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When Do Groups Get It Right? – On the Epistemic Performance of Voting and Deliberation

Simon Scheller *

Abstract: »*Wann treffen Gruppen richtige Entscheidungen? Über die epistemische Leistungsfähigkeit von Wahl- und Deliberationsverfahren*«. This paper examines the claim that democratic decision making is epistemically valuable. Focussing on communication and voting, circumstances are identified under which groups are able to reliably identify the 'correct alternative.' Employing formal models from social epistemology, group performance under varying conditions in a simple epistemic task is scrutinized. Simulation results show that larger majority requirements can favour the veto power of closed-minded individuals, but can also increase precision in well-functioning groups. Reasonable scepticism against other people's opinions can provide a useful impediment to overly quick convergence onto a false consensus when independent information acquisition is possible.

Keywords: Deliberation, voting, agent-based modeling, group decision making, bounded confidence, social epistemology.

1. Introduction

Group decisions are a central element of social interaction. Be it in political assemblies, company boards, or informal groups: A large number of decisions are not taken by single individuals, but by groups. It is thereby often claimed that such group decisions should be made *democratically*, which is mostly justified on the basis of two distinct arguments. The first argument concerns the *fairness* of democratic procedures: Democratic voting is claimed to be the only way to aggregate individual preferences fairly, since it gives equal weight to individual preferences. However, following Arrow (2012), social choice theory has extensively examined this claim and by and large found that all possible voting rules have substantial inherent flaws (see e.g. Riker 1982).

The second argument (which is also at the focus of this paper) concerns the *epistemic quality* of democratic decisions. Going back to Rousseau's idea of the 'general will' (Rousseau 1964) and following Habermas's deliberative ideal (Habermas 1996), deliberative democrats have frequently claimed that demo-

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cratic decision making results in 'better' decisions: "The decision of majorities about which policies to pursue can provide good evidence about which policies are in fact best" (Cohen 1986, 34) – given that public deliberation is guided by the right principles.

There are two ways of substantiating this claim. On the one hand, *deliberation* facilitates the transmission of information: Individuals can improve their knowledge of an issue by talking to each other which, in turn, improves the group's decision (Elster 1998, 11). On the other hand, the epistemic value of democracy can be located in *voting*: As Condorcet's jury theorem illustrates, larger groups perform better under majority rule – as long as individual knowledge is sufficiently independent and individuals have a better than random-chance of being correct (de Condorcet 1785). Yet, both arguments are not without criticism. Effective information transmission is hindered by a variety of psychological biases, cascading phenomena, or polarization. For Condorcet's jury theorem, the assumption of independence is usually not fulfilled, which renders the theorem broadly without real application.

The goal of this paper is to scrutinize those arguments by means of an agent-based model, in which a group of agents faces the simple, epistemic task of making a choice from a set of discrete options. The stylized process of democratic decision making incorporates communication under bounded confidence (Hegselmann and Krause 2002), and voting in the form of majority voting with varying majority thresholds. In an additional model version, agents can also acquire new evidence as an alternative to communication.

Insightful results are obtained: First, while large majority requirements may increase the chances of correct decisions when communication is functioning, it also increases the chances of gridlock when people are closed-minded about an issue. Second, when external sources of information are available, a certain degree of scepticism against other people's views impedes overly quick convergence onto a false consensus and can therefore improve the group's epistemic performance. This corroborates findings by Zollman (2010). On a methodological dimension, the paper makes a contribution by introducing models from social epistemology to the context of democratic decision making. Overall, the model supports advocating a multidimensional view on democracy, showing how deliberation and voting can be combined efficiently.

To lay out all those points, I contextualize the project by outlining the relevant theories and literature in Section 2, summarizing the main arguments from democratic theory, previous theoretical and empirical findings on the impact of democratic mechanisms, as well as formal models from social epistemology. Section 3 describes the basic model of democratic decision making as communication and voting. In a modified version of the model (Section 4), agents also have the alternative of acquiring independent information. Section 5 concludes by showing how these findings can lead to an augmented understanding of democratic decision making institutions, and how they support the epistemic democrat's claim that democratic procedures result in epistemically superior outcomes.

2. Theory and Literature

2.1 The Epistemic Value of Democracy

Talking about the epistemic quality of group decisions presupposes the existence of some sort of 'objective truth.' As List and Goodin argue,

> [t]he hallmark of the epistemic approach, in all its forms, is its fundamental premise that there exists some procedure-independent fact of the matter as to what the best or right outcome is. (List and Goodin 2001, 4)

While this supposition is frequently discussed, I continue under the assumption that matters with an objective truth exist, as do others, for which this is not the case. Duggan and Martinelli (2001, 260) provide illustrative cases for such truth-issues: a jury deciding about the guilt or innocence of a defendant, or a group of doctors deciding about the best treatment for a patient. In both examples, it is clear that all participants share a common goal, and they discuss the best way of achieving said goal. Thus, the arguments of this paper apply to problems that can be reasonably seen as epistemic problems; and there exist enough relevant problems of this sort to render this discussion relevant.

According to Estlund (2009), epistemic quality of decisions must necessarily be guaranteed in order to legitimize democratic procedures, which is why it is essential to establish the epistemic potency of groups. In political philosophy however, discussions regarding the merits of democratic decisions is often solely a normative endeavour, which is, for example, expressed by List and Goodin: "[a] pure epistemic approach tells us that our social decision rules *ought be chosen* so as to track [the] truth" (List and Goodin 2001, 4, my emphasis).

