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Multiple votes, ballot truncation and the two-party system: an experiment

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Abstract Duverger's law states that Plurality Voting tends to favor a two-party system. We conducted laboratory experiments to study whether voting procedures other than Plurality Voting could favor a two-party system as well. Plurality Voting is compared with Approval Voting and Dual Voting, both of which allow to vote for multiple candidates, but differ in whether voters are required to cast all their votes. We find that in most elections held under Plurality Voting and Approval Voting, at most two candidates are viable. By contrast, three candidates are viable in a sizable number of elections held under Dual Voting due to strategic voting. Our evidence suggests that Approval Voting may encourage a two-party system, whereas Dual Voting may encourage multipartism. The voters' ability to truncate ballots (i.e., not cast all their votes) is essential for supporting the two-party system under Approval Voting.

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1 Introduction

Constitutional rules have a significant impact on economic policy-making. Empirical studies have shown that a relationship exists between the effective number of parties and macro-economic variables such as the levels of public deficit and income inequality or the composition of public spending (Lizzeri and Persico 2001; Persson and Tabellini 2003). This paper contributes to understanding how voting procedures affect the political party system. Using a laboratory setting, we compare the effect of several widely discussed voting procedures on the number of viable parties.

Countries that elect their policy-makers by means of Plurality Voting—i.e., the voting procedure where every voter votes for one candidate—tend to have a two-party system. This empirical regularity is known as Duverger's law, which states that "the simple-majority single-ballot system [i.e., Plurality Voting] favors the two-party system" (Duverger 1954, p. 217). This is certainly true in the US with the Democratic and Republican parties.

Some political activists and scholars advocate replacing Plurality Voting with other voting procedures that would allow or force people to vote for more than one candidate. Such electoral reforms have been passed in several countries and municipalities (e.g. New Zealand, San Francisco) and have recently been the object of referenda in two Canadian provinces (British Columbia and Ontario). Electoral reforms are also advocated by several citizens associations (e.g. *Citizens for Approval Voting*). The argument in support of such an electoral reform is based on the following wasting-the-vote effect of Plurality Voting. In Plurality Voting elections, a voter whose most-preferred candidate has no chance of winning the election would waste her vote by casting it for that candidate. Such a voter has therefore an incentive to act strategically and vote for another candidate that she may like less but whose electoral prospects are better. This wasting-the-vote effect of Plurality Voting is said to create a barrier to third-party candidates, even if the candidate is preferred by all voters.[1] The argument then goes that if voters were given several votes to cast for the different candidates, they would no longer fear wasting a vote on a third-party candidate, which would therefore help such a candidate.

Others advise against letting people vote for multiple candidates. They warn that lifting the barriers to third-party candidates would trigger a proliferation of parties. Multipartism could then give rise to coalition governments and the inefficiencies that are often associated with this form of government, e.g. Roubini and Sachs (1989). Since candidates can be elected with less votes in a multiparty system than in a two-party system, inequality could then be on the rise. This is because candidates would have an incentive to target electoral promises to smaller groups of voters, e.g. Lizzeri and Persico (2005).

This paper contributes to the debate on whether letting people vote for multiple candidates would encourage bipartism or multipartism. A common formal interpretation

[1] For theoretical contributions explaining Duverger's law by the strategic behavior of voters, see e.g. Palfrey (1989), Feddersen (1992), Myerson and Weber (1993), Fey (1997). Myerson writes: "...there can be a self-fulfilling prophecy that a vote for the third candidate would be a wasted vote, so that each voter should vote for his preferred among the two established candidates" (Myerson 1999, p. 681).

of Duverger's law is that in Plurality Voting elections, only two parties *receive votes;* e.g. Palfrey (1989), Feddersen (1992), Myerson and Weber (1993). As Myatt (2007) points out however, it is rare to observe a full concentration of votes on only two candidates; trailing candidates usually receive a non-negligible share of the votes. This is confirmed by Hirano and Snyder (2007) who provide empirical evidence that in Plurality Voting elections third-party candidates receive votes. Our analysis of a two-party system takes the latter observation into account, and focuses on the upper-bound on the number of *viable* competitors. A voting procedure may, in the long run, encourage a two-party system if in every election, voter behavior limits to two the number of viable candidates. By contrast, a voting procedure may encourage multipartism if more than two candidates can be viable in elections. We therefore say that a voting procedure yields a two-party system if in any election at most two political parties have their candidates elected with positive probability.

Contrary to conventional wisdom, the theoretical results in Dellis (2007) suggest that voting procedures that let people vote for multiple candidates need not encourage multipartism. Dellis studies scoring rules, a large class of commonly used and studied voting procedures (e.g. Cox 1987; Myerson 2002) that include Plurality Voting and many of its frequently-discussed alternatives. Under a scoring rule, every voter has a set of scores to cast for the different candidates, and the candidate whose total score is the highest wins the election. All scoring rules differ only in the type of ballot a voter can cast; thus, by comparing scoring rules we can isolate the effect of the ballot structure on election outcomes. Assuming a unidimensional policy space,[2] Dellis identifies two classes of scoring rules for which, under standard assumptions on voters' preferences, every equilibrium has at most two political parties with viable candidates. One class includes all the scoring rules under which every voter has a unique maximal top-score vote to cast; Plurality Voting belongs to this class.[3] The other class of scoring rules that yields a two-party system consists of all the scoring rules that admit truncated ballots (allow partial abstention); that is, do not force voters to cast all their scores. An example of such scoring rule is Approval Voting, under which a voter can vote for as many candidates as she wishes. Finally, under all scoring rules that belong to neither of these two classes, voter behavior can lead to more than two viable parties—i.e., parties with viable candidates—and, therefore, may encourage multipartism. Examples are: Dual Voting, under which a voter must vote for exactly two candidates; and Negative Voting, under which a voter must vote for all except one of the candidates. These predictions apply not only to settings that focus solely on voter behavior (Dellis 2007), but also to settings where both voter and candidate behaviors are endogenous (Dellis 2009).

This paper reports the results of a laboratory experiment that tests the above theoretical predictions. We use the experimental laboratory to compare voter behavior and the resulting number of viable candidates under three distinct scoring rules:

[2] Empirical works have shown that citizens' preferences over the different issues tend to be strongly correlated. It has therefore been suggested that assuming a unidimensional policy space need not be restrictive, e.g. Cox (1990), Hinich and Munger (1994) and Bowler et al. (2009).

[3] Other examples of such scoring rules are the Borda Count and Cumulative Voting. We do not consider these rules in the present study.

Plurality Voting, Approval Voting and Dual Voting. We focus on voter behavior, with the set of candidates and their positions given exogenously, as a step towards a more general study of the effect of the voting rules on the number of viable parties. The choice of the voting rules is motivated by three factors: (1) interest from the theoretical perspective; (2) historical precedence; and (3) interest in academic and popular debates. Plurality Voting is chosen as a benchmark; it is also an example of a scoring rule that requires unique maximal top-score vote to cast and thus belongs to the first class identified by Dellis (2007). Approval Voting is chosen as one of the commonly discussed alternatives to Plurality Voting (Brams and Fishburn 1978; Forsythe et al. 1996; Laslier and Van der straeten 2008); it is currently used by several academic and professional associations to elect their officers. Approval Voting is also a scoring rule that admits truncated ballots and thus belongs to the second class of scoring rules yielding a two-party system as identified by Dellis (2007). Finally, Dual Voting, which is also identical to Negative Voting in the three-candidate setting that we study, is chosen as a scoring rule that belongs to neither class and thus may lead to more than two viable candidates and encourage a multiparty system; in fact, in the three-candidate setting Dual (Negative) Voting is the only scoring rule that may encourage multipartism. Dual and Negative Voting procedures have both historical precedence and have generated interest in the theoretical voting literature. Specifically, a procedure close to Dual Voting, where electors were required to vote for exactly two candidates, was used in the first four US presidential elections during 1788–1800 (Nagel 2007). Negative Voting (which is equivalent to voting against one candidate) is of theoretical interest as it is the polar example to Plurality Voting (voting for one candidate).[4] As such, it has been widely studied in the theoretical literature under a variety of names ("negative voting:" Cox (1987), Myerson (2002); "single-negative voting:" Myerson (1999), Austen-Smith and Banks (2005); "anti-plurality voting:" Saari (2000), Regenwetter and Tsetlin (2004), Gaertner (2006)). In the three-candidate setting that we study, Dual (Negative) Voting is also identical to Approval Voting, except it does not admit truncated ballots. This allows us to test whether Dual Voting may lead to a different number of viable parties as compared to Approval Voting, and thus isolate the role of ballot truncation in Approval Voting. To the best of our knowledge, the effect of the ballot truncation has not been studied in the literature before. We show that it is an important feature that may affect election outcomes.

Most experimental work on voting in elections focuses on Plurality Voting, and studies voter behavior under incomplete information and the informational or coordinating role of past elections (Collier et al. 1987; Forsythe et al. 1993), pre-election polls, ballot position, campaign contributions (Forsythe et al. 1993; Rietz et al. 1998) or sequential voting (Morton and Williams 1999; Battaglini et al. 2007).[5] Several studies compare voting rules in multicandidate elections; see Palfrey (2006)

[4] This is best stated by Myerson (1999, p. 675) who writes: "Such negative voting is rarely used, but it offers a nice theoretical contrast with single-positive voting. In our theoretical modeling, we will see some compelling reasons why single-negative voting should not be used in democratic elections. But that is why we want to have a theory of electoral systems: to enable us to see the problems that may be generated by an electoral system before it is used."

[5] Our focus here is on voting behavior in elections; we therefore do not review many other important contributions to experimental political science; see, e.g., Palfrey (2006), for a review.

and Rietz (2008) for comprehensive surveys. Rapoport et al. (1991) study sincere and strategic voting under Plurality and Approval Voting; they report that both types of voting are common in their experiments. Forsythe et al. (1996) compare vote coordination in three-candidate elections under Plurality Voting, Approval Voting, and the Borda Count. They find that close three-way races among candidates occur more frequently under Approval Voting and the Borda Count than under Plurality Voting. Unlike Forsythe et al. (1996), our analysis considers situations where the policy space is unidimensional and voters' utility functions are concave. Van der Straeten et al. (2010) study strategic voting behavior in five-candidate elections under Plurality Voting, Plurality Runoff, Approval Voting, and Single Transferable Vote. Unlike Van der Straeten et al. (2010), our analysis considers how the possibility to truncate one's ballot affects voters' strategic behavior and, in turn, the party structure.

