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Abstract

The objective of this paper is to design a laboratory experiment for an infinite-horizon sequential committee search model in order to test some of the implications obtained by the model in Albrecht, Anderson, and Vroman (2010) (AAV). We find that, compared with single-agent search, the search duration is longer for committee search under the unanimity rule, but is shorter for committee search in which at least one vote is required to stop searching. In addition, according to estimates from round-based search decisions, subjects are more likely to vote to stop searching in committee search than in single-agent search. This confirms that agents are less picky in committee search. Overall, the experimental outcomes are consistent with the implications suggested by the AAV model. However, despite the prediction from the AAV model, we could not obtain a significant outcome in relation to the size order of the

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probabilities of voting to stop searching in committee search for the various plurality voting rules.

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1 Introduction

The decision mechanism of agents regarding whether to stop or continue searching has been considered in many fields of economics, including labor economics, monetary economics, macroeconomics, and industrial organization. Very recently, there has been an emerging interest in committee search, in which a decision is made by a group of multiple agents rather than by a single agent. An evolving theoretical literature duly analyzes the properties of decision-making in the case of committee search (Albrecht, Anderson, and Vroman, 2010; Compte and Jehiel, 2010). However, to our best knowledge, no corresponding empirical studies have been conducted, mainly because it is generally difficult to collect data on committee search processes. This paper is thus the first attempt to provide experimental evidence on committee search and to test the theoretical implications obtained by the committee search model in Albrecht et al. (2010) (hereafter AAV). Overall, we find that our experimental outcomes are consistent with those obtained by the AAV model.

In the AAV model, a group engages in search activity to fill a vacant employment position or searches for a new house as a family. The members of the group or family then decide by vote whether to hire a newly encountered worker or to purchase a house. The AAV model assumes that members are homogeneous with respect to preferences and that each member draws a value from an identical and independent distribution across members. The model then compares the member's reservation value in single-agent search and committee search in an environment where the drawn value differs among the members under various plurality voting rules. The main predictions of the AAV model are that members are less picky in committee search than in standard single-agent search in the sense that each member's threshold is lower and that the members' thresholds vary by voting rule. Another implication obtained in the AAV model is that the search duration increases with the number of votes required to stop the committee search process.

The search environment characterized in the model is usually far removed from the environment observed from the micro data. Therefore, the search environment cannot be perfectly duplicated using micro data. However, we can recreate this search environment in the laboratory using controlled treatments. In recent years, many studies have been devoted to experimental analysis of the single-agent search model (Cox and Oaxaca, 1989 ; Harrison and Morgan, 1990). This experimental task is empirically tractable and attractive for testing the implications of sequential search models. Experimental studies on the sequential search model have proliferated, covering a range of topics such as the effect of unemployment benefit sanctions on individual search behavior (Boone, Sadrieh, and van Ours, 2009) and the differences in individual search behavior by attitudes toward loss and risk (Schunk, 2009). In addition, Schunk and Winter (2009) explored the reasons why in many of these studies agents stop searching earlier than what is theoretically optimal.

We expand upon this body of work by examining the decision-making processes of multiple agents engaged in a committee search activity. The main feature of our experimental design is that we conduct three types of game to identify exactly the predictions of the AAV model where agents are assumed to be homogeneous with respect to preferences. Game A provides the benchmark as a standard single-agent search task, Game B is a committee search task where three group members have a common value drawn from a distribution, and Game C is a committee search task where three group members each draw different values from the same distribution.[1] The difference between Games A and B is attributable to heterogeneity among members with respect to their risk and loss attitudes, time preferences, and any unobserved characteristics.[2] The difference between Games A and C arises from the heterogeneity among members already mentioned, plus additional heterogeneity in the sense of the different values the other members independently draw from the same distribution. Therefore, the difference between the above two differences is caused only by the second form of heterogeneity among members, in that the values drawn by the other members of the group are different. This is similar to the AAV model. In addition, we design three subgames for each of Games B and C: Subgame 1 adopts a plurality voting rule in which the committee search activity is stopped if at least one member votes to stop searching (the one-vote rule); in Subgame 2, the committee search activity is stopped only if at least two-thirds of members vote to stop searching (the majority rule); and in Subgame 3, the committee search activity is stopped only if all members vote to stop searching (the unanimity rule). The results of these subgames

[1] This implies that each member draws a value from an independent and identical distribution.

[2] The heterogeneity of preferences among members in a group is ruled out in the AAV model.

provide evidence concerning the effect of voting rules.

We conducted experimental tests of an infinite-horizon sequential search model with a 5% probability that the experiment coercively ends. With this experiment, the focus is on exploring (i) the search duration and (ii) the probability of voting to stop searching in committee search with various plurality voting rules compared with single-agent search. Our finding regarding search duration is that, compared with single-agent search, the search duration is longer for committee search with the unanimity rule but shorter for committee search with the one-vote rule, after controlling for the heterogeneity of preferences among group members regarding risk and loss attitudes, time preferences and any unobserved factors. However, in our experiments, the difference in search duration between single-agent search and committee search with the majority rule is statistically unclear. These outcomes imply that two effects operate to determine this relationship.

The first effect is that it takes more time to reach an agreement in committee search with the majority rule than it does in single-agent search. Thus, on the one hand, the committee search structure with the majority rule lengthens the search duration. However, on the other hand, the second effect is that committee search with the majority rule lowers each subject's reservation value because she or he is less picky, thereby shortening the search duration. In our experiment, under the majority rule, these opposing effects cancel each other out, leading to the conclusion that there is no difference in search duration between single-agent search and committee search with the majority rule. These results imply that search duration is increasing in the number of votes required to stop the committee search, which supports the first part of Proposition 5 in the AAV model. In addition, a comparison of the search duration between committee search with the unanimity rule and single-agent search shows that the search duration is increasing in group size, holding the unanimity rule fixed. The single-agent search structure is regarded as a special case of the unanimity rule. This supports the implication obtained from the second part of Proposition 4 in the AAV model.

Our second focus is on identifying differences in a subject's willingness to accept a drawn value between single-agent search and committee search. To do this, we estimate the average marginal effects from a probit model to examine the determinants of the probability of voting to stop searching using data from every round-based decision about whether to vote to stop searching. Our findings are that subjects are more likely to vote to stop searching in committee search than in single-agent search, and that this outcome is strongly observed in committee search with the one-vote and majority rules. These estimated results confirm the threshold effect referred to in the AAV model (Proposition 2 therein), in the sense that subjects lower their reservation values in committee search and thus become less picky about the standard of acceptance.

However, our experimental outcome cannot statistically support the AAV model's prediction in terms of the size order of the reservation values among the types of committee search with the various plurality voting rules. The AAV model predicts that we cannot express the reservation value as an inverse hump-shaped function of the number of votes required to stop the search (the second part of Proposition 5 in the AAV model). Unfortunately, given our limited sample size, we cannot significantly support this prediction. However, we can say that the probability of voting to stop the search is at first gently, and then rapidly, decreasing in the number of votes required to stop the search. That is, the reservation value is quantitatively increasing in the number of votes required to stop the search, which is consistent with the AAV model's prediction. We find that subjects stop searching earliest in committee search with the one-vote rule, followed by the majority rule, and then the unanimity rule. This result arises from the subjects' preferences regarding the two negative externalities (one that the committee search activity stops despite the subject's preference to continue searching, and the other that the committee search activity continues despite a subject's preference to stop searching). For the most part, the one-vote and unanimity voting rules are, respectively, most strongly influenced by the first and second externalities, whereas the majority rule is influenced by both externalities, but only moderately. Our results imply that subjects who participated in this experiment incurred a larger disutility from the negative externality whereby the committee search activity stops despite the subject's preference to continue searching than from the other negative externality whereby the committee search activity continues despite the subject's preference to stop searching.

In summary, our experimental outcomes are consistent with the implications in the AAV model in terms of the relationships between committee and single-agent search for search duration and the probability of voting to stop. However, we do not obtain a significant experimental outcome in terms of the relationship of the probability of voting to stop committee search activities among given plurality voting rules. We also obtain other interesting findings in our comparison of the effects of Games B and C on the probability of voting to stop searching. The probit estimates show that many of the estimated coefficients on Games B are significantly positive relative to the reference group for Game A. This implies that subjects are not homogeneous with respect to their risk and loss attitudes, time preferences, and any unobserved factors, and that the heterogeneity of preferences among group members lowers each member's reservation value. Moreover, because the estimated coefficients on each Game C are significantly positive and larger in magnitude than the corresponding ones on Game B, additional heterogeneity exists in that the values the other members draw are different, which reinforces the incentive to vote to stop searching in an earlier round.

The paper is organized as follows. Section 2 discusses the implications of the AAV model in detail. Section 3 explains the strategy for identification, and Section 4 elaborates upon the experimental design. Section 5 includes descriptive statistics and results of the regression analysis. Section 6 provides some concluding remarks.