Regarding deliberation, a range of scholars have provided criteria for optimal deliberative procedures: Habermas's ideal speech situation (Habermas 1996), Rawls's "veil of ignorance" (Rawls 2009), or also Estlund's "imaginary model epistemic deliberation" (Estlund 2009, 175). While these approaches somewhat differ in primary focus and intention, they all prescribe an ideal deliberative procedure that produces desired outcomes if correctly employed.

The same is true for claims regarding the epistemic quality of voting. Condorcet's jury theorem (de Condorcet 1785) provides the key argument: Groups are more likely to make correct decisions under majority rule when the group becomes larger – assuming that individuals are more likely to be right than wrong, and that their individual judgments are probabilistically independent from each other (see e.g. Estlund 2009, 15 for a more detailed description and discussion). However, the theorem is largely dependent upon the fact that the assumptions which it requires are actually fulfilled in a certain situation. If, for example, individual guesses are not independent, the theorem does not say anything about the truth-tracking merits of majority voting.

On that basis, the rest of this paper scrutinizes *deliberation* as a tool of information transmission among groups, and *voting* as a way to aggregate information independently – with regards to their potential to reach better decisions. Doubtlessly, both procedures exhibit a large array of other merits. The work by Elster (1998) constitutes a good starting point for a more extensive overview. However, for the sake of conceptual focus, this stylized description of democratic procedures and the epistemic democrat's claim will constitute the basis of discussion for this paper.

At the same time, there are various alternative ways of exchanging information apart from direct communication. One crucial advantage of exchanging information directly via group communication, however, is that it combines an efficient way of connecting multiple actors as sources and receivers of messages simultaneously. Thus, having a public deliberative forum[1] facilitates the exchange of information in a uniquely efficient way. Apart from its efficiency, a public deliberative forum also provides the immediate opportunity of being subject to a potentially balanced input from all actors. These points motivate the special interest in this form of democratic information exchange.

2.2 Pitfalls and Problems of Deliberative Democracy

In contrast to these optimistic claims about the merits of democratic decision making, there is also a list of problems and pitfalls of deliberation and voting. Being aware of those is a necessary prerequisite to appropriately model democratic procedures on the basis of empirical findings. The following list gives a brief overview of some major issues with group processes.

- *The persuasion bias:* When group members exchange opinions,[2] what weight should one give to other people's opinions, given that information is transferred between multiple individuals along complex channels. Certain pieces of information may therefore receive disproportional attention (Golub and Jackson 2010, 2). As a result, a person's position in a social network – and not just the quality of her information – determines her influence on the group's aggregate beliefs (DeMarzo et al. 2003).
- *The common knowledge effect:* Information that is available to a large number of people is more likely to be accepted, discussed, and empha-

[1] In this context, this does not necessarily have to be in the form of public, personal group deliberation, but can also amount to other forms of exchange.

[2] The terms 'opinion' and 'beliefs' are used interchangeably in the context of this paper since it is explicitly stated that only epistemic matters are addressed here – and purely preferential questions are not, even if some of the described models are usually situated in preferential settings.

sized than less commonly available information (Gigone and Hastie 1993). This potentially leads to a homogenization of opinions, while uncommon opinions are more likely to be dismissed.

- *The social comparison effect:* People desire to be accepted and liked by other individuals in a social group, which some aim to achieve by taking similar opinions to one's peers. Similar to the previous heuristics, social comparison usually results in opinion convergence (Sunstein 2002, 179).
- *Homophily:* People tend to associate more often with people who are like themselves: Two people of the same ethnic background are more likely to get married; Republicans are more likely to exchange opinions with Republicans as opposed to Democrats. Overall, social groups homogenize (Lazarsfeld and Merton 1954). This may have a strong impact on the information one receives (McPherson et al. 2001) and even trigger a self-reinforcing process where people take their opinion itself as a selector for communication partners, and thus self-affirming their own positions.
- *The persuasive argument effect*: Due to her limited capacities, an individual's opinion is based on only a fraction of all available arguments. Since people holding similar sets of arguments can be expected to group around certain positions on the opinion spectrum (homophily), people will frequently be subject to arguments that are supportive of their current position, and much less to arguments that would run counter to their overall view. Hence, selective availability of information from like-minded people produces a confirmatory bias that makes people overconfident in their own opinion (Sunstein 2002, 179).

The described effects constitute a serious threat to the potential merits of deliberation: Contrary to what the arguments by theorists of deliberative democracy suggest, irrational biases and rationally justifiable pitfalls can hinder the efficient aggregation of information. Especially opinion polarization can severely undermine the finding of a rational consensus. One undermining factor is the occurrence of "enclave deliberation" (Sunstein 2006, 186): Within homogeneous, isolated subgroups of people commonly held persuasive arguments increase the members' convictions. Between groups, less interaction takes place. This further polarizes opinions and also the information and arguments people hold and thereby hinders the efficient use of information for group decisions.

Central for the later model description, the essence of the described effects and biases is captured by the bounded confidence model (Hegselmann and Krause 2002, 2006). Their formal model of opinion dynamics is also able to reproduce the described effects of polarization and fragmentation of opinions in groups and requires only very sparse assumptions to do so.

2.3 Literature Review

Looking at the overall picture, positive claims about deliberation and voting are contrasted with serious shortfalls and problems. Assessing the functionality of these tools as democratic mechanisms, scholars have employed formal models and empirical analyses. Economists have studied the interplay between communication and voting, yet with a focus on problems of preference aggregation and information revelation, and hence not for purely epistemic problems (see e.g. Austen-Smith and Feddersen 2006; Doraszelski et al. 2003). Gerardi and Yariv (2007), studying an epistemic group decision problem, find that pre-voting deliberation renders a large class of voting rules equivalent, as long as they are veto-free. While those game theoretic models are able to identify equilibria for a variety of conditions, they capture interaction as a strategic process between fully rational actors. Realising the empirical inadequacy of this supposition, the model in this paper departs from the assumption of perfect rationality.