The present paper yields several interesting results. First, we clearly observe that the voting procedures differ in their effect on the number of viable candidates in elections. We find that the evidence in favor of a two-party system is the strongest for Plurality Voting, followed by Approval Voting, while the evidence in favor of a multiparty system is the strongest for Dual Voting. In most elections held under Plurality and Approval Voting, there were at most two viable candidates. By contrast, in a sizable number of elections under Dual Voting, votes were split equally or almost equally among all three candidates.

We further show that the greater number of viable candidates in Dual Voting elections compared to Plurality and Approval Voting elections is the result of strategic voting behavior. Dellis (2007) attributes the possibility of multipartism in Dual Voting elections to the fact that those voters who decide to vote cannot truncate their ballots and are thus *forced* to vote for two candidates. The voters who prefer a three-way tie to the outright election of their second most-preferred candidate are then led to cast one of their two votes for their most-preferred candidate and dump their second vote on their least-preferred candidate; thus, an equilibrium that involves a three-way tie among candidates may exist. By contrast, such vote dumping should not occur in Plurality and Approval Voting elections because here voters can truncate their ballots and therefore are not forced to vote for more than one candidate. Consistent with this argument, we find strong evidence of strategic vote dumping in Dual Voting elections, but not in Plurality and Approval Voting elections. This suggests that the voters' ability to truncate ballots is essential for Approval Voting to encourage bipartism.

Our experiments also yield some unanticipated results. Notable among these is a strong presence of the middle candidate—i.e., the candidate whose platform lies between the platforms of the other two candidates—among winners under all three voting procedures. Due to multiplicity of equilibria, this focal effect of the middle candidate is not anticipated (even though it is not ruled out either) by the Nash equilibrium theory, even if voters are assumed to use weakly undominated voting strategies.

We further gain some insights into individual voting behavior and voter ability to understand different voting rules. A common practice in the formal voting literature is to assume that people do not cast weakly dominated ballots, that is, ballots that can never affect the electoral outcome in the person's favor compared to some other ballot. Consistent with previous experiments (e.g., Forsythe et al. 1996), we find strong evidence in support of this assumption in the case of Plurality Voting. However, we find that sizeable numbers of weakly dominated ballots were cast in Dual and Approval Voting elections. Moreover, this phenomenon persisted with subject experience in the case of Approval Voting. We argue that this can be explained by voters' low incentives not to cast weakly dominated ballots under Approval Voting, as their payoff consequences of doing so were often negligible. We also find that in spite of a high number of weakly dominated ballots, the aggregate election outcomes under Approval Voting were mostly consistent with Nash equilibria in weakly undominated strategies.

As any study, this work has some limitations. First, we focus on voter behavior and not candidate behavior. Adding the candidate competition aspect in comparing different voting procedures is important but is left for further research. Second, we establish that *in some cases* voting procedures that do not admit truncated ballots, such as Dual Voting, may encourage multipartism. We do not address the question of how likely multipartism is to take place under Dual Voting under a wide range of voter distributions and possible candidate positions. Instead, our objective is to demonstrate that a single feature of a voting rule, namely, admissibility of truncated ballots, may have a large effect on the number of viable parties. Third, we consider a three-candidate setting, under which Dual Voting and Negative Voting are indistinguishable. Consideration of settings with more than three candidates would be necessary to tease out the differences between these two procedures. The focus of the current paper, however, is not on the difference between Dual and Negative Voting, but on the effect of vote truncation. Fourth, we are looking at experimental elections with a relatively small number of voters. The implications of our results for large elections are discussed in Sect. 5. Finally, we assume all voters have complete information about the candidates' and other voters' positions, and do not consider a more realistic setting with incomplete information. All these issues are important but we feel that an experimental test in a simple setting, such as the one we consider in this study, is essential before one could move on to more complex and realistic settings.

The remainder of the paper is organized as follows. Section 2 outlines the theoretical model that forms the basis for our experiment. Section 3 describes the experimental design. Section 4 presents the results. Section 5 concludes.

2 Model

A community of N citizens must elect a representative to implement a policy such as a tax rate or the level of public spending. The set of policy alternatives X is a non-empty interval on $\mathbb{R}$. We assume that citizen ℓ's policy preferences can be represented by a strictly concave utility function $u^{\ell}(\cdot)$, and we define $x_{\ell} \equiv \arg\max_{x \in X} u^{\ell}(x)$ as citizen ℓ's (unique) ideal policy. All citizens are expected utility maximizers.

Let C be a non-empty set of candidates, and let x_i denote candidate i's platform, i.e., the policy that candidate i is committed to implement if elected. We assume that each candidate is put on the ballot by a different party, and we take the number of candidates and their platforms as given.

The citizens vote for candidates simultaneously. The election is held under a scoring rule, where each citizen is given a set of point-scores $\{s_1, \ldots, s_C\}$ to cast for the

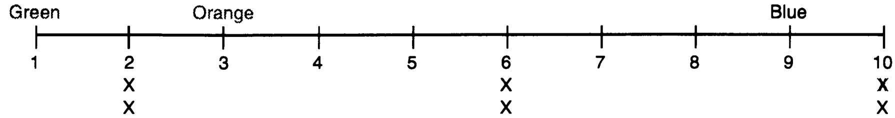

Fig. 1 Experimental design: number line representation

different candidates, with $s_1 \geq s_2 \geq \cdots \geq s_C$. The candidate who receives the most points wins the election. Ties are broken randomly. We denote citizen ℓ's (pure) voting strategy by $\alpha^{\ell}(\mathcal{C}) = \left(\alpha_1^{\ell}(\mathcal{C}), \ldots, \alpha_C^{\ell}(\mathcal{C})\right)$, where $\alpha_i^{\ell}(\mathcal{C})$ is the point-score that citizen ℓ casts for candidate i. In this paper we consider three scoring rules: (1) Plurality Voting (hereafter PV), under which a feasible ballot is any permutation of the vector $(1, 0, \ldots, 0)$; (2) Approval Voting (hereafter AV), under which a feasible ballot is any permutation of any one of the following vectors $(1, 0, \ldots, 0)$, $(1, 1, 0, \ldots, 0)$,..., $(1, \ldots, 1)$; and (3) Dual Voting (hereafter DV), under which a feasible ballot is any permutation of the vector $(1, 1, 0, \ldots, 0)$.[6] Citizens can also abstain from voting, in which case the ballot is the null vector.

Since in our model each candidate is identified with a different party, we say that voter behavior under a given voting procedure leads to at most two viable candidates (parties) if in any Nash equilibrium, defined in the usual way, at most two candidates receive the highest number of votes, i.e., tie for first place. Proposition 1 follows from Dellis (2007).

Proposition 1 *Given a scoring rule, voter behavior leads to at most two viable candidates if every voter*

1. *has a unique top-score vote to cast, i.e.,* $s_1 \neq s_2$*; or*
2. *can truncate his ballot, i.e., a ballot is feasible if it is a permutation of any of the following vectors* $(0, \ldots, 0)$, $(s_1, 0, \ldots, 0)$, $(s_1, s_2, 0, \ldots, 0)$, ..., $(s_1, \ldots, s_C)$.

PV satisfies the first condition of Proposition 1, while AV satisfies the second condition. Thus, under both PV and AV, strategic voting behavior limits to two the number of viable parties. By contrast, DV (and Negative Voting) satisfies none of the conditions of Proposition 1 and, therefore, may encourage multipartism. The example displayed in Fig. 1 illustrates this point. There are three candidates located on the interval $[1, 10]$. One candidate is located at 1 (labeled "Green"), another one at 3 (labeled "Orange") and the third one at 9 (labeled "Blue"). There are six voters whose ideal points are indicated by crosses on the figure. There are two voters with ideal point 2, two voters with ideal point 6, and two voters with ideal point 10. The voters at 2 are indifferent between Green and Orange, and prefer these candidates to Blue; the voters at 6 are indifferent between Orange and Blue, and prefer them to Green; and the voters at 10 prefer Blue to Orange to Green.

It is straightforward to check that in any Nash equilibrium under PV and AV, at most two candidates tie for first place. In contrast, under DV, an equilibrium exists where

[6] As discussed in Sect. 1 above, in the three-candidate setting that we study, Dual Voting is identical to Negative Voting, under which a feasible ballot is any permutation of the vector $(1, \ldots, 1, 0)$.

Table 1 Experimental design: payoff matrix

Position of participant	Payoff by outcome		
	Green (located at 1)	Orange (located at 3)	Blue (located at 9)
2	91	91	11
6	54	70	70
10	32	40	120

all three candidates tie for first place. This equilibrium under DV is due to strategic behavior on the part of the voters located at 10. To see this, note that the voters at 2 and 6 cannot benefit from misrepresenting their preferences and, therefore, should vote for the two candidates who are closest to their position; this generates two votes for Green, four votes for Orange, and two votes for Blue. A voter at 10 may vote for Blue and Orange, in which case Orange wins outright. Or, each voter at 10 may vote for Blue and Green, in which case all three candidates tie for first place. For a payoff structure as in Table 1, voters at position 10 get a higher expected payoff from the three-way tie than from Orange winning outright and, therefore, have an incentive to cast one of their votes for Blue, their most-preferred candidate, and "dump" their other vote on Green, their least preferred candidate. Note that this incentive does not exist under PV and AV since neither of these two voting rules forces people to vote for multiple candidates.

While this example appears specific, it is illustrative of the general properties of the voting rules we study.

Below, we describe an experiment that was designed to test the above predictions.