2 Model

Albrecht et al. (2010) construct a committee search model in which group members decide whether to stop or continue searching by vote. They assume that group members are risk neutral and homogeneous with respect to preferences, and that each member randomly draws a value from an independent and identical distribution across members. We should note that values are therefore uncorrelated across group members. This model setup is a proxy describing the more realistic environment in which members draw the same value, but do not know how other members evaluate the value or their attitudes toward loss and risk.[3] This setting may differ from a realistic situation, but it is analytically tractable and qualitatively identical. Given the value in hand, each group member votes for or against stopping the search.

Albrecht et al. (2010) found that agents are less picky in committee search than in single-agent search because each member faces two negative externalities: (i) committee search continues under a given voting rule despite an individual's preference for the search to stop; and conversely (ii) committee search stops under a given voting rule despite the individual's preference to continue searching. These negative externalities are attributable to the assumption that each member draws a value from the independent and identical distribution. Thus, the reservation value is lower in committee search than in single-agent search, thereby leading to a shorter search duration (a higher probability of stopping the search). The AAV model refers to this as the *threshold effect*. However, there is another effect determining search duration; that is, committee search with plurality voting rules either raises or lowers the probability of stopping the search, given any reservation value. This is referred to as the *vote aggregation effect*. Whether the probability of stopping the search for any given reservation value is higher or lower in committee search than in single-agent search depends on the given reservation value in the single-agent search structure, the discount factor and the plurality voting rule applied. [4]

Figure 1 illustrates an example of the AAV model and decomposes the probability of stopping the search in the case of single-agent search versus committee search into the two effects, i.e., the threshold and the vote aggregation effects. We assume here that a group consists of three members (we design the group as comprising three members in our experiment). In addition, we assume that an individual member conducts a committee search activity with the other two members and faces a uniform distribution $F(x)$ of drawn value x with a lower bound of $\underline{x}$ and an upper bound of $\overline{x}$. The probability of continuing to search $P(x, 3, i)$ is calculated by the sum of the binomial probabilities

[3] Compte and Jehiel (2010) consider the case where members hold the same value but do not know how other members evaluate this value.

[4] The reservation value and the discount factor are closely related in the standard sequential search model. If an individual discounts the future more, then the individual's reservation value is lower, implying that he or she wants to exit the search earlier.

that exactly $i-1$ or fewer among the three members vote to stop, given that the reservation value is x. For example, $P(x, 3, 2)$ indicates the probability that none or only one of the three members votes to stop, in which case this group continues to search under the majority rule. Be aware that $P(x, 1, 1) \equiv F(x)$. $(1 - P(x, 3, i))$ instead represents the probability of stopping the search. In this illustration, the reservation value is lower in committee search with the majority rule (x_c) than in single-agent search (x_s), and the probability of stopping the search is higher in committee search with the majority rule $(1 - P(x_c, 3, 2))$ than in single-agent search $(1 - P(x_s, 1, 1))$. The difference in the probability of stopping the search between committee search with the majority rule and single-agent search is thus decomposed into the threshold effect $(P(x_s, 3, 2) - P(x_c, 3, 2))$ and the vote aggregation effect $(P(x_s, 1, 1) - P(x_s, 3, 2))$.

The vote aggregation effect results in a higher probability of stopping the search in committee search with the one-vote rule than in single-agent search for any given reservation value (see Figure 2). Because the committee search activity stops if any of the three members votes to stop, the probability of stopping the search is higher. This reinforces the shorter search duration that occurs for this type of search. On the other hand, in the comparison of single-agent search versus committee search with the unanimity rule shown in Figure 3, the vote aggregation effect induces a lower probability of stopping the search in the case of the committee search activity for any given reservation value because it takes longer for the three members to reach an agreement. Thus, this type of search leads to a longer search duration. Under the unanimity rule in this specific example, the vote aggregation effect is large enough to dominate the threshold effect, thereby resulting in the longer search duration. In a comparison of single-agent search versus committee search with the majority rule, the vote aggregation effect reinforces the threshold effect within the range of lower reservation values (or lower discount factors), implying a shorter search duration. The vote aggregation effect has the opposite effect to the threshold effect within the range of higher reservation values (or higher discount factors). For sufficiently high reservation values, the threshold effect dominates the vote aggregation effect, leading to a shorter search duration. However, for only moderately high reservation values, the magnitude relation between these two effects reverses, resulting in a longer search duration (see Figure 4).

3 Strategy for identification

This section considers a methodology to identify the implications of the AAV model. In our experiment, we restrict ourselves to the case where the group consists of three members and then compare the experimental outcomes under the various plurality voting rules. We have two main reasons for choosing three-member groups. The first is that this group size is sufficiently large to analyze the search behavior of individual agents in a committee search activity under the various plurality voting rules described below. The second reason is that this small group size allows us to obtain data from a large number of groups in our laboratory with limited capacity.

3.1 Comparison of the single-agent search model and the committee search model

This subsection describes a way of testing and comparing the single-agent search model with a committee search model with a variety of plurality voting rules. Recall that in the AAV model, agents are homogeneous with respect to their risk and loss attitudes, time preferences, and any other unobserved characteristics, and that the difference between single-agent and committee search behavior therefore arises only from heterogeneity in the sense that the values drawn by group members are different and unknown to each other.[5] In our experiment, however, there exists yet another source of heterogeneity in the sense that grouped subjects differ in their risk and loss attitudes, time preferences, and any unobserved characteristics. To eliminate the bias arising from the latter form of heterogeneity, we conduct the following three games.

- **Game A:** A single agent independently decides to stop or continue searching.

[5] The properties of the AAV model remain the same, regardless of whether the different values drawn by the other members are known or unknown. In our experiments, subjects drew the value privately, and therefore no member knew the values that the other members drew.

- **Game B:** A group draws a common value from a distribution (group members know that they hold the same value), and then the group members collectively decide by vote to stop or continue searching.

- **Game C:** Each member of a group draws a value from the independent and identical distribution, and then the group members collectively decide by vote to stop or continue searching.

Using these games, we can observe the search durations of each subject. The difference in the search duration between Games A and B is attributable to the heterogeneity among group members regarding their risk and loss attitudes, time preferences, and any unobserved characteristics. The difference in the search duration between Games A and C is attributable to two types of heterogeneity: heterogeneity in terms of what other members' preferences are, as detailed above, and in the different values that group members draw from the independent and identical distribution. Therefore, the difference-in-differences of the search duration stems only from the heterogeneity in terms of the different values that the group members draw, implying that the heterogeneity in terms of the differences among members regarding their risk and loss attitudes, time preferences, and any unobserved characteristics is eliminated. This method therefore picks up the exact difference in the search duration between single-agent search versus committee search as characterized by the AAV model.

3.2 Comparison of the different plurality voting rules

The AAV model shows that the probability of stopping the committee search activity varies according to the plurality voting rule applied. To identify the effects of the different plurality voting rules, we conduct the following three subgames.

- **Subgame 1:** The committee search activity is stopped if at least one of the group members votes to stop (the one-vote rule).

- **Subgame 2:** The committee search activity is stopped only if two-thirds or more of the group members vote to stop (the majority rule).

- **Subgame 3:** The committee search activity is stopped only if all the group members vote to stop (the unanimity rule).

In Subgame 1, members are faced with the risk that committee search will stop despite an individual member's preference to continue searching, whereas in Subgame 3, committee search continues even if an individual member wants to stop searching. Subgame 2 is the in-between case of Subgames 1 and 3. Using these subgames, we can identify the effects of the risks presented by the different plurality voting rules.

4 Experimental design

We conducted our experiment on February 2, 2010, in the experimental laboratory of the Center for Experimental Research in Social Sciences at Hokkaido University, Japan. The experiment consisted of four separate sessions because of the constraints in laboratory capacity. Each session involved the same eight games in a different order (two games of Game A and three subgames each of Game B and Game C). We designed various experiments of an infinite-horizon sequential search model with a 5% probability that the experiment coercively ends.[6] When the committee search activity is coercively terminated, the subject unconditionally obtains the value drawn in the previous round. Recall was not allowed in this search model, meaning that the value drawn in the previous round is not available for consideration in the current round, except for the case of coercive termination. Although subjects are not encouraged to search longer in a search environment where recall is not allowed, this design is simple and exactly duplicates the structure of the AAV model.

The games differ in terms of the treatments in each experimental session. The experimental processes with the different treatments for single-agent and committee search are set out below.

[6] We also ran finite-horizon versions of the same experiments at Osaka University, Japan. Specifically, participants were told that the experiments would end after 20 rounds. The results from the finite-horizon experiments are qualitatively similar to those from the infinite-horizon experiments.

4.1 Game A: Single-agent search

Game A is the benchmark for a normal single-agent search task. A subject makes a draw from a uniform distribution with a lower bound of zero and an upper bound of 3,000. After making the draw, the subject decides whether to stop or continue searching. If the subject chooses to continue, he or she moves to the next round and makes another draw from the same distribution.