Goeree and Yariv (2011) find experimental evidence that most voting rules are rendered equivalent when communication takes place. They observe that deliberation uniformly improves efficiency and also diminishes the impact of institutional rules significantly. Interestingly, Guarnaschelli et al. (2000) find evidence for strategic voting under unanimity rule. More generally, empirical evidence on the presence and impact of deliberation is difficult to collect as strategic communication (bargaining) and non-strategic communication (arguing) are in practice hard to distinguish, specifically since they usually occur together (Bächtiger and Wyss 2013, 159). In their survey on empirical deliberation studies, Bächtiger and Wyss (2013) identify a variety of contributions that aim at measuring the occurrence of deliberative behaviour. Yet, when looking for effects of deliberation on the epistemic quality of outcomes in group deliberation, the authors report a general lack of studies (Bächtiger and Wyss 2013, 175). Similarly, Bozbay et al. (2014) report a lack of theoretical works on epistemic problems:

> So far, however, [… the literature] has paid only little attention to a different 'epistemic' approach of aiming to track the truth, i.e., reach true group judgments. The theory does not model the private information underlying voters' judgments, thereby preventing itself from studying questions of efficient information aggregation. Yet such an epistemic perspective seems particularly natural in the context of aggregating judgments (rather than preferences). (Bozbay et al. 2014, 2)

As this short (and far from all-encompassing) literature review suggests, a large potential exists for studies on judgment aggregation and truth-tracking in the context of democratic theory. Interestingly enough, such epistemic questions have been taken up by philosophers under the label of 'social epistemology': Scholars of this field envisage science as a process of social knowledge creation, circling around the question of "whether we ought to let our opinions be guided, even if only partly, by those of others" (Douven and Riegler 2009, 326). This question is equally central for considerations in the context of democratic theory.

Scholars of social epistemology frequently employ *formal models* to study truth-tracking capacities of different network structures, information exchange procedures or group constellations. Those formal, often agent-based simulation models have the advantage of providing tools to study concrete procedures and mechanisms in a stylized fashion. When it comes to evaluating democratic procedures, previous literature on democratic theory can merely hope for the merits of deliberation to overcome the shortfalls of social influence. Formal models, in contrast, can help to actually identify circumstances under which groups function well in epistemic tasks, and how certain arguments counterbalance each other.

Muldoon (2013) summarizes the main streams in the literature on social epistemology, of which some will be briefly touched upon here. Weisberg and Muldoon (2009) model science's search for truth as a search for the "highest points" on an "epistemic landscape." Scientists can explore unknown territory or follow others in order to reach states of 'higher' knowledge, while they are driven by a self-interest to be credited for good results. This choice between exploring or following could be translated into a choice between researching or communicating, which informs the extended model in this paper (Section 4).

Others have focused on the role and emergence of consensus in science and society. A baseline model of consensus formation has been presented by Lehrer and Wagner (1981). Although not initially intended as such, their model was later interpreted as depicting communication among scientists as an iterated, weighted updating procedure of individual opinions. Each individual takes into account every other individual's opinion with a certain non-zero weight. Simultaneous and repeated updating can be shown to result in convergence to consensus. French (1956) and DeGroot (1974) describe similar dynamic models.

Zollman (2010) introduces network structures for modelling communication in scientific communities, where agents update their beliefs in a Bayesian fashion. Surprisingly, he finds that fewer connections between agents can be beneficial for reaching the correct solution as this prevents overly quick convergence onto a potentially false consensus, which in turn allows for broader diversity in exploring alternative possibilities.

Hegselmann and Krause (2002) describe a model of opinion dynamics, in which agents communicate by averaging their opinion and those of others. However, they average only with those others that have sufficiently similar opinions than themselves. The psychological effects from above provide an empirical foundation for the model formalization that was chosen: The fact that people only talk to like-minded others can be seen as a clear instance of homophilious behaviour or resulting from social comparison. As information is exchanged more frequently among like-minded people, they will be subject to the common knowledge effect, the persuasion bias, and the persuasive argument effect alike. Further, agents update opinions by simple myopic averaging over all opinions they consider. Thus, modelling behaviour in this way incorporates the empirically found biases from above, especially when it comes to the agent's limited processing capacities and the described affective, non-rational behavioural patterns.

In a model extension, some agents are "attracted" by the true value of the parameter they seek to identify, while regular agents still solely "follow" others in their opinion (Hegselmann and Krause 2006). Notably, a relatively small number of truth-seekers is sufficient for the convergence of the group onto the correct consensus. A feature similar to this extension will also be part of the second model version to be presented below.

While those models have been employed for answering questions about convergence on true scientific knowledge in society, my goal in this paper is to apply such model structures to questions of democratic theory and of group decision making. This lays the ground for studying the efficiency and effectiveness of different decision making rules and communication schemes in producing correct outcomes.

3. The Baseline Model

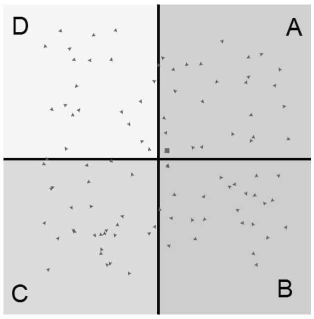
3.1 Model Description

The model at hand is based on a simplistic epistemic problem: A group of agents faces a choice between four options *A*, *B*, *C*, and *D*. These options are graphically represented by the four quadrants of a coordinate system. Further, an optimal point *O* exists with the coordinates (x_o, y_o), which lies in one of the four quadrants. The task of the group is to find out in which of the quadrants the optimal point lies.