3 Experimental design

Experimental subjects in the roles of voters participated in sequences of experimental elections over three candidates. There were three experimental treatments corresponding to three voting procedures: PV (vote for exactly one candidate), AV (vote for as many of the candidates as wished) and DV (vote for exactly two candidates). The motivation for the choice of these voting procedures is explained in detail in Sects. 1 and 2 above. Under all three voting procedures, voters were also given the option to abstain from voting.[7]

There were 12 experimental sessions, with 4 independent sessions held under each of the three voting procedures. The voting procedure was held constant within a session. There were 12 subjects in each session. A session consisted of seven or eight

[7] We gave this option to ensure symmetry across all three voting procedures. Indeed, without this option, participants could have abstained from voting under AV, but not under PV and DV. This is because under AV, voting for all candidates is equivalent to vote abstention. In fact, our participants rarely abstained: they abstained in only 9 out of 1,440 voting decisions under PV, in 71 out of 1,392 decisions under AV (abstaining in 3 cases and voting for all three candidates in 68 cases), and in 62 out of 1,392 voting decisions under DV.

voting series, with four election periods per series.[8] The division of a session into series was meant to provide some opportunity for convergence within a series, while limiting dynamic strategic behavior. At the beginning of each series of election periods, the participants were randomly matched into two groups of six voters each. Within each group, the participants' ideal points were randomly assigned among the voters' locations as described in Fig. 1. The colors associated with the candidates (Green, Orange, and Blue) were also randomly assigned among the candidates' locations described in the figure.[9] The locations of the candidates and of the different participants in the group were common knowledge. However, the identity and the individual voting history of the other participants in the group was not revealed. The experimental instructions (included in supplementary materials) used a neutral terminology with the candidates referred to as "alternatives".

In each election period, an independent election was held within each group. Participants placed votes for the candidates according to the given voting procedure. The candidate who received the most votes in the group won the election. Ties were broken randomly. After all participants had placed their votes, each participant's screen reported the vote totals of the candidates, the winning candidate in their group, and the participant's payoff from the election.

Table 1 reports the payoffs that a participant received from the election depending on his location and on the location of the elected candidate.

The payoff matrix was constructed from strictly concave distance utility functions. Further, the payoffs of a participant at 10 were constructed so that her expected payoff was larger when all three candidates tied for first place than when Orange won outright; this was necessary for a three-way-tie equilibrium to exist under DV. In addition, to address possible concerns for 'equity' across participants, affine transformations of the payoffs were taken so that at each position the payoffs over all three candidates summed up to a similar number.[10] The payoff matrix was common knowledge to all participants.

The Nash equilibrium predictions for each treatment are summarized in Table 2.

The outcome of a Nash equilibrium where candidate x wins outright is denoted by $\{x\}$; the outcome of a Nash equilibrium where candidates x and y tie for first place, and thus each is elected with probability one-half, is denoted by $\{x, y\}$. Notice that under PV and AV no Nash equilibrium exists where all three candidates are tying for

[8] The first session under DV and AV and the first two sessions under PV had eight series of four election periods. As it became obvious that there were no significant differences between the seventh and the eighth series, we shortened all subsequent sessions to seven series of election periods so that no session lasts more than two hours. We include in our analysis the data from these eighth series of election periods. Our results are not sensitive to this inclusion.

[9] During each session we also alternated the line-up described in Fig. 1 with a symmetric line-up, where candidates were located at 2, 8 and 10, and participants were located at 1, 5 and 9. The two line-ups were used to keep the participants from getting accustomed to the same setting, and also to check whether the results are different depending on whether the line-up involved a left extremist (i.e., a candidate located at 1) or a right extremist (i.e., a candidate located at 10). The data indicate no difference in participants' behavior across the two settings. We therefore pool the data and present the results in the context of the line-up described in Fig. 1.

[10] The actual payoff sums are 193 for a participant at 2; 194 for a participant at 6; and 192 for a participant at 10. We noticed that a few participants did compute these sums.

Table 2 Equilibria

Voting rule	Equilibrium outcome	Supporting strategy profiles[b]
PV	{G}	All weakly dominated[c]
	{O}[a]	{G,G,O,O,O,O}
		{G,O,O,O,O,O}
		{G,O,O,O,O,B}
		{G,O,O,B,O,O}
		{G,O,O,O,B,B}
		{O,O,O,O,O,O}
		{O,O,O,O,O,B}
		{O,O,O,B,O,O}
		{O,O,O,O,B,B}
	{B}[a]	{G,G,O,B,B,B}
		{G,G,B,B,O,B}
		{G,G,B,B,B,B}
		{G,O,B,B,B,B}
		{O,O,B,B,B,B}
	{O,B}[a]	{O,O,O,B,B,B}
AV	{G}	All weakly dominated[c]
	{O}[a]	{(G,O),(G,O),(O,B),(O,B),(O,B),(O,B)}
	{B}	All weakly dominated[c]
	{O,B}[a]	{(G,O),(G,O),(O,B),(O,B),B,B}
DV	{G}	All weakly dominated[c]
	{O}[a]	{(G,O),(G,O),(O,B),(O,B),(O,B),(O,B)}
	{B}	All weakly dominated[c]
	{G,O,B}[a]	{(G,O),(G,O),(O,B),(O,B),(G,B),(G,B)}

The colored alternatives are located at: (G)reen—1, (O)range—3, (B)lue—9

[a] Indicates the outcome is a Nash equilibrium in weakly undominated strategies (WUNE)

[b] Only the strategy profiles not containing weakly dominated strategies are listed. The first two entries list the ballot cast by the participants in position 2, the second two by those in position 6, and the last two by those in position 10.

[c] All supporting strategy profiles include weakly dominated strategies

first place. In fact, if we further restrict attention to equilibria in weakly undominated voting strategies, only Orange and Blue are elected with a positive probability.[11] This contrasts with DV where an equilibrium exists with all three candidates, {Green, Orange, Blue}, tying for first place.

As subjects made their voting decisions, they saw: (1) a representation of the locations, as in Fig. 1; (2) a payoff matrix, as in Table 1; (3) a test outcome calculator;

[11] Under PV, a voter's strategy is weakly undominated if the voter votes for a candidate other than his least-preferred candidate. Under AV, a voter's strategy is weakly undominated if the voter votes for all his most-preferred candidates and does not vote for any of his least-preferred candidates. Finally, under DV a voter's strategy is weakly undominated if the voter votes for all his most-preferred candidates.

(4) a ballot; (5) a history that contained, for the current series of election periods, the distribution of vote totals across the three candidates; and (6) the cumulative payoff of the participant. A screenshot of this display is given in Fig. 5 in the supplementary materials. The experiment was computerized using the software z-tree (Fischbacher 2007).

Procedures Experimental participants were recruited among students at the University of Hawaii at Manoa. Upon their arrival, participants were seated at computer terminals. Once all 12 participants were seated, a hard copy of the instructions and an optional record sheet were handed out and instructions were read aloud. Participants were invited to ask questions, which were answered in public. After the instruction phase, participants were walked through a tutorial, followed by two trial, unpaid elections. Paid elections then started. To minimize end game effects, participants were not told the number of election periods in the session.

Each session lasted for around two hours including instruction. At the end of the session, each participant was paid, in cash, the sum of his realized payoffs over all 28 or 32 election periods, at the exchange rate of 1 US dollar per 100 experimental tokens, plus a 5 dollar show-up fee. Payments ranged from 16 to 33 dollars, with an average of 24.58 dollars and a standard deviation of 2.70 dollars.

4 Results

A total of 144 subjects participated in the experiment, with about equal numbers of men and women. Twelve independent sessions were held in total, with four sessions per each voting procedure, and 12 participants per session. There was a total of 240 elections and 1,440 voting decisions in the PV treatment, and a total of 232 elections and 1,392 voting decisions in each of the DV and AV treatments.

We shall proceed in two parts, examining election outcomes first, followed by individual voting behavior. The data aggregated by voting rule are presented in tables in the main text, with more detailed statistics by session included in Tables 10–13 in the supplementary materials. Unless stated otherwise, we use session averages as independent units of observation for statistical tests. To trace possible learning effects, we sometimes compare the data for early election periods (periods 1–12) and late election periods (periods 13–28 or 13–32, depending on the session duration).

4.1 Election outcomes

We start by checking whether the actual election outcomes could be the result of random voting behavior on the part of the participants or whether they are the result of purposeful voting behavior. For this purpose, we compare the actual frequencies of election outcomes with the frequencies that would occur if every participant acted randomly, casting each feasible ballot with an equal probability. The frequencies are reported in Table 3. For each voting procedure, the actual distribution of election outcomes is clearly different from the distribution predicted by random voting (p-values for the Kolmogorov–Smirnov test are less than 0.0001 for each session). We

Table 3 Frequency of outcomes, by voting rule and session

Session	Green	Orange	Blue	Green and Orange	Green and Blue	Orange and Blue	Three-way tie
PV-random[a]	0.24	0.24	0.24	0.08	0.08	0.08	0.05
PV-actual—all	0.00[b]	0.61[c]	0.15[c]	0.00	0.00	0.24[c]	0.00
PV1	0.00	0.73	0.03	0.00	0.00	0.23	0.00
PV2	0.00	0.53	0.28	0.00	0.00	0.19	0.00
PV3	0.00	0.52	0.16	0.00	0.00	0.30	0.02
PV4	0.00	0.64	0.11	0.00	0.00	0.25	0.00
AV-random[a]	0.23	0.23	0.23	0.08	0.08	0.08	0.06
AV-actual—all	0.00[b]	0.48[c]	0.28[b]	0.01	0.00	0.20[c]	0.03
AV1	0.00	0.64	0.22	0.00	0.00	0.14	0.00
AV2	0.00	0.43	0.23	0.02	0.00	0.29	0.04
AV3	0.00	0.50	0.25	0.00	0.02	0.18	0.05
AV4	0.00	0.34	0.41	0.02	0.00	0.20	0.04
DV-random[a]	0.22	0.22	0.22	0.10	0.10	0.10	0.05
DV-actual—all	0.04[b]	0.64[c]	0.09[b]	0.02	0.01	0.07	0.14[c]
DV1	0.02	0.53	0.14	0.00	0.02	0.09	0.20
DV2	0.05	0.59	0.09	0.05	0.00	0.07	0.14
DV3	0.04	0.80	0.04	0.00	0.00	0.00	0.13
DV4	0.07	0.64	0.07	0.02	0.02	0.11	0.07

The colored alternatives are located at: Green—1, Orange—3, Blue—9
[a] The rows that are marked "-random" show the frequency of each outcome if participants voted randomly.
[b] Consistent with Nash equilibrium outcome
[c] Consistent with WUNE (Nash equilibrium in weakly undominated strategies) outcome

can therefore reject the hypothesis that our results are merely the outcome of random voting.