In an infinite-horizon sequential search model, the value of searching for a single agent V_A is given by:

$$V_A = \underbrace{(1-\delta)F(R_A)V_A}_{\text{continuing search}} + \underbrace{\delta \int_0^{R_A} x dF(x)}_{\text{terminating search}} + \underbrace{\int_{R_A}^{3000} x dF(x)}_{\text{accepting the offer}}, \tag{1}$$

where δ represents the exogenous probability that the experiment coercively ends, R_A is the reservation value, and $F(x)$ is the uniform distribution. For simplicity, there is no explicit discount over rounds, which encourages subjects to search longer. Our experiments are designed in such a way that a subject's search activity has to be terminated coercively with a probability of 5% for each round. This probability partially fulfills the role of a search cost that the subject incurs by continuing to search in the next round. The subject then has an incentive to stop searching even in the infinite-horizon sequential search model with no discount over rounds. The sum of the first two terms on the right-hand side in eq. (1) represents the value of rejecting a drawn value. The first of these terms is the value of continuing the search after the subject survives to the next round, and the second of these terms indicates the value of the search activity being terminated after the offer is rejected. When a search activity is coercively terminated, the subject has no choice but to accept the value that she or he rejected in the previous round.[7] The final term represents the value of accepting a drawn value. Because the reservation value of gaining R_A is equivalent to the value of searching in the next round ($R_A = \delta R_A + (1-\delta)V_A$), we obtain $R_A = V_A$.

[7] The experiment is designed to reduce the loss that each subject would have incurred if the search was terminated after she or he had decided to continue to search. This encourages the subject to search longer. In other words, in a design where each subject receives no payment when the search activity is terminated coercively, it is expected that she or he will not engage in the search activity for many rounds.

4.2 Game B: Committee search with a common value

Game B involves a form of committee search in which all members of a group draw a common value from the uniform distribution with a lower bound of zero and an upper bound of 3,000, and they know that they have the same value. Whether the committee search stops or continues is then decided by vote among group members under various plurality voting rules. Because group members are randomly reshuffled in every game, no member knows who the other two group members are, which rules out the presence of a learning effect regarding other group members' voting behavior.

If group members are homogeneous with respect to preferences, as in the AAV model, the committee search model with a common value is reduced to the single-agent search model shown in Game A. Therefore, the value for a group member of searching by committee V_B is:

$$V_B = \underbrace{(1-\delta)F(R_B)V_B}_{\text{continuing search}} + \underbrace{\delta\int_0^{R_B} x\,dF(x)}_{\text{terminating search}} + \underbrace{\int_{R_B}^{3000} x\,dF(x)}_{\text{accepting}}. \quad (2)$$

Because $R_B = \delta R_B + (1-\delta)V_B$, we obtain $R_B = V_B$. According to eq. (2), if all group members are homogeneous with respect to preferences, they all either accept or reject a drawn value together, regardless of which voting rule is employed.

If there is a difference in the reservation values between Games A and B in our experiment, it is largely attributable to the heterogeneity of preferences in search activity among members. In our experiment, Game B consists of three subgames, each of which differs according to the plurality voting rules explained in Section 3.2.

4.3 Game C: Committee search with different values

In Game C, similarly to Game B, group members decide by vote whether to stop or continue searching. However, unlike Game B, each group member separately makes a draw from a uniform distribution with a lower bound of zero and an upper bound of 3,000, which means that the drawn values are identically independent across the group members. Game C, like Game B, consists of three subgames, C-1, C-2, and C-3, as explained in Section 3.2.

Suppose that committee search is stopped if at least one group member votes to stop searching (Subgame C-1: one-vote rule). The value for a subject of searching by committee V_{C1} is given by:

$$
\begin{aligned}
V_{C1} = {} & \underbrace{(1-\delta)F(R_{C1})^3 V_{C1}}_{\text{continuing committee search after the subject votes to continue}} \\
& + \underbrace{\delta F(R_{C1})^2 \int_0^{R_{C1}} x dF(x)}_{\text{terminating committee search after the subject votes to continue}} \\
& + \underbrace{\int_{R_{C1}}^{3000} x dF(x)}_{\text{accepted by self}} + \underbrace{[1-F(R_{C1})^2] \int_0^{R_{C1}} x dF(x)}_{\text{accepted by one or both of the others, but not by self}} . \qquad (3)
\end{aligned}
$$

The sum of the first two terms on the right-hand side in eq. (3) represents the value of committee search when all group members vote against stopping the search. The first of these two terms denotes that the committee group survives to the next round with a probability of $(1-\delta)$, but the second term shows that the group has to stop searching, and thus the group obtains the value drawn in the previous round. The sum of the third and fourth terms in eq. (3) indicates the value for the subject of accepting the drawn value. The third term represents that at least one member, including the subject, votes to stop searching, and the fourth term shows that one or both of the other two members vote for stopping the search, although the subject votes against it. Because $R_{C1} = \delta R_{C1} + (1-\delta)V_{C1}$ according to the reservation value rule, we obtain $R_{C1} = V_{C1}$.

Next, we consider a committee search model in which committee search is stopped only if at least two out of three members vote to stop searching (Subgame C-2: majority rule). The value for a subject of searching by committee V_{C2} is obtained as follows:

$$
\begin{aligned}
V_{C2} \quad = \quad & \underbrace{(1-\delta)[F(R_{C2})^3+3(1-F(R_{C2}))F(R_{C2})^2]V_{C2}}_{\text{continuing committee search}} \\
& + \underbrace{\delta[F(R_{C2})^2+2(1-F(R_{C2}))F(R_{C2})]\int_0^{R_{C2}} xdF(x)}_{\text{terminating committee search after the subject votes to continue}} \\
& + \underbrace{\delta F(R_{C2})^2 \int_{R_{C2}}^{3000} xdF(x)}_{\text{terminating committee search after the subject votes to stop}} + \underbrace{[1-F(R_{C2})]^2 \int_0^{R_{C2}} xdF(x)}_{\text{accepted by others, but not by self}} \\
& + \underbrace{[1-F(R_{C2})^2] \int_{R_{C2}}^{3000} xdF(x)}_{\text{accepted by self and one or both other members}} \quad . \qquad (4)
\end{aligned}
$$

The first term on the right-hand side in eq. (4) shows the value of continuing the committee search activity after the committee survives to the next round. $[F(R_{C2})^3+3(1-F(R_{C2}))F(R_{C2})^2]$ implies the probability that at least two members vote against stopping the search. The second and third terms represent the value of the committee search activity being coercively terminated. The second term shows the case in which at least two members, including the subject, vote against stopping the search before termination of the committee search activity, whereas the third term deals with the case in which the subject votes for stopping the search, but the other two members vote against it before termination. The fourth and fifth terms indicate the value for the subject of stopping the committee search activity; the fourth term shows the case in which the subject votes against stopping the search, but the other two members vote for it, whereas the fifth term indicates that the subject and one or both of the other two members vote to stop searching. As discussed above, we have $R_{C2} = V_{C2}$.

Finally, we move to the committee search model in which committee search is stopped only if all members of the group vote to stop (Subgame C-3: unanimity rule). The value for a subject of searching by committee V_{C3} is given by:

$$
\begin{aligned}
V_{C3} \quad = \quad & \underbrace{(1-\delta)[1-(1-F(R_{C3}))^3]V_{C3}}_{\text{continuing committee search}} \\
& \underbrace{+\delta[F(R_{C3})^2+2(1-F(R_{C3}))F(R_{C3})+(1-F(R_{C3}))^2]\int_0^{R_{C3}} xdF(x)}_{\text{terminating committee search after the subject votes to continue}} \\
& \underbrace{+\delta[F(R_{C3})^2+2(1-F(R_{C3}))F(R_{C3})]\int_{R_{C3}}^{3000} xdF(x)}_{\text{terminating committee search after the subject votes to stop}}+\underbrace{[1-F(R_{C3})]^2\int_{R_{C3}}^{3000} xdF(x)}_{\text{accepted by all members}}. \quad (5)
\end{aligned}
$$

The first term on the right-hand side in eq. (5) represents the value for the subject of continuing the committee search after her or his committee survives to the next round, whereas the last term denotes the value for the subject of accepting a drawn value when all of the members vote to stop the search unanimously. The second and third terms represent the value of the committee search activity being coercively terminated. The second term indicates the value of the committee search activity being terminated after at least the subject votes against stopping the search. In the third term, committee search is terminated after at least the subject votes for stopping the search, but one or both of the other members vote against it.

4.4 Hypotheses

This subsection sets out our experimental hypotheses developed to test the theoretical implications of the AAV model. Because Albrecht et al. (2010) found many novel and interesting implications from their committee search model, we cannot test all possible hypotheses arising from it. Accordingly, we focus the laboratory experiment on testing two sets of hypotheses relating to: (i) the comparison of search duration between single-agent and committee search under various plurality voting rules; and (ii) the comparison of the willingness to stop searching between single-agent and committee search under various plurality voting rules. For the first set of hypotheses (regarding search duration), we test the theoretical implications of the first part of Proposition 5 and the second part of Proposition 4 in Albrecht et al. (2010). For the second set of hypotheses (regarding the willingness to stop searching), we test the implications of Proposition 2 and the second part of Proposition 5.