Each agent receives an independent signal for the coordinates of *O*. The signal for the *x*-coordinate is given by a random draw from the uniform distribution from the interval [$x_o – 50; x_o + 50$]. Analogously, the signal for the *y*-coordinate is given by a random draw from the uniform distribution from the interval [$y_o – 50; y_o + 50$]. Thus, a position on the two-dimensional plain with the four quadrants can be ascribed to each agent, enabling a neat graphical representation of the epistemic problem. The agent's position thereby represents her best guess for the true value of *O*.

For the subsequent simulations, the optimal point is fixed at (*3, 3*) in order to keep the epistemic problem's difficulty and each individual's primary chance of making a correct judgment constant. The model screenshot in Figure 1 depicts an exemplary random distribution of 100 agents on the opinion space. The optimal point *O* at (*3, 3*) is marked by the grey square in the bottom left corner of the top right quadrant *A*.

Figure 1: Graphic Illustration of the Underlying Epistemic Problem



An intuitive interpretation of such a problem would be a choice between policies, the utility of which is determined by two separate utility dimensions with linearly decreasing marginal utility. For example, imagine a city council that needs to evaluate different project proposals for a railway extension with regards to the dimensions cost and environmental impact, and needs to choose one of those discrete options. Each option must be evaluated regarding both dimensions, and the people need to judge what combination provides an optimal solution.

At the beginning of each round, all agents take a vote on the four discrete options. Each agent votes for the option she considers best, i.e. the quadrant she is located in. An agent's position, in turn, is based on all the signals she has previously had access to, and agents are assumed to vote solely based on that opinion without any strategic or other considerations.[3] As soon as one of the options reaches the necessary quorum of votes, this option is considered the group's choice.[4]

If no qualified majority is found in a vote, agents have the possibility to communicate. They do this by "proclaiming" their current position to all other agents. However, communication works under a setting of bounded confidence (Hegselmann and Krause 2002): Agents listen only to other agents which have beliefs that are similar enough to their own beliefs. More specifically, an agent listens to another agent if the distance between them is smaller than ε. Techni-

3 Austen-Smith and Banks (1996) challenge the assumption that each agent simply votes for her preferred option as irrational under certain circumstances. This shall, however, be of no further concern in this paper, and a myopic and heuristic-based decision behaviour is prescribed for the agents, as for instance in Zollman (2010, 2013), and most importantly because it is considered the more realistic behavioural assumption for epistemic questions.

4 If more than two options reach the quorum at the same time (which is only possible if no absolute majority is required), the option with most votes is chosen. If two or more quorum-reaching alternatives tie, the winner is picked randomly between these options. These special cases are very rare and have no impact on the model analysis.

cally, the parameter ε describes a circle-shaped area with radius ε around an agent's position. All agents within this area are considered for opinion updating, all agents outside of this circle are ignored. A small ε-value therefore means that an agent listens only to others with very similar opinions, while a large ε describes an agent that is much more open for contrasting or contradictory information.

Updating occurs by simple averaging over all considered agents, including the agent itself. All communication and updating happens simultaneously. Each communication round is followed by another vote. This iterated process continues until the majority threshold is reached, or is terminated if no more communication occurs, i.e. if agents either have the identical positions or do not listen to each other. Failure to reach the necessary quorum when communication breaks down is counted as an incorrect decision. As soon as a decision is made, new random initial signals are allocated and the process starts anew. Thus, all individual decisions are independent from each other. This completes the description of the baseline model.

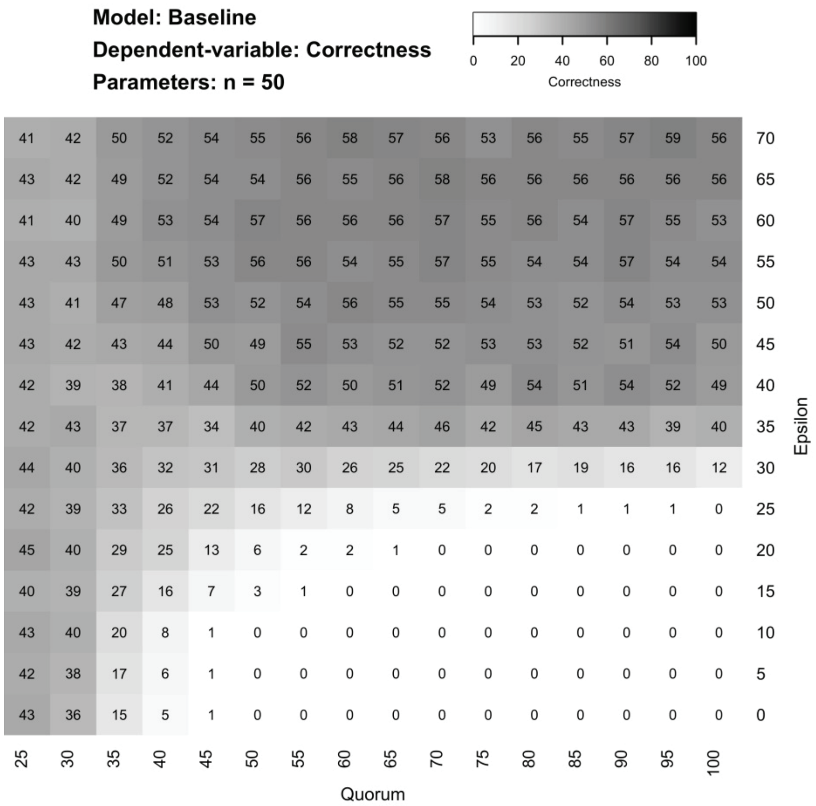
3.2 Results

This first analysis incorporates two parameters which supposedly influence the epistemic performance of groups. These are the *quorum*, i.e. the majority threshold that is required for a decision to be made, and *ε*, which describes how open individual agents are for divergent opinions. These parameters constitute the independent variables of the experiment. For each parameter constellation, 1,000 individual decision problems were simulated, each decision problem with a randomly assigned distribution of initial signals. As argued, the optimal point *O* remains the same for all problems in order to guarantee comparability.