The dynamics of electoral outcomes within series of elections gives further evidence against random voting. Figure 2 displays probabilities of electoral outcomes occurring in an election conditional on the preceding election outcome in the series.[12]

Figure 2 indicates that for each commonly occurring election outcome, the probability that outcome takes place more than doubles, and often triples or more, if the same outcome occurred in the preceding election. Results of a multinomial logit regression estimation (available in Table 14 in the supplementary materials) confirm that the previous election outcome within a series is a powerful predictor of the current election outcome; this is true under all voting rules and for all electoral outcomes other than those that occurred very infrequently. This suggests that voters used elections within

[12] Rarely-occurring outcomes, such as Green winning outright or tying with either Orange or Blue, but not both, are not displayed as they never happened twice in a row. Such outcomes may indeed be attributed to noise in voting behavior.

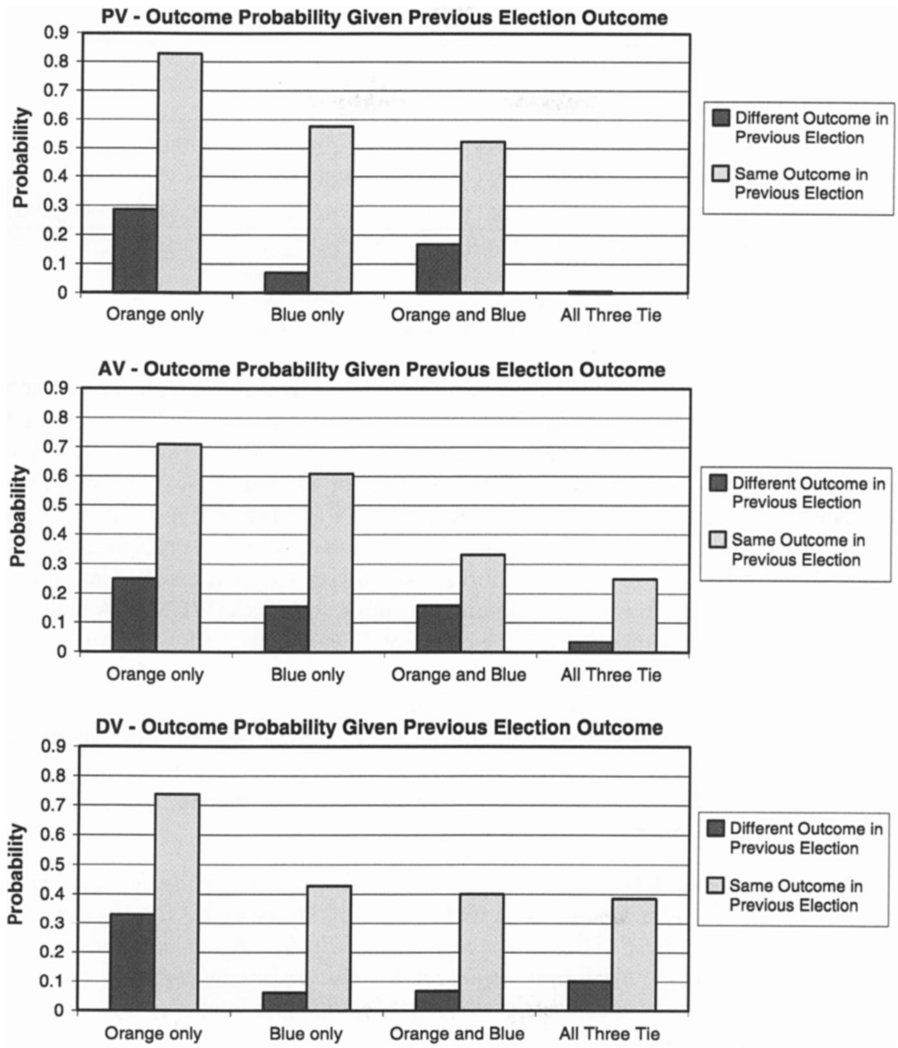

Fig. 2 Probability of election outcomes conditional on previous election outcome within series

series to coordinate on certain outcomes, rather than picked their votes randomly.[13] We therefore conclude that not only are outcomes not random, but they are persistent within series as well.

We continue by checking whether the election outcomes are consistent with the Nash equilibrium predictions. Success rates for each voting procedure are reported

[13] In this regard, our findings are in line with Forsythe et al. (1993) who report that in elections under PV, majority voters tended to coordinate their votes behind the majority candidate who led in the preceding elections.

Table 4 Nash and weak undominance Nash equilibrium outcomes by voting rule

Mean (SD)	NE outcomes, share			WUNE outcomes, share		
	All	Early	Late	All	Early	Late
PV	0.996 (0.065)	1.000 (0.000)	0.993 (0.083)	0.996 (0.065)	1.000 (0.000)	0.993 (0.083)
AV	0.957 (0.204)	0.948 (0.223)	0.963 (0.189)	0.681 (0.467)	0.583 (0.496)	0.750 (0.435)
DV	0.905 (0.294)	0.823 (0.384)	0.963 (0.189)	0.776 (0.418)	0.677 (0.470)	0.846 (0.363)

The numbers in parentheses are the standard deviations

in Table 4; Table 10 in the supplementary materials gives more detailed statistics by session.

We find that under PV, 99.6% of election outcomes are consistent with the outcome of a Nash equilibrium; the corresponding percentages are 95.7 and 90.5% for AV and DV, respectively. These numbers are even higher if one considers late election periods. Indeed, under PV 99.3% of late election outcomes (or 143 out of 144) are consistent with Nash equilibrium predictions, and under both AV and DV 96.3% of late election outcomes (or 131 out of 136) are consistent with Nash equilibrium predictions.

The predictive power of Nash equilibrium is still very strong if one restricts attention to Nash equilibria in weakly undominated voting strategies (WUNE). A ballot is said to be weakly undominated if there does not exist another ballot that makes the participant always at least as well off and sometimes strictly better off. As Table 4 further reports, under PV 99.6% of election outcomes are consistent with the outcome of a Nash equilibrium in weakly undominated voting strategies; the corresponding percentages are 68.1 and 77.6% for AV and DV, respectively. These numbers are even higher for late election periods: 99.3% for PV, 75.0% for AV, and 84.6% for DV.

Conclusion 1 summarizes these results.

Conclusion 1 *For each voting procedure the actual distribution of election outcomes and the dynamics of election outcomes within series of elections are significantly different from those predicted by random voting. Almost all election outcomes are consistent with (pure-strategy) Nash equilibrium predictions. An overwhelming majority of election outcomes are also consistent with Nash equilibrium in weakly undominated (pure) voting strategies.*

We now briefly touch upon the equilibrium selection issue. Given the multiplicity of Nash equilibria in weakly undominated strategies (WUNE), it is of interest to consider which equilibrium outcomes occur more frequently than others, and which candidates appear most often in the winning set (i.e., the set of candidates who get the most votes). WUNE predictions (Table 2) suggest that under PV and AV, only two candidates—Orange and Blue—may be part of the winning set, whereas under DV, all three candidates—Green, Orange and Blue—may appear in the winning set. Table 5 reports the frequency with which each candidate is in the winning set for each voting procedure (see also Table 11 in the supplementary materials).

The data strongly confirm the above WUNE predictions. In fact, Orange, the middle candidate, is almost always in the winning set: in 85.4% of the elections held under PV, 72.0% of the elections held under AV, and 86.2% of the elections held under DV.

Table 5 Frequencies of each alternative appearing in the winning set, by voting rule

Mean (SD)	Green			Orange			Blue		
	All	Early	Late	All	Early	Late	All	Early	Late
PV	0.004 (0.065)	0.000 (0.000)	0.007 (0.083)	0.854 (0.354)	0.854 (0.355)	0.854 (0.354)	0.392 (0.489)	0.438 (0.499)	0.361 (0.482)
AV	0.043 (0.204)	0.052 (0.223)	0.037 (0.189)	0.720 (0.450)	0.625 (0.487)	0.787 (0.411)	0.509 (0.501)	0.594 (0.494)	0.449 (0.499)
DV	0.207 (0.406)	0.146 (0.355)	0.250 (0.435)	0.862 (0.346)	0.833 (0.375)	0.882 (0.323)	0.302 (0.460)	0.302 (0.462)	0.301 (0.461)

The numbers in parentheses are the standard deviations
The colored alternatives are located at: Green—1, Orange—3, Blue—9

Blue, the candidate at 9, is often in the winning set as well—in 39.2, 50.9 and 30.2% of the elections held under PV, AV and DV, respectively. By contrast, Green, the candidate at 1, is (almost) never in the winning set under PV (0.4% of the times), is rarely there under AV (in only 4.3% of elections), but is frequently in the winning set under DV (in 20.7% of elections).[14] The percentage of times Green is in the winning set is significantly higher under DV than under either PV or AV ($p = 0.0286$ for a Wilcoxon Mann–Whitney test).

We conclude that WUNE theory is a good predictor of equilibrium outcomes as well as of the set of candidates which regularly appear in the winning set. Interestingly, we further find that in our design the middle candidate—Orange—is the candidate who is the most frequently in the winning set under all three voting procedures. Thus, the data suggest that a centrist candidate may serve as a focal candidate that allows voters to better coordinate on an equilibrium.