We begin with the first set of hypotheses.

- **H1 (the first part of Proposition 5):** The average search duration is increasing in the number of votes required to stop committee search. In addition, the average search duration is shorter (longer) in the case of committee search with the one-vote rule (unanimity rule) than in the case of single-agent search.

If this hypothesis is statistically supported, as indicated in the AAV model, then, compared with single-agent search, the probability of stopping the search is higher in committee search with the one-vote rule but lower in committee search with the unanimity rule. The probability of stopping the search in committee search with the majority rule lies between the other plurality voting rules.

- **H2 (the second part of Proposition 4):** The average search duration is increasing in the number of group members, given that the number of votes required to stop searching equals the number of group members.

To test this hypothesis, we compare the average search duration between committee search with the unanimity rule where the search is stopped if all three members of the group vote to stop and single-agent search where the individual search stops if "one out of the one member of the group" decides to stop the search. Our expectation is that the search duration is longer in the case of committee search with the unanimity rule than in the case of single-agent search.

(H1) and (H2) address the combined effects (the threshold and vote aggregation effects) on the average duration of committee search. The next step is to employ the probit model to estimate determinants of individual voting behavior regarding stopping searching, using data from each round-based decision from the eight games. This identifies the threshold effect whereby subjects are less picky in committee search than in single-agent search, as described in Proposition 2 in Albrecht et al. (2010). We then move to the second set of hypotheses as follows.

- **H3 (Proposition 2):** A subject votes for stopping the search in an earlier round of committee search, regardless of the plurality voting rules, compared with single-agent search.

This test allows us to capture the threshold effect and compares the reservation values between single-agent and committee search using the various plurality voting rules. The final hypothesis we test in our experiment is the implication from the second part of Proposition 5.

- **H4 (the second part of Proposition 5):** The reservation value is not permitted to be an inverse hump-shaped function of the number of votes required to stop the committee search activity. In other words, in committee search, the reservation value cannot be lower under the majority rule than under the one-vote rule. At the same time, the reservation value cannot be lower under the majority rule than under the unanimity rule.

We thus test the null hypothesis that $R_{C1} \geq R_{C2}$ *and* $R_{C2} \leq R_{C3}$, where R_i represents the reservation value for game i. In other words, the probability of voting to stop the committee search activity cannot be expressed as a hump-shaped function of the number of votes required to stop the search.

In addition, we test whether group members are on average homogeneous with respect to their risk and loss attitudes, time preferences, and any unobserved characteristics. If the estimated coefficients on the dummy variables from Game B are not jointly different from zero in the probit estimation of individual voting behavior, we can support the hypothesis that group members are homogeneous with respect to their preferences. This draws our attention to eliminating the bias arising from the heterogeneity of preferences across group members when the four hypotheses are tested. Section 5 provides the estimated results.

4.5 Administration and payoffs

We conducted four sessions. The order of games in each session was as follows: first session: Games A, B-3, B-2, B-1, C-3, C-2, C-1, and A; second session: Games A, C-1, C-2, C-3, B-3, B-2, B-1, and A; third session: Games A, C-3, C-2, C-1, B-1, B-2, B-3, and A; and fourth session: Games A, B-1, B-2, B-3, C-1, C-2, C-3, and A. We instructed the subjects to play a training game that was the same as Game A once before the experiment began. Although we might not be able to rule out the possibility that this training affected the subjects' behavior in the first Game A, this step was necessary to ensure that the subjects correctly understood the nature of the experiment. We ran Game A twice as the first and last games in each session. This enables us to determine whether an anchoring effect arises in the sense that there is any difference in the search behavior between the first and last Game A. The anchoring effect implies that the subjects' behavior is affected by results that they obtained in previous games. The subjects were 60 undergraduate students from various academic disciplines. We ran the experiments entirely on computers using the software package *Z-Tree* (Fischbacher, 2007). [8]

The instruction sheet presented full information about the search task.[9] Following the experiment, the participants answered a questionnaire and the payoff procedures took place. With regard to payoffs, we emphasized that: (i) the subjects' payoff was truncated at JPY0 (EUR0) (i.e., they could not incur losses from the search task) and (ii) they would earn an appearance fee of JPY1,000 (EUR7.9).[10] The performance pay was determined based on the result from one of the eight games randomly chosen by each subject. The expected total payoff was JPY2,500 (EUR19.75) to 3,000 (EUR23.7). Therefore, because the on-duty time for the experiment was approximately 90 minutes, the hourly wage was calculated at JPY1,600 (EUR12.64) to 2,000 (EUR15.8). This is approximately twice as much as the average hourly wage for college students in Japan, implying that we set the appropriate way of payoff to encourage subjects to work hard.

[8] The programs were produced by Takanori Kudou, a graduate student of the Engineering Division of Electrical, Electronic and Information Engineering, Osaka University.

[9] The instruction sheet is reproduced in the appendix.

[10] We use the exchange rate of JPY100 to EUR0.79 for February 2, 2010, the date when the experiment was conducted.

5 Results

5.1 Search duration

We begin with some descriptive statistics before undertaking statistical hypothesis tests of the first set of hypotheses (H1) and (H2). Table 1 provides selected descriptive statistics, including the averages and standard deviations of the durations for the infinite-horizon sequential search model. We find that the average search duration for single-agent search in the first Game A differs from that in the last Game A at the 5% level of significance, implying that there may be an anchoring effect in the sense that a subject's search behavior is influenced by results she or he obtained in the previous experimental games. This may result in an identification bias in the statistical tests. The average search duration is longer for committee search under the majority and unanimity rules when group members have different values (Game C) compared with when they have the same value (Game B), but the reverse is observed when the one-vote rule applies. As the required number of votes to stop searching increases, the average search duration becomes longer, regardless of whether group members draw the same or different values.

Table 2 provides the results of t-tests of the difference in search duration between committee search under the different plurality voting rules versus single-agent search. The top three rows of this table compare the average duration for single-agent search and committee search in which all group members draw the same value (Game B). We find that the null hypothesis that the average duration of committee search with the one-vote rule is equal to or larger than that of single-agent search is rejected at the 10% level of significance. Conversely, compared with single-agent search, the average duration is shorter in committee search with the majority rule and longer in committee search with the unanimity rule, but in both these cases, the difference in the average duration between the two models is not significantly different from zero.

According to the AAV model, group members are homogeneous with respect to their risk and loss attitudes, time preferences, and any unobserved characteristics, and therefore share the same threshold. Therefore, when the group members make the same draw and evaluate it in common, neither the threshold nor the vote aggregation effect arises, resulting in no difference in the average duration between the single-agent and committee search models, regardless of which plurality voting rule applies.

Although the differences in the average search duration between single-agent and committee search with the majority and unanimity rules in Game B are statistically insignificant, this does not necessarily mean that group members are homogeneous with respect to their preferences. If group members are heterogeneous in terms of their preferences, they evaluate the same drawn value differently, in a case of which both threshold and vote aggregation effects arise. On the one hand, it takes more time to reach an agreement in committee search with the majority and unanimity rules than in single-agent search, which lengthens the search duration. On the other hand, each subject's reservation value decreases because she or he is less picky, thereby shortening the search duration. It is possible that the two opposing effects cancel each other out, which suggests that group members might have been homogeneous with respect to their preferences. To correctly test the implications of the AAV model where members are homogeneous, it is necessary to test the difference in the threshold level among group members, which is analyzed in Section 5.2.

The bottom three rows in Table 2 compare the average duration between single-agent and committee search in which group members draw different values (Game C). Recall that the difference in the average duration between the two models arises from the heterogeneity of preferences among group members, as discussed above, and from the other heterogeneity in terms of the different draws that other members make. The search duration is shorter in committee search with the one-vote rule than in single-agent search at the 1% level of significance. Similarly, the search duration is longer in committee search with the unanimity rule than in single-agent search at the 1% level of significance. The average search duration is insignificantly shorter in committee search with the majority rule than in single-agent search. We have not yet identified whether the difference in average duration arises from the heterogeneity among group members with respect to their preferences or from the other heterogeneity in the sense that the draws other members make are different. We can correctly confirm the implications of the AAV model by correspondingly deducting the differences displayed in the top three rows in Table 2 from the differences displayed in the bottom three rows. We test the null hypothesis that the *difference-in-differences* of the average search duration, (Game C-1 – Game A) – (Game B-1 – Game A) = Game C-1 – Game B-1, is zero. The same procedure applies to the other two voting rules.