Epistemic group performance is measured by the probability of making a correct decision (i.e. to choose option *A*) under a given parametrisation, labelled *correctness*. To evaluate efficiency of the procedures, the variable *time* measures the average number of communication rounds until a decision is made – regardless of whether the decision is right or wrong. *Correctness* and time constitute the dependent variables of the experiment. The interest of the analysis therefore lies on how *ε* and the *quorum* influence *correctness* and *time*. In Figure 2, the *quorum* is depicted on the *x*-axis; *ε* is located on the *y*-axis. *Correctness* is displayed in the resulting grid and illustrated by color-coding. Figure 2 shows results for a group of 50 agents.[5]

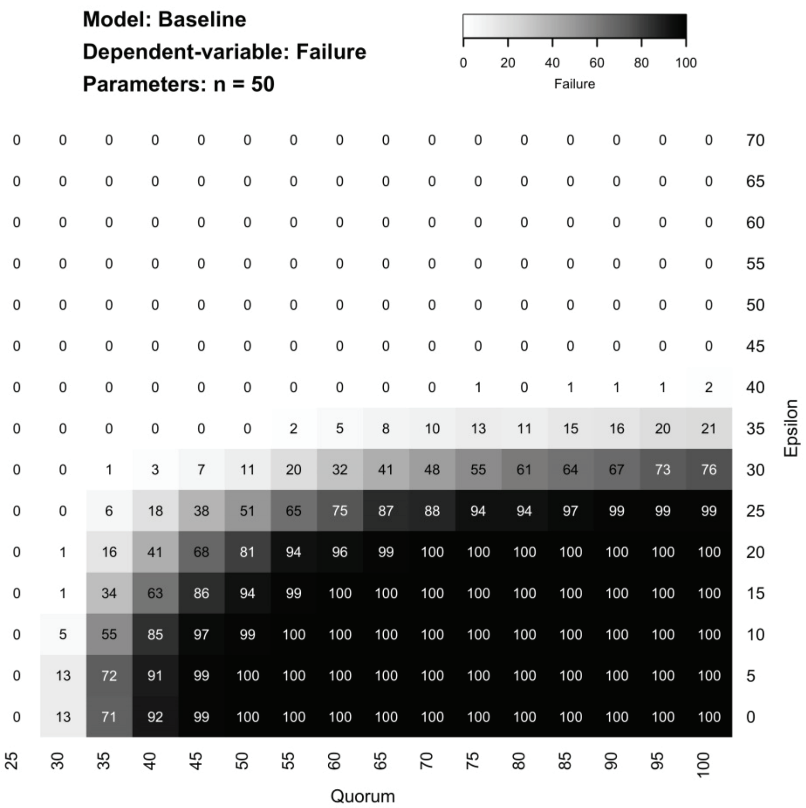
[5] In a series of robustness checks, increasing the number of agents significantly increased correctness, and decreased correctness for smaller groups. This corroborates classic jury-theorem findings, since more agents offer a larger pool of information, individual errors are more likely to cancel out, and thus more people increase the likelihood of a correct group decision. For the analysis of this paper, detailed results regarding the impact of group size were omitted for the sake of focus and simplicity.

Figure 2: Correctness Results in the Baseline Model



The most striking feature of Figure 2 is twofold: First, no correct decisions are reached for small ε and a large enough *quorum* (bottom right corner). As it turns out, this stems from failures to reach a decision (see Figure 3): For small ε, it is very likely that agents do not communicate with each other since they are outside each other's confidence bounds. Thus, if the necessary quorum is not reached already at the outset, the lack of communication prevents the formation of the necessary majority. The larger the required majority, the more likely this scenario becomes.

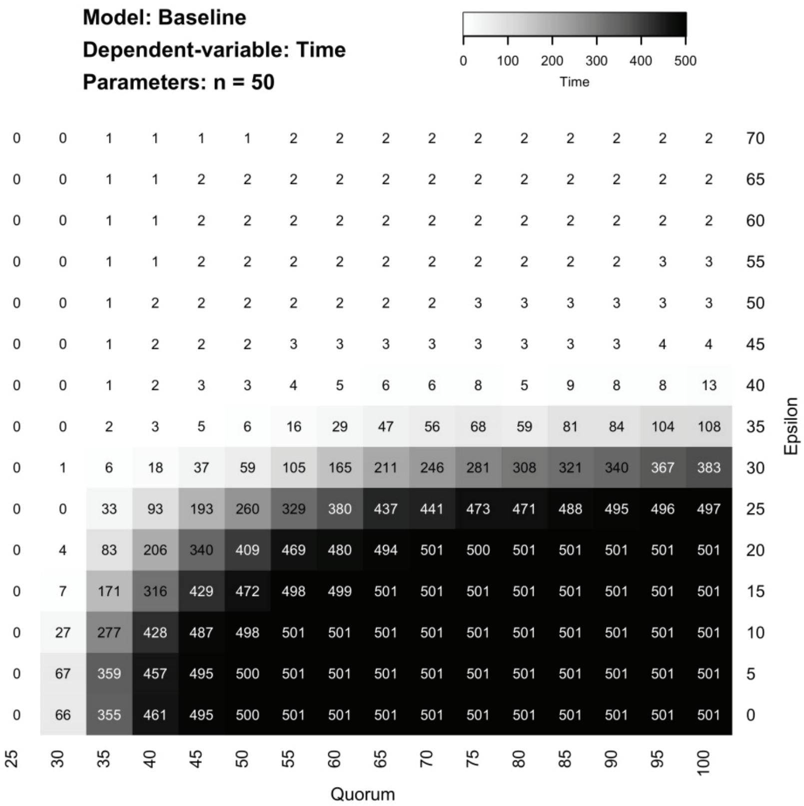
Figure 3: Failure Results in the Baseline Model



