A$  has rank  $\frac{(3+1)+0-2}{2} = 1$ ,  $B$  has rank  $\frac{(3+1)+1-1}{2} = 2$ , and  $C$  has rank  $\frac{(3+1)+2-0}{2} = 3$ . An important feature of the (generalized) rank is that it allows assignment of numerical ranks to all choice alternatives even in cases where decision makers lack strict preferences among some alternatives or have incoherent (e.g., “intransitive”) preferences. Multiple options may share the same rank, but only at most one option can have rank 1, namely if the individual strictly prefers this option to all alternatives. At most one option can have rank  $n$ , and this is the case precisely if the decision maker strictly prefers every other option to this option. Ranks are multiples of  $\frac{1}{2}$ .

### Six Social Choice Methods.

I now review six social choice methods that have received varying degrees of scientific attention. Throughout, assume  $N$  many decision makers who have preference relations  $\mathcal{R}_1, \mathcal{R}_2, \dots, \mathcal{R}_N$ , respectively.

The first method implements pairwise contests among choice alternatives.

**CONDORCET CRITERION:** Choice alternative  $X$  is socially preferred to choice alternative  $Y$  according to the *Condorcet Criterion* if more people strictly prefer  $X$  to  $Y$  than  $Y$  to  $X$ , i.e., if the number of relations containing  $(X, Y)$  exceeds the number of relations containing  $(Y, X)$ . A candidate is the *Condorcet winner* if it beats each competitor by the Condorcet Criterion. The *Condorcet Paradox* denotes the fact that a Condorcet winner need not exist. While, arguably, the Condorcet Criterion is generally viewed as the most natural implementation of democratic aggregation, a substantial theoretical literature has predicted an omnipresent threat of the Condorcet Paradox, and leading textbooks strongly caution against using this method (e.g., Shepsle and Bonchek, 1997). Condorcet is rarely used in multicandidate elections.

The next three methods are called “Scoring Rules” (or “Positional Voting Methods”) because they assign overall scores to candidates based on their ranks in the individual preference relations.

**PLURALITY:** Each candidate receives a point from each individual preference relation on which this

candidate's rank equals 1. Preference relations are discarded if no option has rank 1. In practice, this usually amounts to the world's most common voting method: Each valid ballot contains one vote for one candidate (which is counted as having rank 1). Candidates are socially ordered by decreasing total score.

**BORDA:** For each preference relation, each option scores  $n$  minus its rank in that relation. The social order sorts the options from highest to lowest total Borda Score. Equivalently, for each candidate, one can compute the arithmetic mean of its ranks across the given collection of preference relations and socially order the alternatives by increasing mean rank. The Borda Score has been the main conceptual competitor of the Condorcet Criterion for over two centuries. Like Condorcet, it is rarely used.

**ANTIPLURALITY:** Each option receives a penalty point from each preference relation on which its rank equals  $n$ . Preference relations are discarded if they do not allocate a rank of  $n$  to anyone. In practice, this usually amounts to the rarely used voting procedure in which each valid ballot contains a single vote against a single candidate. The aggregate order is by increasing total number of penalty points.

A major theoretical critique of scoring rules is that the social preference among two choice alternatives could be altered through the introduction (or removal) of third candidates. The following iterative single-seat election method is heavily used around the world. It also appears to be the most promoted (and frequently adopted) method for electoral reform for all levels and types of government in the United States.

**ALTERNATIVE VOTE, HARE SYSTEM, INSTANT RUNOFF:** To be elected, a candidate must have rank 1 on more than 50% of all ballots. As long as no candidate meets this quota, candidates with smallest number of rank 1 votes are sequentially eliminated and all ranks are recomputed on the ballots, until a candidate meets the quota. Notably, the American Psychological Association uses this method to elect its president.

Finally, I include a method based on statistical measures of central tendency.

**MEDIAN GENERALIZED RANK:** For each candidate, find the median of its ranks across preference relations. Socially order the choice alternatives according to the magnitude of that median rank.

### **Some Established Wisdom in Social Choice Theory.**

I focus on three major concerns of social choice theory: 1) Impossibility theorems, 2) the Condorcet Paradox and 3) the concept of Condorcet Efficiency.

1) The famous *Impossibility Theorem* of Nobel Laureate Kenneth Arrow (1951) shows that, logically,

there cannot exist a social choice procedure that satisfies a certain set of prerequisite conditions for rational aggregation of preferences. One of its conditions forbids outcomes like the Condorcet Paradox. Another requirement of Arrow's paradox is that any acceptable method must satisfy the list of conditions in all conceivable distributions of preferences, whether they occur in real life or not. A number of other impossibility results in the theoretical literature are of a similar nature.

2) Riker (1982) provided a summary table for extensive prior research on the likelihood of the Condorcet Paradox. According to that table, the paradox should be omnipresent, especially for large numbers of candidates and large numbers of voters. Riker assumed that every decision maker's preference translates into a "complete" ranking, i.e., no two options have equal rank. The table makes the *Impartial Culture* assumption, according to which every electorate is a random sample from a uniform distribution over such complete rankings. Social choice theorists readily acknowledge that the real world looks nothing like an Impartial Culture. Yet, Riker's table is standard fare in basic courses on social choice.