Table 3 gives the results of t-tests of the difference in the average duration between single-agent and committee search after controlling for heterogeneity among group members. As shown in the first row of the table, the average search duration is shorter in committee search with the one-vote rule than in single-agent search at the 1% level of significance. Similarly, the null hypothesis that the average search duration in committee search with the unanimity rule is equal to or shorter than the average duration in single-agent search is rejected at the 1% level of significance. Another interpretation of this result is that as the number of group members increases from one to three, holding the unanimity rule fixed, the average search duration becomes longer. The single-agent search model is then considered a special case of the committee search model with the unanimity rule. This result is consistent with the second part of Proposition 4 in the AAV model. Looking at the differences between single-agent and committee search with the majority rule in Table 3, we cannot significantly reject the null hypothesis that the two average durations are equal. The AAV model predicts that if the reservation value of single-agent search (or the discount factor) is extremely low or extremely high, the average search duration is shorter in committee search with the majority rule, but otherwise it is longer, as illustrated in Figure 4. Therefore, it is not surprising that these outcomes are obtained from our experiment. An examination of the differences in committee search with the various plurality voting rules shows that the average search duration is increasing in the number of votes required to stop the search. This outcome supports the first part of Proposition 5 in the AAV model.

Table 4 provides the ordinary least squares estimates of the determinants of search duration in the infinite-horizon sequential search version. The dependent variable is each subject's search duration in each game, while the vector of independent variables consists of dummy variables for treatment, game order, each subject's attitude toward risk, a dummy variable for female gender, and/or dummy variables for individual effects. The variable regarding the game order indicates the order in which the subject played the games in each session. The variable for risk attitude is included to partially control for individual heterogeneity. To collect this variable, we administered a questionnaire to all participants after eight games and asked three questions about their attitude toward risk. Of these, we selected one question relating to the price subjects were willing to pay for a lottery with a 25% chance of winning JPY2,000 (EUR15.8) and a 75% chance of receiving JPY0 (EUR0).[11][12] We then calculated the index measuring the extent of absolute risk aversion using the method in Cramer et al. (2002).[13] If this index is positive, a subject is considered risk averse; if negative, the subject is considered risk seeking. If the index is exactly zero, the subject is risk neutral.

We control for individual effects in column [1] of Table 4, and replace the individual effects with other individual characteristics represented by absolute risk aversion and gender in columns [2] and [3], respectively. The columns in Table 4 indicate almost the same results: the coefficient on Game C-1 is negative, whereas that on Game C-3 is positive, both at the 1% level of significance when the reference group is defined as the first Game A.[14] The coefficient on Game B-1 is negative at a marginal level of significance (10%) in columns [2] and [3]. From the estimates of search duration, we find that in committee search with the one-vote rule, group members are heterogeneous with

[11] We again use the exchange rate of JPY100 to EUR0.79 on February 2, 2010, corresponding to when the experiment was conducted.

[12] The other two questions were: "With at least what chance of rain do you take an umbrella?" and "What price are you willing to pay for a lottery with a 25% chance of winning JPY200 (EUR1.6) but a 75% chance of receiving JPY0 (EUR0)?" In the first question, subjects that responded with a lower value were considered to be more risk averse. We also estimated the determinants of search duration using indices of absolute risk aversion obtained from these questions and obtained similar results.

[13] According to Cramer et al. (2002), the extent of absolute risk aversion is calculated as follows:

$$\frac{0.25 \times 2000 - price}{0.5(0.25 \times 2000^2 - 2 \times 0.25 \times 2000 + price^2)},$$

where *price* implies the price that a subject is willing to pay for the lottery with a 25% chance of winning JPY2,000 (EUR15.8) but a 75% chance of receiving JPY0 (EUR0).

[14] Note that the coefficients on games are the same in all columns. This is because, in the estimates of search duration where there are eight observations for search duration for each subject, individual characteristics are perfectly uncorrelated with the treatment variables (games) that are given exogenously.

respect to their risk and loss attitudes, time preferences, and any other unobserved characteristics. However, we should note that, as mentioned before, both threshold and vote aggregation effects arise if group members evaluate the common drawn value differently. It is then possible that the threshold and vote aggregation effects are opposite and cancel each other out in Games B-2 and B-3. In this case, the estimated coefficients on these games become insignificant despite the heterogeneity of preferences among group members. We cannot exactly identify whether or not group members are homogeneous in terms of search behavior based on the estimates of search duration in Table 4.

Assuming that group members are heterogeneous in terms of their preferences, we test the first set of hypotheses regarding search duration, (H1) and (H2), by deducting the coefficients on Game B from the corresponding values for Game C, using the estimated results from column [1] of Table 4. We obtain the same results as Table 3, as shown in Table 5. The null hypothesis that the search duration in committee search with the one-vote rule is equal to or longer than the search duration in single-agent search is rejected at the 1% level of significance. Similarly, we reject the null hypothesis that the average search duration in committee search with the unanimity rule is equal to or shorter than the average duration in single-agent search at the 1% level of significance. This implies that the search duration is increasing in group size, holding the unanimity rule fixed. This result again supports the second part of Proposition 4 in the AAV model (H2). We cannot reject the null hypothesis of no significant difference in the search duration between committee search with the majority rule and single-agent search. As discussed, this result is not surprising because the AAV model shows that the search duration is either shorter or longer in committee search with the majority rule, depending mainly on the reservation value of the single-agent search model and the agent's discount factor. We confirm that the search duration is increasing in the number of votes required to stop committee search. This result is again consistent with the first part of Proposition 5 in the AAV model (H1).

Consider now the estimated coefficients on the other independent variables. The variable regarding the game order is statistically insignificant in all columns of Table 4. In the estimates of the search duration, we can say that the anchoring effect whereby a subject's behavior is affected by how she or he behaved in the previous games is minor. We estimate the effects on the search duration of individual characteristics represented by absolute risk aversion and gender. In columns [2] and [3] of Table 4, we find that the coefficients on these variables are insignificant.

5.2 The probability of voting to stop

This subsection considers each round-based decision by subjects on whether to vote for stopping the search and then tests the second set of hypotheses regarding the probability of voting to stop the search, (H3) and (H4). Table 6 displays the average marginal effects of the probit model to estimate determinants of the vote to stop searching, using the round-based data on search decisions. The dependent variable is dichotomous, taking a value of one if a subject accepts a drawn value in the case of single-agent search or votes to stop searching in the case of committee search, and zero otherwise. The independent variables are dummy variables for treatment, the drawn value, the round, game order, attitude toward risk, a dummy variable for female gender, and/or dummy variables for individual effects. The purpose of these estimations is to capture differences in the probability of voting to stop the search, or in the reservation value between committee search and single-agent search, and then to extract the threshold effect quantitatively.

We control for individual effects in columns [1] and [2] of Table 6. Column [1] excludes the independent variable for round whereas column [2] includes this variable. We replace the individual effects with other individual characteristics represented by absolute risk aversion and gender in columns [3] and [4], respectively. In all columns, the coefficients on Game B-2, Game B-3, and all Games C are positive at the 1% level of significance, compared with the reference group of the first Game A, whereas the coefficients on Game B-1 are significantly positive at the 5–10% level. Because the coefficients on Games B are significantly positive and different from zero, we can say that heterogeneity exists in terms of preferences among group members, which encourages subjects to vote in favor of stopping the search in an earlier round. Because the coefficients on committee search are larger when the group members draw different values (Games C) than when the group members draw the same value (Games B), regardless of the plurality voting rule, the remaining heterogeneity regarding the different values that other members draw from the distribution reinforces the incentive to vote to stop searching in an earlier round. These results confirm the threshold effect, which suggests that the reservation value is lower in committee search than in single-agent search in the AAV model.

Table 7 provides the results of the tests of hypothesis (H3) that subjects are less picky in committee search, regardless of which plurality voting rule is employed, than in single-agent search. Each coefficient on Games C represents the average marginal probability of voting to stop in Games C, compared with that in the first Game A, using the estimated results in column [2] of Table 6. We should note that, as before, we test (H3) by deducting the coefficients on Games B from those corresponding to Games C, which allows us to control for the heterogeneity of preferences across group members. As shown in Table 7, we significantly reject the null hypotheses that the average marginal probability of voting to stop in Game C is equal to or lower than that in Game B under the one-vote and majority rules. This implies that subjects vote to stop the search in an earlier round under the one-vote and majority rules. We thus support Proposition 2 in the AAV model (H3), stating that subjects are less picky in terms of their acceptance standard in committee search than in single-agent search. However, contrary to our expectations, we cannot reject (H3) in the case of the unanimity rule.