We now investigate the party structure under each of the three voting procedures. We have said that a voting procedure encourages a two-party system if in every election, at most two parties have a viable candidate. By contrast, we have said that a voting procedure may encourage a multiparty system if more than two parties can have viable candidates. In Sect. 2 we suggest that, theoretically, a candidate may be said viable if he wins the election outright or ties for first place. Thus, the frequency of three-way ties in election outcomes is a theoretically appealing measure that may be applied to small laboratory elections to study if a voting procedure encourages bipartism or multipartism. However, this measure is less appealing for practical purposes as one may not expect the knife-edge case of a three-way-tie equilibrium to occur in the field, especially in large nation-wide elections.[15] Even in a small, tightly controlled laboratory setting it is virtually impossible for the exact equilibrium to occur in all of

[14] Observe that Orange and Blue are both Condorcet winners (i.e., candidates who defeat every other candidate in a pairwise contest) while Green is a Condorcet loser (i.e., a candidate who is defeated by every other candidate in a pairwise contest). Thus, the Condorcet loser is almost never elected under PV and AV, but is regularly in the winning set under DV. However, this feature is design-specific and need not hold in general.

[15] Interestingly, however, Nagel (2007) appeals to the historical example of the 1800 US presidential election to argue that voting procedures such as Dual Voting make ties quite likely in real world elections. He

Table 6 Measures of multipartism in election outcomes

Mean (SD)	Three-way ties, share			Average 2nd to 3rd place spread, %			Effective number of parties, #		
	All	Early	Late	All	Early	Late	All	Early	Late
PV	0.004 (0.065)	0.000 (0.000)	0.007 (0.083)	31.86 (13.78)	33.92 (0.13)	30.49 (0.14)	1.86 (0.333)	1.87 (0.283)	1.85 (0.363)
AV	0.030 (0.171)	0.031 (0.175)	0.029 (0.170)	16.40 (11.33)	14.53 (11.22)	17.72 (11.26)	2.59 (0.303)	2.63 (0.304)	2.57 (0.302)
DV	0.138 (0.346)	0.052 (0.223)	0.199 (0.400)	9.25 (8.00)	11.64 (8.60)	7.56 (7.10)	2.80 (0.167)	2.77 (0.170)	2.82 (0.161)

Numbers in parentheses are the standard deviations

the 232 or 240 elections that were conducted under each voting procedure; one would expect to see some learning and experimentation on the part of participants under any voting rule. Thus, a more practical measure of multipartism is desirable. Forsythe et al. (1996) use the spread between the second and third place vote percentages as a measure of the two-party system in their experimental elections, noting that a large spread would suggest a two-party system, while a small spread would indicate three-way close races. The effective number of parties is another measure that is frequently used in the electoral systems literature to assess party fragmentation. This measure is calculated on the basis of each party's proportion of the total votes P_V, and is given by: $N_V = 1/\left(\sum(P_V)^2\right)$; see, e.g., Gallagher and Mitchell (2005).

Table 6 reports each of the three measures we have just discussed—the frequencies of three-way ties, the percent vote spreads between the second and third place candidates, and the effective number of parties—for every voting rule (see also Table 12 in the supplementary materials).

Three-way ties occurred in 0.4% of the elections held under PV, in 3.0% of elections held under AV, and in 13.8% of elections held under DV; thus, three-way ties virtually never happened in PV elections, and the frequency of three-way ties in AV elections is not statistically different from the frequency of three-way ties in PV elections ($p = 0.1786$ for a Wilcoxon Mann–Whitney rank order test using session averages as units of observation). By contrast, the frequency of three-way ties in DV elections is both statistically different from zero and statistically different from the frequency of three-way ties in PV and AV elections at conventional significance levels ($p = 0.0286$).

All three voting procedures differ significantly both in terms of the average spreads between the second and third place vote percentages, and the effective number of parties ($p = 0.0286$ for the differences between any two voting rules, Wilcoxon Mann–Whitney rank order test, for both measures). PV is characterized by the largest average vote spread between the second and third vote percentages (31.86%) and the smallest effective number of parties (1.86), followed by AV (16.40% second-third place vote spread and 2.59 effective parties), then followed by DV which has the smallest

Footnote 15 continued
further argues that ties among candidates may not be completely unrealistic in large elections, as party leaders may serve a coordinating role in such elections.

second-third place vote spread (9.25%) and the largest effective number of parties (2.80). Note that even though the differences between the vote spreads and the effective number of parties appear larger in magnitude between PV and AV (as well as PV and DV) than between AV and DV, the differences between any two voting procedures are statistically significant.[16]

We also observe that the differences in the above measures across the three procedures evolved from early to late elections. From Table 6, we observe that three-way ties under DV occurred much more often in late elections than in early elections (5.2% or 5 out of 96 early elections, as compared to 19.9% or 27 out of 136 late elections). The frequencies of three-way ties increased, the average second-third place vote spreads decreased, and the effective numbers of parties increased from early to late elections in all sessions under DV. In contrast, there were no significant changes in any of the three measures between early and late elections under either PV or AV.[17]

In sum, based on the frequency of three-way ties, we cannot reject the hypothesis that voting under PV and AV leads to at most two viable candidates; while we can reject this hypothesis for voting under DV. The measures of vote spreads between the second and third place vote percentages, and the effective number of parties, also imply that the evidence in favor of the two-party system is the strongest for PV, followed by AV, and the evidence in favor of multipartism is the strongest for DV. These results are summarized in Conclusion 2.

Conclusion 2 *There were at most two viable candidates in each election held under Plurality Voting and most elections held under Approval Voting. In contrast, many elections held under Dual Voting were characterized by close three-way races among the candidates. The difference between Plurality Voting and Approval Voting on one side, and Dual Voting on the other side, became more pronounced as the participants gained experience with the voting procedures.*

The above analysis has three implications. First, in line with the previous literature, our data indicate that there is a strong tendency toward at most two viable parties in any election under PV. Second, AV election outcomes suggest that allowing people to vote for multiple candidates may yield smaller vote spreads and higher effective number of parties than under PV, but there is still a tendency towards at most two viable candidates in any given election under AV. Third, by comparing election outcomes under AV with those under DV, we are able to study the effect of ballot truncation on

[16] Theoretically, in our design the effective number of parties in WUNE may vary between 1 and 2.57 for PV, as compared to 2.57 and 2.78 for AV, and 2.57 and 3 for DV. Under random voting, the average number of parties would be 2.18 for PV, 2.69 for AV, and 2.70 for DV. Furthermore, the average spread between second and third place vote percentages under random voting would be 19.6% for PV, 11.9% for AV, and 13.5% for DV. Thus, the actual average effective number of parties is within the bounds predicted by the WUNE theory for each voting rule, and lower than under random voting for both PV and AV, while higher than under random voting for DV. Likewise, the actual spread between second and third place vote percentages is higher than under random voting for both PV and AV, but is lower than under random voting for DV. This gives additional evidence in favor of equilibrium behavior and against random voting for the voting rules considered.

[17] To mitigate possible dynamic effects within series of elections, we also considered the statistics for the first election of each series. The results are largely the same.

election outcomes. Our results suggest that disallowing vote truncation (as under DV) while requiring voters to vote for multiple candidates may encourage multipartism.

4.2 Individual voting behavior

In this section, we look at behavioral regularities behind the election outcomes described above. We start by considering whether the observed tendency toward multipartism under DV may be attributed to random factors, or if it is due to strategic voting. For this purpose, we focus our analysis on strategic votes that are distinct from sincere ones. A vote is said to be sincere if whenever the voter votes for a candidate, he also votes for all the candidates he prefers to that candidate.[18] By contrast, a vote is said to be non-sincere strategic if it is neither sincere nor weakly dominated. We further take a closer look at whether individual votes are consistent with a Nash equilibrium in weakly undominated strategies (WUNE). In our setting, a vote is consistent with WUNE if and only if it is not weakly dominated.

Recall from Sect. 2, that in our experimental setting, an equilibrium with a three-way tie occurs under DV only if the voters located at 10 behave strategically, casting one vote for their most-preferred candidate, Blue, and dumping their second vote on their least-preferred candidate, Green. (If, instead, they vote sincerely for the two candidates they most prefer, Blue and Orange, then Orange wins outright.) By contrast, the same voters have no incentive to cast a vote for Green if the election is held under PV or AV; in fact, such vote is then weakly dominated. We now investigate the voting behavior of our participants when they are located at 10.

Table 7 reports the frequencies with which the participants at 10 cast each available ballot (see also Table 13 in the supplementary materials). First, observe that among all voting decisions made by the participants at 10, only 1.67% (8 out of 480) of the voting decisions under PV, and only 8.41% (39 out of 464) of the voting decisions under AV, include a vote for Green. By contrast, under DV, 50.44% of the voting decisions made by the participants in this position (234 voting decisions out of 464) include a vote for Green. This frequency is significantly higher than under PV and AV. Second, the non-sincere strategic ballot consisting of a vote for Green and a vote for Blue was cast 43.97% of the times under DV, whereas the same ballot was cast only 4.31% of the times under AV. Moreover, under DV, this ballot was cast much more frequently in late election periods than in early election periods (39.06% of the times in early periods compared to 47.43% in late periods), whereas under AV the frequency was left virtually unchanged (4.17% in early periods compared to 4.41% in late periods). Figure 3 further demonstrates that in late DV elections many of the participants chose to cast the non-sincere strategic ballot each time they were located at 10.

18 This means that, under PV, a voter votes sincerely if he votes for (one of) his most-preferred candidate(s). Under DV, a voter votes sincerely if he votes for the two candidates he prefers. Finally, under AV, a voter votes sincerely if he votes either for his most-preferred candidate, or for the two candidates he prefers. This definition of sincere voting corresponds to the one proposed by Brams and Fishburn (1978). Forsythe et al. (1996) include weakly undominated sincere votes into the strategic category. For our setting, a set of votes that are strategic according to Forsythe et al. (1996) definition corresponds to the set of votes consistent with WUNE.