Second, apart from the parameter area where the group fails to make a decision, ε appears to have a slight positive effect on *correctness*. Unbiased communication, in this scenario, seems to be at least not worse than being sceptical against alternative opinions.

The impact of *quorum*-size is similarly small, yet a clear and strong positive impact occurs when the quorum is increased from 30% to 35%. Here, the quorum enables communication to happen in the first place, since for a 30%-threshold, a decision is usually already found in the very first vote and hence without any communication taking place. A large enough *quorum* thus forces people to communicate. Yet, this can work only if people are also willing to communicate (e.g., if ε is large enough). For small ε-values, the larger quorum causes failure to reach a majority. Even larger *quora* do not seem to make any further difference for *correctness*, and only increase the chances of gridlock.

Figure 4: Time Results in the Baseline Model



Decisions are found very quickly for large and very small ε-values (see Figure 4): For large ε, discussion is very efficient and does not take much time. For very small ε, no communication occurs anyway. Thus, either a decision is found relatively quickly – or not at all. Only for intermediate values of ε, decisions take up to 11 communication rounds. This behaviour stems from the basic mechanics of bounded-confidence updating process: Opinion convergence is slowest when ε-intervals are large enough to connect some agents, yet small enough not to connect too many agents at the same time. Then, as also described by Hegselmann and Krause (2002), opinions converge over multiple steps. The more they converge, the more likely it becomes that the necessary *quorum* is reached, and, of course, the larger the *quorum*, the more convergence is required.

Unfortunately, longer discussions do not promote better decisions in this model. For those intermediate ε-parametrizations, no decision is reached even after this longer time. The intermediate values of ε lead to polarization between only a few points of attraction, which explains why communication takes longer. It also explains why there is no success eventually: When a small number of clusters forms, one of them needs to be much larger than the rest so as to attract enough agents for the quorum to be reached. The larger the quorum, the less likely this becomes. Thus, looking at the interplay of *time* and *correctness* implies that there is not really a trade-off between quicker yet less precise or slower yet more precise decision mechanisms in this version of the model. This is due to the specific dynamics of the bounded confidence process, which either leads to culmination in one point rather quickly – or not at all. Interestingly, this replicates findings by Golub and Jackson (2010). Their model is based on network structures that are subject to naive opinion updating on the basis of DeGroot (1974). The authors equally report that the time of convergence and whether or not the group converges onto the correct solution are usually independent.

4. The Research-Talk Model

4.1 Model Description and Background

In the baseline model, agents change their views only through communication. As has become obvious in the analysis, the time dimension could not be reasonably interpreted. One major reason for this is that communication has no opportunity cost, since time cannot be spent any other way. This is clearly not a realistic depiction of decision making in reality. A logical alternative choice of action is suggested once again by the theory of social epistemology, which models the scientific process as communication and *individual information acquisition by independent research* (see e.g. Hegselmann and Krause 2006; Weisberg and Muldoon 2009; Zollman 2010). The idea translates easily to the context of democratic decision making: Alternative to receiving information from others, people also have the possibility to collect information independently. This setting allows comparing whether time should be better spent researching or communicating. In practice, independent information acquisition can refer to collecting data, visiting the location of an infrastructure project, or simply researching a subject on the internet or by other sources. For the formal model, it is deliberately left open what specific actions 'researching' adheres to.

Formally, whether an agent communicates or researches is decided probabilistically before each round. The probability that the agent chooses to research is given by the parameter *pr*, which is externally set and equal for each agent. If, for example, $pr = 0.3$, an agent will choose the option research with a probability of 30%, and communicate with a probability of 70%. If *pr* = 0, all agents will communicate all the time, which is equivalent to the baseline model. If *pr* = 1, all agents will perform research all the time and never communicate. The random choices of individual agents are independent from each other.

When an agent researches, the distance between her current 'best guess' and the true optimal point *O* is reduced by one percent.[6] In other words, researching moves the agent's position one percent closer to the true value. This is in close analogy to Hegselmann and Krause (2006), who capture researching by the parameter α.

The communication process itself remains unchanged. However, note that researching agents are excluded from the communication process for the round in which they perform research. Other agents do not receive signals about their positions and can, hence, not be considered by communicating agents.[7]

Further, a new criterion for decision-failure must be provided, since infinite researching would potentially stretch the decision process tremendously. This not only exhausts computational resources quickly, but is also unrealistic in the context of democratic decision making: After a certain time, groups can be expected to terminate a decision process when no agreement is found. A similar argument for process termination is employed by Zollman (2010, 31). I choose 500 rounds as the limit after which a decision process counts as failed.[8]

4.2 Results

Figures 5 and 6 display results for the extended model in the same way as before: The *x*-axis displays the *quorum*, the *y*-axis ε. To study the impact of the new parameter *pr*, a series of these plots for various values of *pr* is presented. For the analysis, I focus on the most interesting similarities and differences to the reference model without research.