Next, we compare the coefficients on Games C in terms of the magnitude to test the second part of Proposition 5 (H4). The probability of voting to stop searching varies according to the plurality voting rules. Albrecht et al. (2010) showed that the reservation value cannot be inverse hump-shaped in the number of votes required to stop searching; that is, the probability of voting to stop the committee search cannot be expressed as a hump-shaped function of the number of votes required to stop the search. Table 8 displays the results from testing (H4) using the estimated results from column [2] of Table 6. The first row in Table 8 tests the null hypothesis that the average marginal probability of voting to stop the search in Game C-1 is equal to or lower than that in Game C-2, while in the second row, we test the null hypothesis that the average marginal probability of voting to stop the search in Game C-3 is equal to or lower than that in Game C-2. As before, we control for the heterogeneity of preferences among group members by deducting the coefficients for Games B from the corresponding values for Games C. As shown in Table 8, we cannot significantly reject the two null hypotheses, contrary to our expectations. Nevertheless, we note that the statistical hypothesis testing does not necessarily imply that we *accept* that the probability of voting for stop is hump-shaped in the number of votes required to stop the committee search.

In addition, Table 8 indicates that the probability of voting to stop is at first gently and then rapidly decreasing in the number of votes required to stop the search. This provides weak evidence to quantitatively support the prediction of the AAV model that a subject votes in favor of stopping the search in an earlier round under the one-vote rule (Game C-1), followed by the majority rule (Game C-2) and the unanimity rule (Game C-3). In other words, the reservation value is lowest in Game C-1, followed by Game C-2, and then Game C-3. One of the reasons for this result may be that the subject's preferences in relation to the two negative externalities (i.e., the first externality relating to the committee search stopping despite the subject's preference to continue, and the second externality where the committee search continues despite the subject's preference to stop) are different. Recall that the one-vote and unanimity rules are strongly influenced by the first and second externalities, respectively, whereas the majority rule is influenced by both externalities, but only moderately. If the subject incurs a larger disutility from the first externality than the second, she or he tends to vote to stop in an earlier round under the one-vote rule, followed by the majority rule, and then the unanimity rule, because she or he does not want other members to stop the committee search, despite her or his preference to continue searching. On the other hand, if the subject incurs a larger disutility from the second externality than from the first, she or he tends to vote to stop in an earlier round under the unanimity rule, followed by the majority rule, and then the one-vote rule, because she or he does not want other members to continue the committee search despite her or his preference to stop searching. Our results then provide weak evidence that subjects incur a larger disutility from the negative externality involving the stopping of the committee search despite the subject's preference to continue than from the second negative externality relating to the committee search continuing despite the subject's preference to stop.

Other interesting variables also affect the probability of voting to stop searching. The coefficient on drawn value is positive at the 1% level of significance in all columns of Table 6. When a subject draws a higher value, she or he is more likely to vote to accept it. According to column [2] of Table 6, the coefficient on round remains positive at the 1% level of significance. This refutes our expectation that the round is not a determinant of voting to stop searching in an infinite-horizon sequential search. The variable regarding the game order is negative at the 1–5% levels of significance in all columns. This implies that subjects vote more aggressively in favor of continuing to search in later games.

A final question is whether there are any systematic differences in the probability of voting to stop searching among subjects. To explore this, we employ the individual characteristics, including the extent of absolute risk aversion and gender. The variable indicating the extent of absolute risk aversion is as expected. Its coefficient on absolute risk aversion is positive at the 1% level of significance in column [3] of Table 6, implying that more risk-averse subjects are more likely to vote to stop searching in an earlier round.

6 Concluding remarks

This paper described a laboratory experiment to study an infinite-horizon sequential search-by-committee model and tested some of the implications obtained in Albrecht et al. (2010). To date, there have been no empirical studies on committee search, mainly because of the difficulty in collecting suitable data. Using our laboratory experiment, we collected original data from subjects. This paper's main contributions are to provide experimental evidence about committee search and then to test the properties of search duration and voting behavior for various plurality voting rules. Our experimental design involved decomposing the source of the difference in search behavior between single-agent search and committee search into effects caused by heterogeneity with respect to preferences among group members and other heterogeneity in terms of the different values other members draw from the identically independent distribution.

Our findings are summarized as follows. After controlling for the heterogeneity of preferences among group members, the average search duration is longer in committee search with the unanimity rule than in single-agent search, whereas the average search duration is shorter in committee search in which at least one vote is required to stop the search than in single-agent search. In a comparison of single-agent search versus committee search with the majority rule, the hypothesis of no difference in search duration is not significantly rejected. This result is not surprising given the properties of the AAV model stating that the duration of committee search is either longer or shorter than that of single-agent search, depending on the value of the discount factor. These results imply that search duration is increasing in the number of votes required to stop committee search. This supports the first part of Proposition 5 in the AAV model (H1). In addition, we found that the search duration is increasing in group size, holding the unanimity rule fixed, when we compare the search duration in single-agent search with that in committee search with the unanimity rule. This result is consistent with the second part of Proposition 4 in the AAV model (H2).

To identify the threshold effect whereby negative externalities caused by committee search involving voting operate to lower a member's reservation value, we estimated the determinants of voting to stop searching. We found that subjects are more likely to vote to stop searching in committee search than in single-agent search. These estimated results confirm the threshold effect, in the sense that agents are less picky in committee search than in single-agent search, as the AAV model indicates in Proposition 2.

The AAV model predicts that the reservation value cannot be inverse hump-shaped in the number of votes required to stop searching. That is, the probability of voting to stop searching cannot be hump-shaped in the number of votes required to stop searching. Unfortunately, our experimental outcome cannot significantly support this prediction in terms of the size order of the reservation values. We also cannot rule out the possibility that the reservation value is expressed as an inverse hump-shaped function of the number of votes required to stop searching. Comparing the size of the coefficients on games, however, we found that the probability of voting to stop searching is at first gently and then rapidly decreasing in the number of votes required to stop searching, meaning that the reservation value is lowest under the one-vote rule, followed by the majority rule, and then the unanimity rule. This is weakly and quantitatively consistent with the predictions of the AAV model. This result implies that subjects who participated in the experiment incurred larger disutility from the negative externality involving committee search stopping despite a preference to continue, than from the second negative externality relating to committee search continuing despite a preference to stop.

Overall, our experimental outcomes are consistent with the implications in the AAV model in terms of comparisons of the search duration and the probability of voting to stop searching for committee versus single-agent search. However, the outcomes cannot statistically support the AAV model's prediction according to the different plurality voting rules in terms of comparison of the probability of voting to stop searching in the committee search model.

Of greatest interest to us now in this research topic is whether we would obtain the same experimental results with larger groups. As in the AAV model, we confirmed from the test of (H2) in our experiment that the search duration was longer as the group size increased from one to three under the unanimity rule. Our expectation is that the search duration will become even longer as the group size increases to, say, five under the unanimity rule because the vote aggregation effect operates more strongly. We therefore need to check for consistency in our results for larger groups. This provides one of many directions for our future research.

7 Appendix: Instructions

Note: Following are the instructions for Session 4 at Hokkaido University. Other sessions differed from this session in terms of the order of the games.

Welcome to our experiment! In this experiment, you will be asked to play eight games. In each game, you will be asked to choose either to accept a value that is randomly selected from a uniform distribution with a lower bound of zero and an upper bound of 3,000, or to refuse this value and move on to the next round to wait for a higher value. If you are willing to accept an offered value, you click on the "Y" displayed on the PC screen; if not, you click on the "N". You can continue to search as long as you want, but please remember that your search activity will be terminated coercively with a probability of 5%, in which case you will automatically receive the value drawn in the round immediately before termination. Your score will be determined according to the values that you accept.

We would like you to play eight different games. The first game is as follows.

- Game A: In each round, the computer randomly selects a value from a uniform distribution with a lower bound of zero and an upper bound of 3,000. You decide whether to accept the value drawn from this distribution. If you accept the value, then you finish your search and the value is your score. If you do not accept the value, you move on to the next round and observe another value newly drawn by the computer.

The next three games are as follows.

- Game B-1: You are grouped with two other participants. Grouping is done randomly by the computer, and no member knows who the other members are. In this treatment, you play a committee search activity with the other two members. In each round, the computer randomly selects a value for *all* three group members, including you, from a uniform distribution with a lower bound of zero and an upper bound of 3,000. All three group members, including you, receive the same value. You independently decide whether to accept the drawn value. If you prefer to accept the value, you vote for stopping the search, but if you do not accept the value, you vote against stopping. This committee search activity is stopped if at least one member of the group votes for stopping. Otherwise, your group moves on to the next round and observes another value newly drawn by the computer.

- Game B-2: The process of Game B-2 is similar to that of Game B-1 except for the plurality voting rule; that is, this committee search activity is stopped only if at least two-thirds of the members of the group vote for stopping.

- Game B-3: The process of Game B-3 is similar to that of Game B-1 except for the plurality voting rule; that is, this committee search activity is stopped only if all three members of the group vote for stopping.

The next three games are as follows:

- Game C-1: You are grouped with two other participants. Grouping is done randomly by the computer, and no member knows who the other members are. In this treatment, you play a committee search activity with the other two members. In each round, the computer randomly selects for *each* group member a value from a uniform distribution with a lower bound of zero and an upper bound of 3,000. Each group member therefore has a different value, and you do not know what value the other two members draw, and vice versa. You decide whether to accept the drawn value. If you accept your value, you vote for stopping the search, but if you do not accept your value, you vote against stopping. This committee search activity is stopped if at least one member of the group votes for stopping. Otherwise, your group moves on to the next round, and each member receives another value newly drawn by the computer.