Table 7 Ballots cast by participants in position 10, percent

Ballot	PV			AV			DV		
	All	Early	Late	All	Early	Late	All	Early	Late
Green only	1.67[a]	2.08[a]	1.39[a]	3.02[a]	1.04[a]	4.41[a]	–	–	–
Orange only	14.38[b]	16.15[b]	13.19[b]	4.31[a]	2.60[a]	5.51[a]	–	–	–
Blue only	82.50	79.69	84.38	73.92	77.08	71.69	–	–	–
Green and Orange	–	–	–	1.08[a]	1.04[a]	1.10[a]	6.47[a]	6.25[a]	6.62[a]
Green and Blue	–	–	–	4.31[a]	4.17[a]	4.41[a]	43.97[b]	39.06[b]	47.43[b]
Orange and Blue	–	–	–	10.78	13.54	8.82	41.38	44.79	38.97
All three	–	–	–	2.37[a]	0.52[a]	3.68[a]	–	–	–
Abstain	1.46[a]	2.08[a]	1.04[a]	0.22[a]	0.00[a]	0.37[a]	8.19[a]	9.90[a]	6.99[a]
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The colored alternatives are located at: Green – 1, Orange – 3, Blue – 9

[a] The ballot is weakly dominated

[b] The ballot is non-sincere strategic

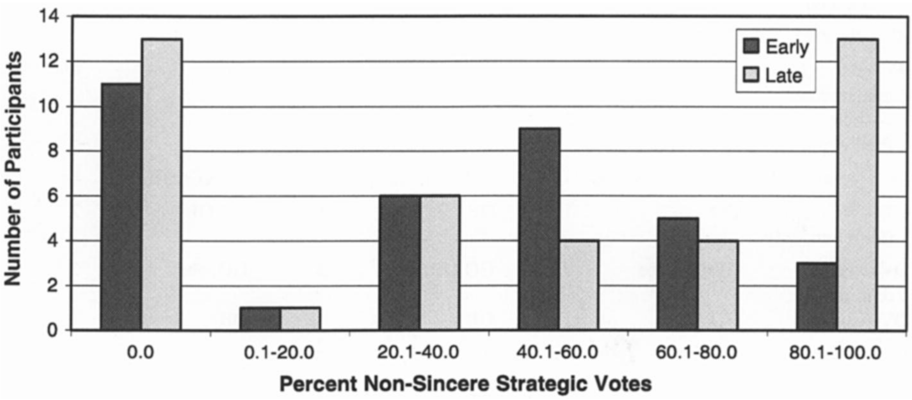

Fig. 3 Distribution of non-sincere strategic votes among voters in position 10 under Dual Voting

Finally, note that in DV elections the non-sincere strategic ballot (Green, Blue) was cast more often than the sincere ballot (Orange, Blue)—43.97% as compared to 41.38%. This difference is even more pronounced if one takes participants' learning into account; the corresponding percentages for late election periods are 47.43% for the non-sincere strategic ballot as compared to 38.97% for the sincere ballot. This observation is quite remarkable since casting the sincere ballot (Orange, Blue) and casting the non-sincere strategic ballot (Green, Blue) are both equilibrium strategies for the voters at 10 under DV; the sincere ballot is part of the Nash equilibrium where Orange wins outright, whereas the non-sincere strategic ballot is part of the three-way-tie equilibrium (both equilibria are in weakly undominated strategies). However, the voters at 10 prefer the three-way-tie equilibrium because of a higher expected payoff.

These results are summarized in Conclusion 3.

Table 8 Classification of individual ballots

Ballot type	Position 2		Position 6		Position 10	
	List	Number	List	Number	List	Number
Plurality Voting—all	G,O,B, abs	4	G,O,B, abs	4	G,O,B, abs	4
PV—WUNE (undominated)	G, O	2	O,B	2	O,B	2
PV—weakly dominated	B, abs	2	G, abs	2	G,abs	2
PV—sincere[a]	G,O	2	O,B	2	B	1
PV—strategic, non-sincere[b]	n/a	n/a	n/a	n/a	O	1
PV—best Predictor[c]	O	1	O,B	2	B	1
Approval Voting—all	G, O, B, GO, GB, OB, GOB, abs	8	G, O, B, GO, GB, OB, GOB, abs	8	G, O, B, GO, GB, OB, GOB, abs	8
AV—WUNE (undominated)	GO	1	OB	1	B, OB	2
AV—weakly dominated	G, O, B, GB, OB, GOB, abs	7	G, O, B, GO, GB, GOB, abs	7	G, O, GO, GB, GOB, abs	6
AV—sincere[a]	G,O,GO	3	O,B,OB	3	B, OB	2
AV—strategic, non-sincere[b]	n/a	n/a	n/a	n/a	n/a	n/a
AV—best Predictor[c]	O, GO	2	O,B,OB	3	B	1
Dual Voting—all	GO, GB, OB, abs	4	GO, GB, OB, abs	4	GO,GB,OB,abs	4
DV—WUNE (undominated)	GO	1	OB	1	GB,OB	2
DV—weakly dominated	GB,OB, abs	3	GO,GB, abs	3	GO, abs	2
DV—sincere[a]	GO	1	OB	1	OB	1
DV—strategic, non-sincere[b]	n/a	n/a	n/a	n/a	GB	1
DV—best predictor[c]	GO	1	OB	1	GB,OB	2

The possible ballots are (G)reen, (O)range, (B)lue, a ballot for multiple candidates (eg GO), and (abs)tention
[a] Abstention and voting for all three candidates are not included in the set of sincere ballots, as they significantly reduce predictive success of sincere voting
[b] Not possible with three alternatives under AV (see Brams and Fishburn 1978, Theorem 3), and only possible for voters in position 10 under PV and DV in our setting
[c] Sets of strategies that maximize Selten's measure of predictive success

Conclusion 3 *Close three-way races in the Dual Voting experimental elections emerged because of strategic voting behavior on the part of participants. In contrast, under both Plurality Voting and Approval Voting, participants in the strategic position cast very few votes for their least-preferred candidate, leading to at most two viable candidates.*

We next look at how often participants cast weakly undominated ballots, which in our setting are equivalent to WUNE ballots (see Table 2 in Sect. 3 above and Table 8 below). A high frequency of weakly dominated ballots may suggest that the voting

Table 9 Frequencies of ballots and Selten's measure of theories' predictive success

Ballot type	All			Early			Late		
	Actual frequency	Relative size	Predictive measure	Actual frequency	Relative size	Predictive measure	Actual frequency	Relative size	Predictive measure
PV—WUNE (undominated)	0.972	0.500	0.472	0.965	0.500	0.465	0.976	0.500	0.476
PV—weakly dominated	0.028	0.500	−0.472	0.035	0.500	−0.465	0.024	0.500	−0.476
PV—sincere	0.924	0.417	0.507	0.911	0.417	0.495	0.932	0.417	0.515
PV—strategic, non-sincere[a]	0.144	0.250	−0.106	0.161	0.250	−0.089	0.132	0.250	−0.118
PV—best predictor[b]	0.908	0.333	0.575	0.901	0.333	0.568	0.913	0.333	0.580
AV—WUNE (undominated)	0.638	0.167	0.471	0.635	0.167	0.469	0.640	0.167	0.473
AV—weakly dominated	0.362	0.833	−0.471	0.365	0.833	−0.469	0.360	0.833	−0.473
AV—sincere	0.871	0.333	0.538	0.870	0.333	0.536	0.873	0.333	0.539
AV—strategic, non-sincere[c]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
AV—best predictor[b]	0.825	0.250	0.575	0.804	0.250	0.554	0.839	0.250	0.589
DV—WUNE (undominated)	0.875	0.333	0.542	0.849	0.333	0.516	0.893	0.333	0.560
DV—weakly dominated	0.125	0.667	−0.542	0.151	0.667	−0.516	0.107	0.667	−0.560
DV—sincere	0.728	0.250	0.478	0.719	0.250	0.469	0.735	0.250	0.485
DV—strategic, non-sincere[a]	0.440	0.250	0.190	0.391	0.250	0.141	0.474	0.250	0.224
DV—best predictor[b]	0.875	0.333	0.542	0.849	0.333	0.516	0.893	0.333	0.560

[a] The frequencies of non-sincere strategic ballots under random voting under PV and DV are calculated only for voters at position 10, as all ballots for all other voters are either sincere or weakly dominated
[b] Sets of strategies that maximize Selten's measure of predictive success
[c] Not possible under AV with three alternatives

rule is not fully understood by the participants. Further, we consider whether WUNE voting explains our participants' individual behavior better than sincere voting for each voting procedure.

Table 8 presents classification of all ballots into WUNE (undominated), weakly dominated, sincere and non-sincere strategic ballots. Table 9 reports the frequencies with which the actual votes in each category were cast, and the relative size of the set of predicted outcomes, i.e., the proportion of all feasible ballots that are consistent with the given category. The table further reports Selten's measure of predictive success for each of the corresponding behavioral theories, which is given by the difference between the actual frequency observed in the data and the relative size of the set of predicted outcomes (Selten 1991). Tables 8 and 9 also list the sets of "best predictor" ballots, i.e., those ballots that maximize Selten's measure.

We first consider the observed frequencies of weakly dominated ballots. From Table 9, weakly dominated ballots were rarely cast under PV (only 2.8% of ballots overall), whereas a significant fraction of the ballots cast under DV (12.5%) and an extremely high fraction of the ballots cast under AV (36.2%) were weakly dominated. For any two voting procedures, the frequencies with which weakly dominated ballots were cast are statistically different ($p = 0.0286$ for a Wilcoxon Mann–Whitney test in all cases). Furthermore, while the share of weakly dominated ballots under DV dropped from 15.1% in early election periods to 10.7% in late periods, it remained high throughout the sessions under AV: 36.5% in early election periods and 36.0% in late periods.

The widespread and persistent use of dominated strategies by experimental subjects under AV but not under PV is consistent with Rapoport et al. (1991), who attribute this phenomenon, in part, to the novelty and complexity of AV as compared to PV; see also Forsythe et al. (1996). In addition, we note that in most cases under AV, casting a weakly dominated ballot did not make a payoff difference for the voter who cast it. Out of all cases when a weakly dominated ballot was cast under AV, only in 19.1% of these cases the voter who cast it could have changed the election outcome in his or her favor by casting a different ballot. This compares to 39.0% under PV, and 53.5% under DV. This indicates that voters under AV had little incentive to learn not to cast weakly dominated ballots. Further, Selten's measure of the predictive success of dominated voting is highly negative for all three voting rules, including AV, indicating that the weakly dominated strategies were used much less frequently than would be the case under random voting. Thus, we may conclude that the widespread use of dominated ballots under AV as compared to PV and DV should be attributed to a larger share of weakly dominated ballots among all feasible ballots under AV, as well as the participants' low incentives not to cast weakly dominated ballots under this voting procedure.