For small probabilities of research and high enough *quora*, the parameter area where the group fails to find agreement remains. However, failure can be

6 Robustness checks have shown that manipulating this one-percent value changes merely the relative strength of certain effects and for what parameter regions they occur, but it does not qualitatively alter any of the core results.

7 A similar probabilistic setup was proposed by Douven and Riegler (2009) as an extension to the bounded-confidence model. Here, the model diverges from the specification by Hegselmann and Krause (2006), in which agents take a weighted average between researched and communicated information. Arguably, it is more realistic when an agent has to pick how to spend her time and therefore makes a choice between two discrete options. This may potentially also have interesting effects on the outcome since certain agents are temporarily excluded from the communication process.

8 The impact of the decision time limit plays a major role for the results, and has been extensively analysed as part of the robustness analysis. While severe quantitative shifts in the results do occur, the quality of the results remains the same as long as they are not overruled by predictable effects of a significantly shorter or longer time limit.

eliminated by increasing *pr*, as shown in Figure 5: Already for *pr* = 0.6, gridlock hardly occurs. This, however, comes with a cost: As Figure 6 shows, time strongly increases with larger *pr* and when ε is small. Had the maximum *decision-time* been lower, failures would occur more often.

Thus, a high research probability is beneficial if ε is small – a result that makes intuitive sense: Collecting one's own evidence is superior when communication does not work. Put the other way round: When ε is too small for agents to be connected, individual research can help to bridge the gap.

Figure 5: Correctness Results in the Research-Talk Model for Varying *pr*

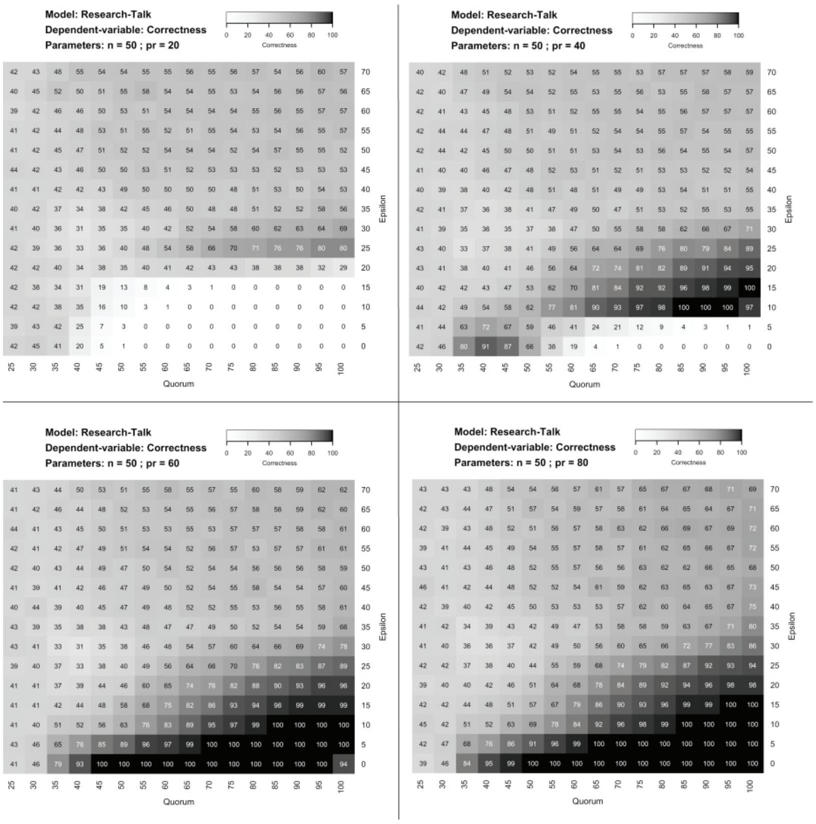
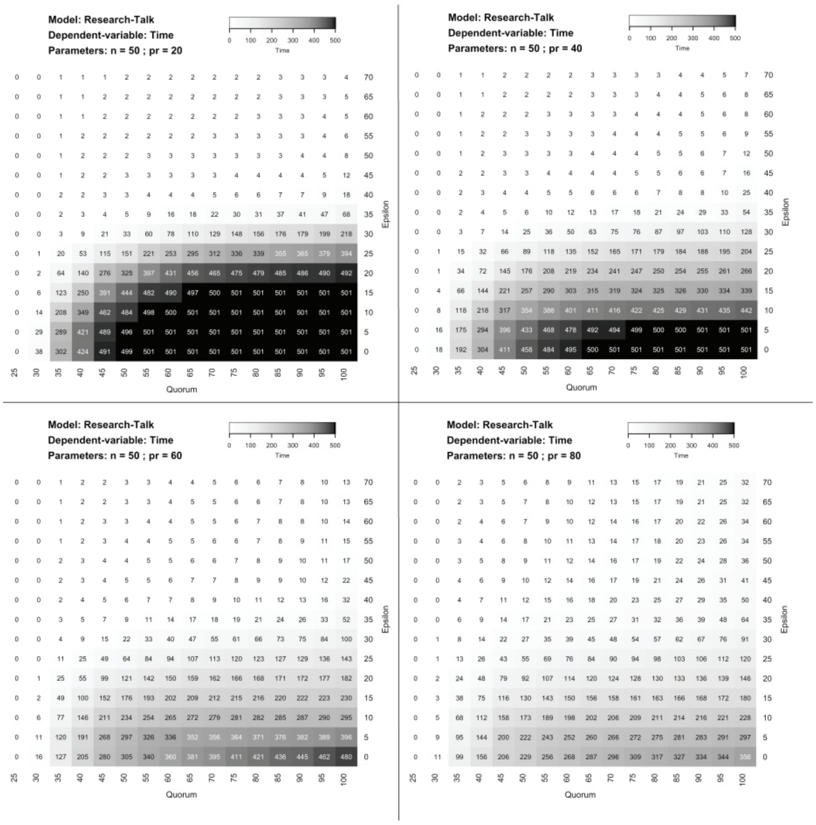