- Game C-2: The process of Game C-2 is similar to that of Game C-1 except for the plurality voting rule; that is, this committee search activity is stopped only if at least two-thirds of the members of the group vote for stopping.

- Game C-3: The process of Game C-3 is similar to that of Game C-1 except for the plurality voting rule; that is, this committee search activity is stopped only if all three members of the group vote for stopping.

The final game is as follows.

- Game A: In each round, the computer randomly selects a value from a uniform distribution with a lower bound of zero and an upper bound of 3,000. You decide whether to accept the value drawn from this distribution. If you accept the value, then you finish your search and the value is your score. If you do not accept the value, you move on to the next round and observe another value newly drawn by the computer.

Before starting the experiment, we would like you to practice Game A once. Please let us know if you have any questions. We will explain the rule of each game again before it starts. After the experiment, please respond to a questionnaire. You will be paid an appearance fee of JPY1,000. The performance pay will be determined based on one of the scores from the eight games you randomly choose, and your payment will be calculated as JPY1 for each scoring point. Payment processes will take place after the experiment is concluded. Please be quiet and do not communicate with other participants during the experiment. Thank you for your participation.

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Table 1: Average Search Durations

	Value	Voting rule	#Searchers	Sample	Mean	S.D.	Max	Min
Game A(1)			1	60	3.233	3.306	18	1
Game B-1	common	one vote	3	60	2.650	1.571	6	1
Game B-2	common	majority	3	60	2.750	1.684	6	1
Game B-3	common	unanimity	3	60	3.600	2.981	13	1
Game C-1	different	one vote	3	60	1.300	0.561	3	1
Game C-2	different	majority	3	60	2.850	1.921	7	1
Game C-3	different	unanimity	3	60	11.700	8.947	32	1
Game A(8)			1	60	4.633	4.422	21	1
Average				60	4.090	4.992	32	1

Game A(1) and Game A(8) represent the first and last trial of Game A, respectively.

Table 2: Comparisons with Single-Agent Search (First Game A)

Game B-1	common	one vote	The search duration is shorter at the 10% level of significance.
Game B-2	common	majority	The search duration is insignificantly shorter.
Game B-3	common	unanimity	The search duration is insignificantly longer.
Game C-1	different	one vote	The search duration is shorter at the 1% level of significance.
Game C-2	different	majority	The search duration is insignificantly shorter.
Game C-3	different	unanimity	The search duration is longer at the 1% level of significance.

Note: We compared the means of the search durations using the one-tailed t-test.

Table 3: Comparisons of Search Durations between Single-Agent Search and Committee Search

First Game A	Game C-1	The search duration is shorter in Game C-1 at the 1% level of significance.
First Game A	Game C-2	The search duration is insignificantly longer in Game C-2.
First Game A	Game C-3	The search duration is longer in Game C-3 at the 1% level of significance.

Note: To control for heterogeneity of preferences among group members, we tested the implications of the AAV model by deducting a difference of the search duration between first Game A and Game C from a difference of the search duration between first Game A and Game B. In fact, we compared the means of the search durations between Games B and C using the one-tailed t-test.

Table 4: Estimates of Search Durations (OLS)

Search duration	[1]	[2]	[3]
Game B-1	-1.1383	-1.1383 *	-1.1383 *
	(0.6916)	(0.6564)	(0.6607)
Game B-2	-1.0383	-1.0383	-1.0383
	(0.6682)	(0.6491)	(0.6521)
Game B-3	-0.1883	-0.1883	-0.1883
	(0.7324)	(0.7043)	(0.7051)
Game C-1	-2.4883 ***	-2.4883 ***	-2.4883 ***
	(0.6502)	(0.6118)	(0.6162)
Game C-2	-0.9383	-0.9383	-0.9383
	(0.6790)	(0.6500)	(0.6543)
Game C-3	7.9117 ***	7.9117 ***	7.9117 ***
	(1.1441)	(1.2278)	(1.2293)
Game A(8)	0.2900	0.2900	0.2900
	(1.0881)	(1.1284)	(1.1336)
Game order	0.1586	0.1586	0.1586
	(0.1242)	(0.1254)	(0.1258)
Risk aversion		-353.158	
		(503.46)	
Female			0.0282
			(0.3641)
Constant	1.6102	3.169 ***	3.0311 ***
	(1.1131)	(0.4777)	(0.6668)
Individual effect	YES	NO	NO
N	480	480	480
F-test	4.2342	26.6111	26.5625
R2	0.4781	0.3668	0.3660

Robust standard errors are in parentheses. *** 1% significance, ** 5% significance, * 10% significance. The dependent variable is each subject's search durations. Game B-1 (common value + one-vote rule), Game B-2 (common value + majority rule), Game B-3 (common value + unanimity rule), Game C-1 (different values + one-vote rule), Game C-2 (different values + majority rule), Game C-3 (different values + unanimity rule). Game A(8) is the single-agent search game that subjects played in the last trial, which captures the anchoring effect, compared with the first trial of Game A (A(1)). We calculate the absolute risk aversion index using the willing -to-pay price for a lottery with a 25% chance of winning JPY2,000 (EUR15.8) but a 75% chance of receiving JPY0 (EUR0).

Table 5: Tests for Search Durations

	Null hypotheses	Difference in the coefficients	Std. Err.	t value	p-value	Test
[1]	Coef(C-1)-Coef(B-1)≥0	-1.3500	0.3691	-3.6600	0.0000	Rejected
[2]	Coef(C-2)-Coef(B-2)=0	0.1000	0.4144	0.2400	0.8090	Not Rejected
[3]	Coef(C-3)-Coef(B-3)≤0	8.1000	1.1312	7.1600	0.0000	Rejected

Note: Each row represents differences in the search duration between Games B and Games C by each plurality voting rule, using the results from column [1] of Table 4, when the reference group is defined as the first Game A. The magnitude of the coefficients on Game B is attributable to the heterogeneity among group members in terms of their preferences. The magnitude of the coefficients on Game C is attributable to the heterogeneity of preferences among group members plus the heterogeneity in terms of what value the other group members draw. Therefore, the differences between the coefficients between Game B and C indicate the marginal effects derived only by the second heterogeneity in terms of what value the other members draw, after controlling for the first heterogeneity of preferences among group members.

Table 6: Average Marginal Effects on the Probabilities of Voting to Stop the Search (Probit Estimations)

Willing to accept=1	[1]		[2]		[3]		[4]	
	Coef.		Coef.		Coef.		Coef.	
Drawn value	0.0003	***	0.0003	***	0.0003	***	0.0003	***
	(0.0000)		(0.0000)		(0.0000)		(0.0000)	
Round			0.0039	***	-0.0016		-0.0017	
			(0.0010)		(0.0012)		(0.0012)	
Game B-1	0.0460	*	0.0566	**	0.0664	**	0.0798	**
	(0.0265)		(0.0271)		(0.0320)		(0.0326)	
Game B-2	0.0859	***	0.0949	***	0.0981	***	0.1117	***
	(0.0239)		(0.0243)		(0.0288)		(0.0293)	
Game B-3	0.1098	***	0.1170	***	0.1174	***	0.1335	***
	(0.0343)		(0.0348)		(0.0338)		(0.0332)	
Game C-1	0.1153	***	0.1311	***	0.1360	***	0.1500	***
	(0.0319)		(0.0318)		(0.0434)		(0.0451)	
Game C-2	0.1496	***	0.1577	***	0.1497	***	0.1575	***
	(0.0254)		(0.0254)		(0.0323)		(0.0330)	
Game C-3	0.1360	***	0.1182	***	0.1299	***	0.1412	***
	(0.0218)		(0.0231)		(0.0254)		(0.0253)	
Game A(8)	0.0285		0.0317		-0.0037		0.0096	
	(0.0321)		(0.0325)		(0.0372)		(0.0373)	
Game order	-0.0111	***	-0.0116	***	-0.0087	**	-0.0094	**
	(0.0035)		(0.0035)		(0.0042)		(0.0042)	
Risk aversion					58.507	***		
					(14.3315)			
Female							0.0165	
							(0.0124)	
Individual effect	YES		YES		NO		NO	
N	1963		1963		1963		1963	
Pseudo R2	0.7839		0.7896		0.6255		0.6201	
Wald chi2	350.95		341.84		451.01		460.35	
Log pseudolikelihood	-268.378		-261.329		-465.161		-471.936	

Robust standard errors are in parentheses. *** 1% significance, ** 5% significance, * 10% significance. The dependent variable represents one if a subject chooses to stop searching, regardless of whether the search is actually ended. Game B-1 (common value + one-vote rule), Game B-2 (common value + majority rule), Game B-3 (common value + unanimity rule), Game C-1 (different values + one-vote rule), Game B-2 (different values + majority rule), Game C-3 (different values + unanimity rule). Game A(8) is the single-agent search game that subjects played in the last trial, which captures the anchoring effect, compared with the first trial of Game A (A(1)). We calculate the absolute risk aversion index using the willing -to-pay price for a lottery with a 25% chance of winning JPY2,000 (EUR15.8) but a 75% chance of receiving JPY0 (EUR0).