We now compare the predictive power of WUNE voting with that of sincere voting. Table 9 reports that for PV, WUNE strategies were cast more often than sincere strategies. Yet, the measure of predictive success is higher for sincere voting than for WUNE voting ($p = 0.0625$, the lowest attainable with 4 sessions, binomial sign test). For AV, sincere voting is both more frequent, and has a higher measure of predictive success than WUNE voting ($p = 0.0625$). For DV, however, WUNE voting is both more frequent than sincere voting and has a higher predictive power than sincere voting (again, $p = 0.0625$).

Consideration of strategies that are best predictors (Table 8) for the data sheds light on why sincere voting has a higher predictive success under PV and AV, while WUNE has a higher predictive success under DV. Observe that under PV, the set of WUNE ballots is almost identical to the set of sincere ballots, except for the voters located at 10. For these voters, voting consistent with WUNE admits a non-sincere strategic vote for Orange along with a sincere vote for Blue. By contrast, sincere voting prescribes voting for Blue only. The PV best predictor strategy indicates that voters at 10 indeed voted overwhelmingly for Blue, not Orange, leading to a better predictive power of sincere voting as compared to WUNE voting. This voting pattern of voters at 10 under PV may be explained by their preference for Blue winning outright, or Orange and Blue tying, rather than Orange winning outright (all these outcomes are consistent with WUNE; see Table 2). Thus, it is likely that sincere voting has better predictive power under PV because the sincere voting equilibria are preferred by the voters at 10 to the non-sincere strategic voting equilibria, rather than because voters were unable to reason strategically. Consideration of strategies used under DV further supports this strategic reasoning hypothesis. Observe that the list of the best predictor strategies under DV are exactly the same as the list of the WUNE strategies for each voter. This suggests that voters vote sincerely if it is in their best interest (as under PV in our setting), but, provided enough incentives to vote non-sincerely, people may quickly learn to do so (as under DV in our setting).

Looking at the best predictor strategies under AV tells a different story. The relative success of sincere voting as compared to WUNE voting under AV is explained by voters at positions 2 and 6 often not voting for both of their most-preferred candidates, as WUNE prescribes, and only voting for one of them; e.g., voters at 6 often voted just for Orange, or just for Blue, instead of always voting for Orange and Blue. Such behavior is consistent with sincere voting but is weakly dominated.[19] Yet, as noted above, such weakly dominated voting pattern rarely made a payoff difference for the voters under AV.

Conclusion 4 summarizes the above observations.

Conclusion 4 *Under Plurality Voting, a higher predictive success of sincere voting as compared to WUNE voting is explained by voters in the strategic position having a preference for the sincere voting equilibria over the equilibria supported by non-sincere strategic voting. Likewise, under Dual Voting, a higher predictive success of WUNE voting as compared to sincere voting is explained by voters in the strategic position having a preference for the non-sincere strategic voting equilibrium over the sincere voting equilibrium. Under Approval Voting, sincere voting explains the participant behavior better than WUNE voting due to the frequent use of sincere weakly dominated strategies. Participants often used weakly dominated strategies under Approval Voting as their incentives not to use these strategies were low.*

Finally, we look at heterogeneity in behavior among participants.

Figure 4 illustrates the distribution of weakly dominated ballots among participants. While many participants rarely cast weakly dominated ballots, a few did cast weakly dominated ballots almost every period. We reject the hypothesis that there was no individual heterogeneity using the Kolmogorov–Smirnov one-sample test under all three voting rules (p-value <0.0001). A similar result applies with regards to the casting of the non-sincere strategic ballot in DV elections; see Fig. 3, above. Some participants were systematically casting the non-sincere strategic ballot each time they were located at position 10, starting early on in the session. By contrast, others never cast the non-sincere strategic ballot. Again, these differences are highly significant (p-value <0.0001). We conclude:

[19] In comparison, Forsythe et al. (1996) report that equilibrium-consistent voting explains their data better than sincere voting. In their setting there is a strict ranking between the first and second most preferred candidates for all voters, and voting for some, but not all of the best preferred candidates is not an option for voters under AV. Other experimental studies find that participants often do not report all of their most-preferred alternatives, but may report only some of them; e.g., Olson and Porter (1994).

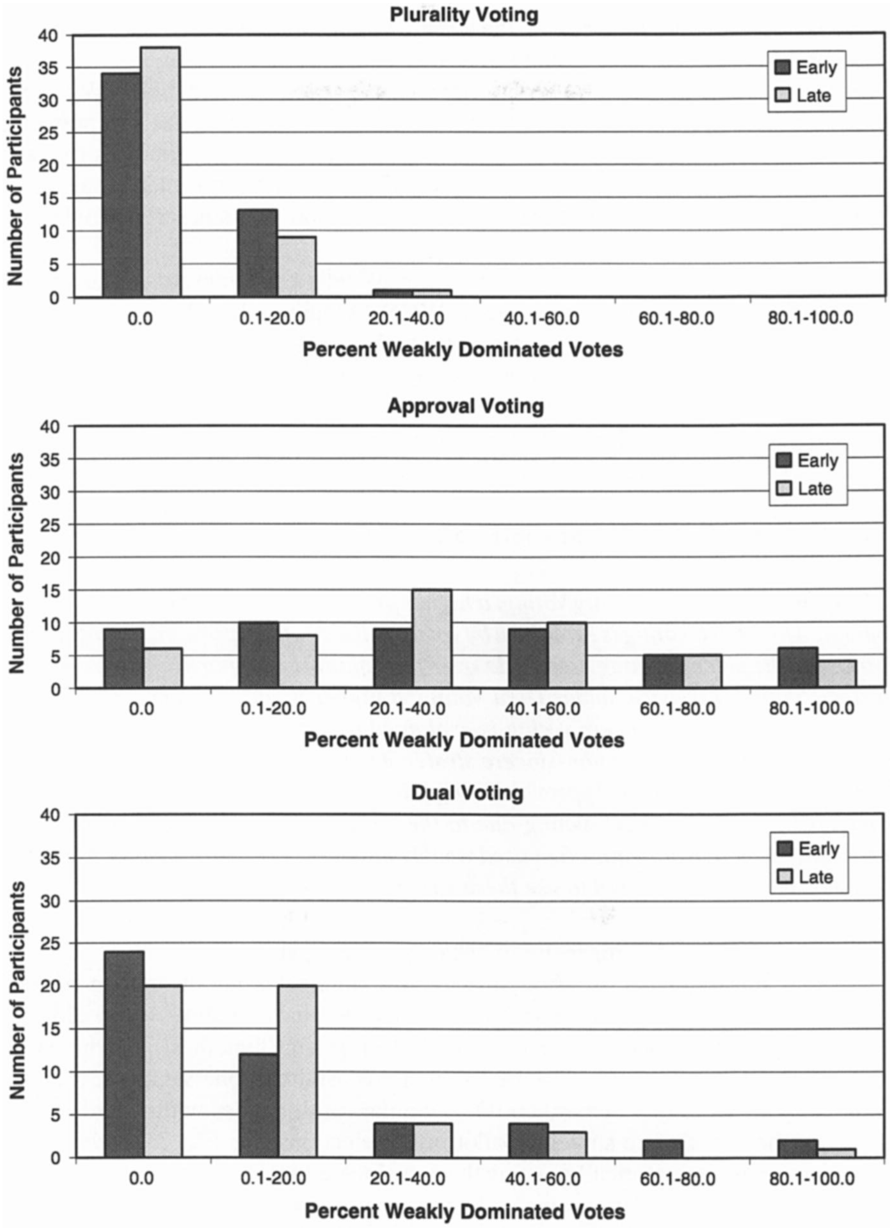

Fig. 4 Distribution of weakly dominated votes among voters, by voting rule

Conclusion 5 *Participants were heterogeneous both in their propensity to cast weakly dominated ballots and in their propensity to cast the non-sincere strategic ballot under Dual Voting.*

Interestingly, individuals casting weakly dominated ballots did not always affect aggregate voting outcomes. Weakly dominated votes were cast by individual voters in many elections; yet, most of the election outcomes are consistent with the outcome of a Nash equilibrium in weakly undominated strategies (Conclusion 1 in Sect. 4.1 above). The starkest example is AV, where 93.5% of elections (or 217 out of 232) include at least one weakly dominated ballot, but 68.1% of electoral outcomes (or 158 out of 232) are still consistent with Nash equilibria in weakly undominated strategies (Table 4). This suggests that in aggregate, people's 'mistakes' largely cancelled each other out, thereby yielding the same outcomes as if all the ballots cast were weakly undominated.[20] In contrast to 'mistakes', participants' purposeful (strategic) behavior often did have an effect on electoral outcomes: many outcomes under DV corresponded to the Nash equilibrium under strategic voting (Conclusions 2, 3).

Our findings are therefore in line with previous laboratory studies, which report that individual voting behavior in multicandidate elections is mostly consistent with rationality, although voters often differ in their voting strategies; e.g., Forsythe et al. (1996), Rietz (2008). Yet, this research provides new evidence of how the strength of payoff incentives affects voters tendency to cast or not cast weakly dominated strategies, and to choose between sincere and non-sincere strategic ballots.

4.3 Bounded rationality

While a majority of our findings are consistent with Nash equilibrium in weakly undominated strategies (Conclusions 1–3), some participant behavior is not predictable in a fully-rational setting (Conclusions 4, 5). We now briefly discuss two popular models of bounded rationality, Quantal Response Equilibrium and level-k reasoning, to see the extent they can further explain participant behavior. The full details of this analysis are given in the supplementary materials.