Figure 6: Decision-Time in the Research-Talk Model for *pr* = 40



The simulation also shows that the group performs better for moderate ε-values compared to both small and large values of ε if only some research is possible ($pr < 0.4$). How is this possible? I argue that this replicates findings by Zollman (2010) that less densely connected epistemic communities exhibit a better performance since they do not converge onto a 'false consensus' too quickly but give the group enough time to gather independent information. For larger *ε*, a rash decision would be made before agents had enough time to carry out sufficient independent research. For smaller *ε*, time becomes a strong determinant factor, in some cases leading to failure to find agreement, and generally rendering the process much less efficient. Too much independent research also slows down the process indirectly: Since fewer agents enter the communication arena, and the larger gaps between fewer agents reduces the amount of communication that takes place in a given round. In conclusion, a reasonable degree of scepticism against socially gathered information impedes herding effects and information cascades, while still being able to benefit from other people's input.

While the previous considerations are mostly applicable to large *quora*, more research is a feasible tool for smaller majority requirements. For example, pure research already performs really well when a 40% threshold is required. A focus on communication is therefore more efficient if large *quora* must be met. For lower requirements, more researching can result in a better performance.

In summary, the extended model enables studying the trade-off between correctness and time systematically and implies the following conclusions: Well-functioning and unbiased *communication* provides an efficient epistemic tool. Yet, it can be prone to convergence onto a false consensus if too little independent information is fed into the process. *Independent researching*, in contrast, makes the epistemic process more precise at the cost of slowing down the decision making process. Stricter majority requirements can make a process more reliable, but also slower and more failure-prone. When a large threshold-level is externally given, communication provides an efficient means for meeting such a demanding requirement. In a larger context, these findings justify a perspective on democracy that argues for a multi-faceted view on democratic procedures: While combining the beneficial effects of voting and deliberation as described by the Condorcet jury theorem and deliberative democrats is generally possible, the model analysis illustrates that voting and talking cannot be combined arbitrarily.

5. Conclusion

Deliberation and voting play a central role in arguing for the epistemic quality of democratic decision making processes. Yet, empirical findings suggest broad potential for various pitfalls in the processes. The described agent-based model provides a vehicle that allows for a more balanced view on the merits and problems of voting and deliberation, and to disentangle interaction effect between the two. This paper thereby provides a multi-faceted perspective on democratic decision making, combining seminal works from political philosophy, psychology, and social epistemology.

By studying the interplay between voting rules and communication structures, insightful perspectives on democratic decision making are obtained. Consider for instance the impact of majority requirements: Unanimity is often argued for on the basis that nobody's opinion can be overruled. This might grant it the attribute of inclusiveness. Quite to the contrary, the model analysis highlights that large majority requirements lend strong veto powers to closed-minded individuals with extreme views. As long as people are open to communicating with each other, large *quora* can augment a group's epistemic capacities. However, if people's opinions polarize as a result of a lack of openness, strict majority requirements can also lead to gridlock and standstill by granting a veto power to closed-minded people.

Does this mean that scepticism against other opinions is generally bad? As has been shown, moderate openness to communication can be superior to too much or too little openness by preventing the group from converging onto a false consensus too quickly. A balanced mix between independent information collection and dissemination can thus impede the occurrence of group think phenomena, information cascades, and other herding tendencies. This corroborates findings by Zollman (2010), who finds similar results with regards to less densely connected communication networks. For this to work, however, reliable external sources of information must be available.

Taking such insights into account when choosing problem specific decision making rules makes for better institutional designs. This paper's analysis can thus inform structural decisions in politics and elsewhere. Additionally, such models can provide conceptual understanding for real world phenomena, such as the functioning or failure of expert groups, political committees, or other decision making bodies.

From a methodological perspective, the model illustrates how agent-based simulations can contribute structure and substance to arguments that are hard to underpin empirically. Certainly, no purely theoretical model can appropriately substitute empirical data, and the model's high degree of abstraction implies that applications to real world cases cannot be made easily. Yet, when there is no well-founded basis on which to make a claim (in the present case: the epistemic quality of group decisions), it is better to make an argument on the basis of a clearly outlined, hypothetical scenario that captures a broad range of possibilities, rather than to make a claim on no basis at all. At the same time, there is an independent quality in identifying and understanding the causal structures underlying a certain process. In an abstract model, central causal effects can be focussed on while ignoring 'empirical noise.' Analysing such a model can help to highlight certain causal mechanisms and how they influence outcomes in a sense of studying the fundamental building blocks in a complexly interacting system. In doing so, potential causal explanations for certain real world phenomena can be presented.

In a larger framework, this paper also feeds into a justification of democratic decision making for epistemic groups. By employing formal models from social epistemology, it is shown that communication and voting structures can produce epistemically superior outcomes. Cohen's initially quoted suggestion that "the decision of majorities about which policies to pursue can provide good evidence about which policies are in fact best" (Cohen 1986, 34) can therefore not only be confirmed, it can also be made concrete and substantiated by the model. The findings from the model go beyond the classic jury-theorem-results by also considering the impact of communication style (especially openness for other opinions) and different decision rules. Additionally, time is introduced as a dimension of analysis. This allows for the evaluation of questions regarding the efficiency of decision making schemes. Thus, one can not only say how groups can get it right, but also what an efficient decisions procedure for a certain group should look like, and how certain pitfalls can be overcome.

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