Table 7: Tests for Threshold Effects

	Null hypotheses	Difference in the coefficients	Std. Err.	z value	p-value	Test
[1]	Coef(C-1)-Coef(B-1)≤0	0.0745	0.0307	2.4264	0.0078	Reject
[2]	Coef(C-2)-Coef(B-2)≤0	0.0628	0.0187	3.3591	0.0000	Reject
[3]	Coef(C-3)-Coef(B-3)≤0	0.0011	0.0226	0.0505	0.3050	Not Reject

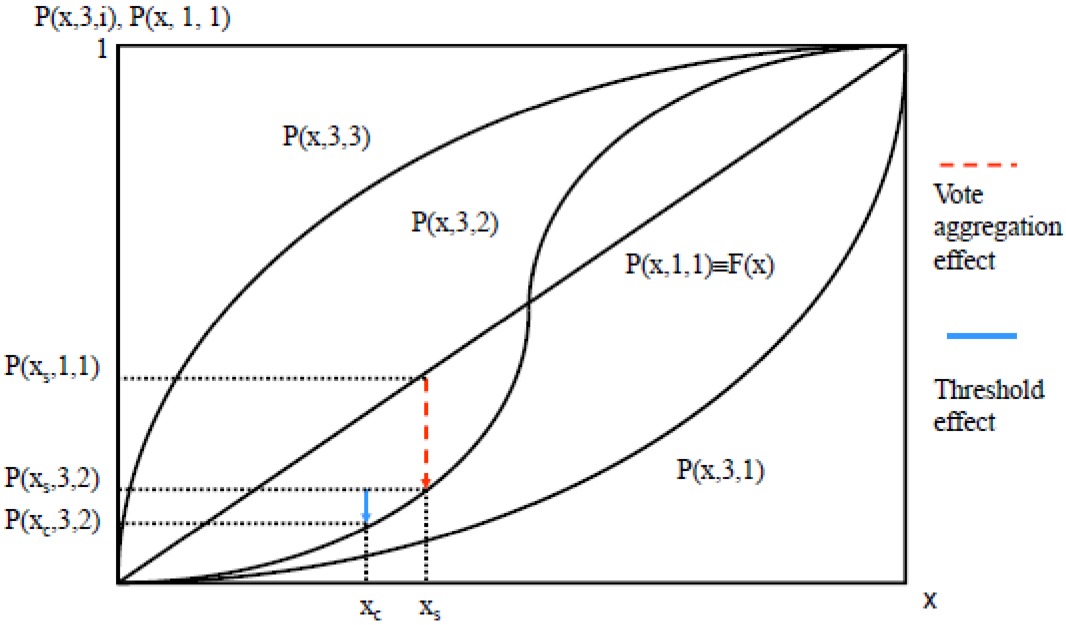
Note: The coefficients on Games B and C show the average threshold effects compared with the first trial of Game A from column [2] of Table 6. The magnitude of the coefficients on Game B is attributable to the heterogeneity among group members in terms of their preferences. The magnitude of the coefficients on Game C is attributable to the heterogeneity of preferences among group members plus the heterogeneity in terms of what value the other group members draw. Therefore, the differences between the coefficients between Games B and C indicate the average threshold effects derived only by the second heterogeneity in terms of what value the other members draw, after controlling for the first heterogeneity among group members.

Table 8: Comparisons of the Reservation Values among Plurality Voting Rules

	Null hypotheses	Difference in the coefficients	Std. Err.	z value	p-value	Test
[1]	[Coef(C-1)-Coef(B-1)]-[Coef(C-2)-Coef(B-2)]≤0	0.0117	0.0356	0.3292	0.3707	Not Reject
[2]	[Coef(C-2)-Coef(B-2)]-[Coef(C-3)-Coef(B-3)]≥0	0.0616	0.0285	2.1634	0.9846	Not Reject

Note: The coefficients on Games B and C also show the average probability effects of voting to stop searching, compared with the first trial of Game A from column [2] of Table 6. Similarly to Table 7, the differences between the coefficients between Games B and C indicate the average probability effects of voting to stop searching derived only by the second heterogeneity in terms of what value the other members draw, after controlling for the first heterogeneity among group members. In other words, [1] tests the null hypothesis that the "reservation value" is equal to or lower in the majority rule than in the one-vote rule. [2] tests the null hypothesis that the "reservation value" is equal to or larger in the unanimity rule than in the majority rule.

Figure 1: The probability of continuing the search under each plurality voting rule



Note: [1-P(x, 1, 1)] and [1-P(x, 3, i)] represent the probability of stopping the search.

Figure 2: Threshold and vote aggregation effects under the one-vote rule

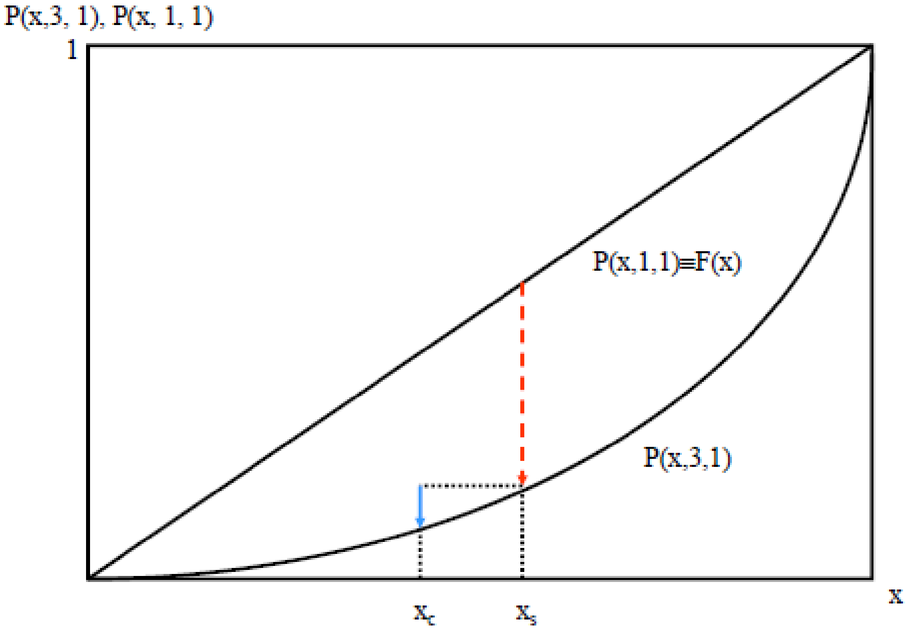


Figure 3: Threshold and vote aggregation effects under the unanimity rule

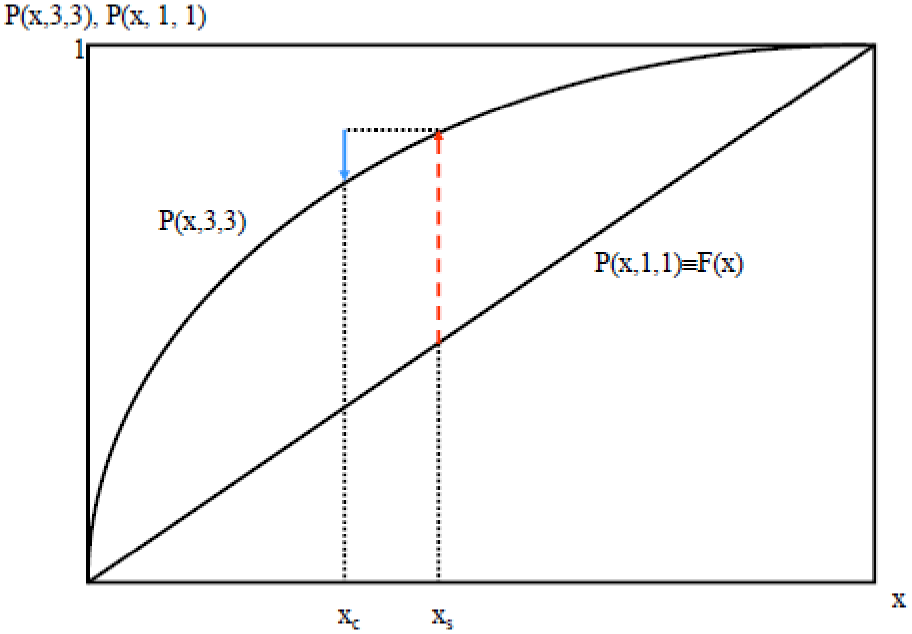


Figure 4: Threshold and vote aggregation effects under the majority rule