Quantal Response Equilibrium (QRE, McKelvey and Palfrey 1995) is a stochastic version of the Nash Equilibrium, which allows for voters' errors in actions and beliefs. For our experiment, QRE correctly predicts that as participants' errors decrease, the limit strategies for QRE equilibrium still contain weakly dominated strategies; in fact, it drastically over-predicts the shares of weakly dominated ballots. This again suggests that assuming participants do not cast weakly dominated ballots may be an overly restrictive assumption, if payoff consequences of such behavior are small. Further, QRE correctly predicts that voters under DV often voted strategically. In fact, it predicts that for voters in position 10 under DV, the only strategy that is consistent with the QRE limiting strategy is the non-sincere strategic vote (Green, Blue).

[20] The experimental evidence that outcomes of many institutions, especially markets, are robust to individual 'errors', has been used by experimental economists to justify the rationality approach to social sciences. Charles Plott writes: "Claims about the irrelevance of models of rational choice and the consequent irrelevance of economics are not uncommon…If one looks at experimental markets for evidence, the pessimism is not justified. Market models based on rational choice principles…do a pretty good job of capturing the essence of very complicated phenomena" (Plott 1986, p. S325). Colin Camerer also notes that "…better models of individual decision making may not improve market level predictions; whether they do so is fundamentally an empirical question that economic experiments help answer…" (Camerer 1995, p. 589).

The level-k reasoning model categorizes subjects into different types or 'levels' of rationality (Nagel 1995; Costa-Gomez and Crawford 2006). This model explains the observed participant heterogeneity (Conclusion 5) by their different levels of reasoning. For DV, it explains why some subjects cast predominantly sincere ballots while others cast predominantly non-sincere strategic ballots when in the strategic position at 10: lower-level subjects cast sincere ballots because they fear Green winning outright, while higher-level subjects cast non-sincere strategic ballots because they believe that Orange will win outright otherwise. Further, level-k reasoning predicts that under PV, the voters in position 10 who apply some minimal reasoning should vote according to the sincere voting equilibrium, for Blue, and not cast the non-sincere strategic ballot for Orange; this feature is also supported by our data (Conclusion 4, above).

These findings are fully consistent with and provide additional insights for the Conclusions 3, 4, and 5. Interestingly, however, neither model explains the focal nature of the centrist candidate (Orange) observed in our data.

5 Discussion and conclusion

Duverger's law states that Plurality Voting tends to favor a two-party system. This empirical regularity has been explained by the wasting-the-vote effect of Plurality Voting: fearing to waste their vote on an underdog, voters are led to behave strategically and vote for the *serious* contender they prefer (instead of voting sincerely for the contender they most prefer). Such strategic behavior on the part of voters triggers a desertion of the trailing candidates and a concentration of the votes on two candidates. Dellis (2007) shows that, under standard assumptions on voter preferences, this Duvergerian logic generalizes to some voting procedures other than Plurality Voting. Approval Voting, in particular, is one of those voting procedures. The key feature of Approval Voting that allows it to encourage bipartism is the admissibility of truncated ballots: voters are allowed, but not forced, to vote for multiple candidates. Forcing the voters to vote for more than one candidate, as under Dual Voting, may generate incentives for strategic vote dumping, which may give rise to multipartism.

Our experimental results provide evidence that is in line with the above predictions, in a controlled laboratory setting that focuses on voter behavior. In the overwhelming majority of our Plurality Voting and Approval Voting elections, either one candidate won the election outright, or two candidates tied for first place. Although elections under Approval Voting were characterized by smaller vote margins between candidates as compared to elections under Plurality Voting, there was still a tendency towards at most two viable candidates under Approval Voting. In contrast, the Dual Voting elections often resulted in close races or three-way ties among the candidates. We show that this was due to strategic voting in the form of vote dumping by certain voters, and thus provide evidence that voters' ability to truncate ballots is essential for Approval Voting to encourage bipartism.

Our experimental results may appear at odds with Forsythe et al. (1996), who report that in their experiment, close three-way races often take place under Approval Voting. However, these results are not in fact contradictory. Our study considers voting over candidates located on a unidimensional policy space, and assumes that voter preferences can be represented by strictly concave utility functions (and are thus single-peaked). In contrast, the voter preferences considered in Forsythe et al. (1996) are not compatible with those assumptions; instead they may stem from a multidimensional policy setting. We argue that both settings are interesting. Which setting applies to which real-world situation is largely an empirical issue.

Another issue in relating our experiment to the real world is whether these small-scale results are informative about possible outcomes in larger elections. In particular, a large number of three-way ties observed in Dual Voting elections may be attributed to a setting with a small number of strategic players, where the exact three-way tie equilibrium may be easily achieved; yet a similar three-way tie outcome may be unrealistic in a setting with several thousands or millions of voters. While we cannot provide direct evidence that the results observed in our experiments may carry over to large elections, our results may be still informative for the following reason. Many researchers argue that strategic voting, if it is in the party's interest, may take large (even national) scale through coordinating role of political leaders or parties (e.g., Nagel 2007). Political parties may run extensive campaigns and make suggestions to their supporters on how to vote in the election.[21] If parties and interest groups guide the voters, then strategic voting behavior that was observed in our small experimental elections may, under certain circumstances, also be encouraged and observed in larger scale elections. Even though exact three-way ties are unlikely to happen in real elections, such strategic voting may lead to close three-way races among candidates.[22]

With the above limitations in mind, our results help ease fears raised by many scholars—including the supporters of Approval Voting—that using Approval Voting for political elections would encourage multipartism. This fear was best captured by Cox (1997, p. 95) when he wrote: "...many believe that [Approval Voting] would lead to multipartism, although there is no empirical evidence on this score." Notice that our results relative to Approval Voting are the more remarkable in our experimental

21 This is done for example in Australia, where legislative elections are held under the Single Transferable Vote (a voting rule which is significantly more complex than any of the voting rules we consider here). In Lower House elections, it takes the form of voting cards that parties distribute to voters when they enter the polling station and that suggest voters a specific ballot to cast. In Senate elections, it takes the form of political parties submitting beforehand a ballot and voters having the option to tick a box on the ballot paper to select the ballot submitted by that party. For more details on the Australian electoral system and the coordination role by political parties, see Chaps. 3 and 6 in Farrell (2001).

22 Results of simple Monte Carlo simulations also indicate that the conclusions drawn on the basis of our small laboratory elections may carry over to larger elections, provided that the voter behavior does not change significantly. We conducted 5,000 elections per each voting procedure in the setting identical to our actual experiment, but with 300 simulated voters (100 voters per position). For each election, each voter's ballot was drawn from the actual pool of ballots cast in one of the series of experimental elections under this voting procedure (see Conclusion 1 for the consistency of voter behavior within election series). The results of the simulated elections are arguably more realistic than those observed in our small laboratory elections: three-way ties never occurred under any of the three voting rules. Yet, the qualitative differences between Dual Voting on one hand, and Plurality and Approval Voting on the other hand, became even more pronounced in these large simulated elections: Dual Voting was characterized by significantly smaller vote margins between candidates than the other two voting procedures. Moreover, Dual Voting was the only voting procedure among the three under which the extremist candidate (Green) ever appeared in the set of winning candidates, a feature characteristic of multipartism under our particular setting.

setting as our participants were unfamiliar with Approval Voting and as no education effort had been undertaken prior to the experiment.

We also obtain some interesting insights into individual behavior. First, we observe that even though non-sincere strategic voting may be widespread under some circumstances, it does not necessarily occur in all cases when theoretically possible. Our analysis suggests that voters choose to vote sincerely if it is in their best interest to do so (as under PV in our setting), but, provided with enough incentives to vote non-sincerely, voters may quickly learn to do so (as under DV in our setting).

Further, our analysis sheds light on whether people are likely to cast weakly undominated votes under each voting procedure that we study. A reasonable (and rather minimal) requirement for a voting procedure to be implementable is that people understand it well enough that they do not cast weakly dominated ballots. Our analysis also has implications for the usefulness of the weak undominance refinement that is often used in the theoretical voting literature. In our experiment, weakly dominated votes are almost never cast under Plurality Voting. Likewise, Nash equilibrium voting in weakly undominated strategies explains the behavior better than any other behavioral theory under Dual Voting. Thus, the Plurality Voting and Dual Voting procedures appear simple enough for voters to understand, also suggesting that weak undominance Nash equilibrium is a reasonable equilibrium refinement, at least if restricted to the analysis of these voting procedures. Under Approval Voting, however, people often cast weakly dominated ballots and do not learn not to do so over time, even in a simple experimental setting like ours. This calls into question the claim made by the supporters of Approval Voting that Approval Voting is simple for voters to understand. It also questions the validity of applying the weak undominance Nash equilibrium refinement to the analysis of all voting procedures. Most likely, however, the casting of weakly dominated ballots under Approval Voting persisted in our experiment because it had little payoff consequences for the voters. Further, despite the prevalence of participants casting weakly dominated ballots, most of our experimental elections delivered an outcome that was consistent with the outcome of a Nash equilibrium in weakly undominated voting strategies. This suggests that in aggregate people's 'mistakes' may cancel each other out, thereby yielding the same electoral outcomes as if all the ballots cast were weakly undominated. Finally, there is some hope that the use of weakly dominated votes would not be that widespread if Approval Voting was used for political elections. Indeed, party elites and media—two actors that are absent from our experiment—may undertake an education effort toward the citizens.

As a word of caution, we emphasize that we see our results as preliminary evidence on the effect of the three voting rules on the number of viable parties. Many robustness checks with varying numbers and locations of voters and candidates are needed. Further, to make the setting more realistic, it is important to incorporate strategic candidacy decisions into the analysis. Another issue to consider is that of path dependence in electoral reforms. The current experiment shows that multipartism may arise under Dual Voting, but it is silent about whether multipartism is likely to occur *following an electoral reform* where Plurality Voting is replaced with Dual Voting. More generally, in the presence of multiple equilibria—as is the case in our setting—we would like to know which of them will become focal following the replacement of Plurality Voting with another voting procedure. Our evidence indicates that an equilibrium with the middle candidate in the winning set might be focal.

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