3) Despite the presumed threat of the Condorcet Paradox, the Condorcet Criterion continues to be appealing. The *Condorcet Efficiency* of, say, the Borda score, is the conditional probability that the Borda winner matches the Condorcet winner, given that a Condorcet winner exists, in samples drawn, typically, from an Impartial Culture. The overall picture painted by this literature reinforces the literature on impossibility theorems: Competing social choice procedures are based on logically incompatible principles, and, under standard theoretical assumptions, cannot be expected to yield mutually consistent outcomes.

Saari (1999, 2000a,b, 2001) has developed a sophisticated mathematical framework with the potential to construct preference distributions that yield nearly any prespecified pattern of disagreements among a range of social choice methods, as long as such a disagreement is mathematically possible.

### **Behavioral Social Choice: Empirical Findings**

I sketch behavioral work on 1) the Condorcet Paradox and 2) the consensus among consensus methods.

1) Regenwetter et al. (2006) developed a methodological framework for *Behavioral Social Choice* in which the mathematical properties of social choice procedures can be evaluated against empirical behavioral data. The original book and its predecessor papers placed a major emphasis on the empirical hunt for the Condorcet Paradox. Regenwetter et al. (2006), as well as subsequently Regenwetter et al. (2007a) and

Regenwetter et al. (2007b) considered a variety of real and experimental ballot and national election survey data sets. They found virtually no evidence for the empirical occurrence of the paradox. The only cases where the paradox could not be ruled out were cases that lacked statistical identifiability or statistical replicability. List and Goodin (2001), Regenwetter et al. (2006), Tangian (2000) and others also discussed theoretical explanations for the absence of the paradox. Most notably, the predictions in Riker's famous (1982) table completely collapse as soon as the underlying theoretical assumptions deviate ever so slightly from the Impartial Culture. Others, including Feld and Grofman (1992) and Mackie (2003), have previously questioned from a variety of angles whether the famed prevalence of the Condorcet Paradox is empirically valid. Dryzek and List (2003) and List et al. (2007) suggest that deliberation among decision makers may help to eliminate the paradox.

2) Regenwetter et al. (2006) and its predecessor papers compared the two most important historical competitors, Condorcet and Borda, using a variety of techniques to infer preference distributions from Approval Voting ballots and from national election survey data of three countries. Regenwetter et al. (2007a) inferred Condorcet, Borda and Plurality outcomes from Approval Voting ballots using more sophisticated inference techniques. Regenwetter et al. (2007b) compared Condorcet, Borda, Plurality, and the Alternative Vote using four sets of American Psychological Association ballots that used the Alternative Vote. In all cases, they found striking agreements between rival social choice methods. Tangian (2000) discussed theoretical situations in which Condorcet and Borda will tend to agree.

In important pioneering work, Felsenthal et al. (1993), using 37 election data sets, had concluded that different versions of multiseat Plurality, Borda, and the Alternative Vote, as well as two other methods, were very similar. They reported that a type of Plurality method showed relatively the greatest signs for violations of rationality principles. More recently, in Psychology, Hastie and Kameda (2005) studied nine social choice rules, including Condorcet, Borda, Plurality, as well as an averaging and a median rule. These authors used a simulated test bed of a hunter-gatherer society that had to carry out a signal-detection-like task. They found high agreement of all methods with the Condorcet Criterion. For instance, in 12-member groups, six out of eight methods chose the Condorcet Winner with probability exceeding .85.

**Behavioral Social Choice: Methodological Issues.**

Several methodological issues complicate theoretical and empirical social choice research. I review three problems: 1) Model dependence, 2) statistical replicability, and 3) the role of strategic behavior.

1) Theoretical assumptions can have profound implications on social choice results. For instance, we have seen that deviating ever so slightly from the Impartial Culture assumption can literally reverse theoretical predictions. Like rational choice theory, behavioral social choice also requires theoretical modeling, and often technical assumptions. For instance, inferences from incomplete or imperfect data are usually only possible with the help of some technical assumptions. These assumptions, should they be invalid, could distort empirical findings. It is therefore crucial to analyze the same data from multiple, and fundamentally different, angles and to investigate the extent to which modeling assumptions may impact substantive conclusions. Regenwetter et al. (2006, 2007a,b) systematically varied their assumptions and concluded that, while inferred social orders sometimes changed with assumptions, the empirical absence of the Condorcet Paradox and the amazing congruence among social choice methods carried through across their different approaches.

2) Theoretical social choice research in Economics and Political Science usually treats ballots as deterministic and flawless representations of the decision makers' intended votes. The Florida recount of the 2000 U.S. presidential election has invalidated this assumption on a large scale. Regenwetter et al. (2006), Regenwetter et al. (2007a), Regenwetter and Rykhlevskaia (2007), and Regenwetter and Tsetlin (2004) have motivated and developed maximum likelihood and Bayesian statistical inference tools for probabilistic (random sample) ballot or survey data. Regenwetter et al. (2007b) used bootstrap methods for evaluating the statistical replicability ("confidence") of inferred social choice outcomes.

A caveat with early empirical work is that data sets tended to be sparser (tens to hundreds of observations) than some recently investigated data sets (tens of thousands of observations). Inferences made from sparse data could be sensitive to small perturbations in the data, i.e., statistical replicability may be low.

3) It remains extremely difficult to formulate statistically testable models with identifiable parameters in a way that allows to infer preference distributions from empirical data when decision makers distort their preferences strategically. Regenwetter et al. (2007a) developed such a method for Approval Voting data under the assumption that individual preferences satisfy a general type of Thurstone model (Thurstone,

1927). They provided statistical evidence that decision makers were not voting strategically. Much other behavioral work cited in the present paper relies on assumptions about sincere expression of voter preferences. A major challenge for future work is to incorporate strategic components into other models without requiring overly artificial subsidiary technical assumptions when dealing with survey or ballot data.

### **An Illustrative Behavioral Analysis.**

Following the approach of Regenwetter et al. (2007b), I provide a brief empirical illustration on American Psychological Association presidential election ballots. This 2004 election featured five presidential candidates and 16,245 voters. If the social orders were to disagree, the huge number of observations should give us ample statistical power to determine such disagreements with ease. For purposes of brevity, I treat the ballots as so-called “weak orders” from which one can readily compute the Condorcet, Plurality, Borda, Antiplurality, Alternative Vote, and Median Generalized Rank outcomes using the definitions I gave above. The Alternative Vote elects one option, it does not socially rank the candidates. I report the degree of agreement among Condorcet, Plurality, Borda, Antiplurality, Alternative Vote, and Median Generalized Rank as to who is the winner and the degree of agreement among Condorcet, Plurality, Borda, Antiplurality, and Median Generalized Rank on who is the loser. With “winner(s)” I mean the candidate(s) with the lowest generalized rank in the social order. With “loser” I mean a (unique) candidate, if there is one, who has generalized rank five in the social order.

We “bootstrapped” 1,000 samples, each of size 16,245 (with replacement) from the original data. *Of these 1,000 samples, all 1,000 yielded identical and unique winners for Condorcet, Plurality, Borda, Antiplurality, and the Alternative Vote.* In 895 samples this winner was further matched by a unique and identical winner under the Median Generalized Rank. In the remaining 105 samples, the Median yielded additional, tied, winners. None of these 1,000 samples yielded a Condorcet Paradox. *All 1,000 samples yielded identical losers across all five methods.* I omit alternative models and methods for brevity.

Is this perfect consensus among archival consensus methods surprising? The social choice literature on the Impartial Culture would draw samples with replacement from a uniform distribution, rather than an empirical distribution. To circumnavigate the problem of ties in the Median Generalized Rank, consider the winners under Condorcet, Plurality, Borda, Antiplurality, and the Alternative Vote, and the losers

under Condorcet, Plurality, Borda, and Antiplurality. While these outcomes match 100% in our bootstrap, simulated samples from an Impartial Culture led to such an agreement 3% of the time. In samples from a uniform distribution over allowable APA ballots (using the weak order approach) we found such agreement also only 3% of the time. The standard theoretical benchmarking methods suggest extreme disagreement among methods: Out of 1,000 simulated draws from an Impartial Culture, 25% yielded outcomes where a candidate had rank 1 in the social order of one method and rank 5 in the social order of another method. For a uniform distribution over allowable APA ballots, the corresponding proportion was 33%. In our behavioral analysis, such disagreements occurred not even once in 1,000 draws!

### **Perspectives on Preference Aggregation.**

The apparent rarity of the Condorcet Paradox and the apparent empirical consensus among mutually incompatible social choice procedures call for a descriptive theory of behavioral social choice that provides explanations for these puzzling findings. Countless interesting open questions regarding these two important phenomena remain: When and why are social choice procedures empirically congruent? Does it matter whether we study preferential data reflecting personal tastes, where no objective “right answer” may exist, versus judgmental data, where objective optimal choices exist? For judgmental data, what is the role of ecological cues for the consensus among consensus methods? Similarly, what are the roles of group deliberation, group size, persuasion campaigns, and strategic behavior? To what extent do properties of the choice alternatives drive the agreement among social choice rules, and to what extent may institutions play a role? What role do computational complexity, as well as heuristics and biases in information processing, play? What types of decision environments foster consensus among consensus methods, and thus, permit uncontestedly “democratic” aggregation? How does the practical nonmanipulability (Tideman, 2006) affect the empirical agreement among competing methods?

While many of these cognitive, social and political processes have been studied extensively in other contexts, future research should synergize these fields to make better sense of social choice behavior.

Finally, a large open question concerns the exact policy implications of this research paradigm if, indeed, widespread consensus among consensus methods is validated and begins to be explained.

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