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FEATURES OF REACHING CONSENSUS IN THE PRESENCE OF THE LEADER AND THE HEAD IN A SOCIAL GROUP

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A B S T R A C T

The question of how the time to reach a consensus and its variability change under the conditions of the appearance of an informal leader or an official head in a group is examines.

The research demonstrated the distinction known in psychology (for small groups) between the behaviour of an official head of a group and a leader. From the results, it was concluded that the presence of a leader in a group provides a more balanced decision that takes into account the positions of other members of the group. In case if there is a head, consensus is achieved on average in fewer number of interaction cycles, but the consensus decision is based only on the opinion of the head himself. It was found that the variability of the average number of agreements in a group is higher if the group has a leader rather than a head. This confirms that leadership is a more complicated system of relations in a group compared to authoritarian management. The authoritarianism of group members affects the speed of reaching consensus in both cases: the higher the average authoritarianism of the group, the greater is the average number of agreements required to achieve consensus.

1. INTRODUCTION

Any organization, large or small, consists of groups (divisions) where people interact with each other, influence each other, make decisions based on the opinions of other people. Such behavior of individuals in groups is covered by the concept of "group dynamics", introduced by the American social psychologist Kurt Lewin in the early 1940s. According to the definition of K. Levin, “group dynamics is a discipline that studies the positive and negative forces that operate in a given group” (Spivak, 2001). Group dynamics is manifested, among other things, in such processes as management and leadership in a group. At the same time, management is considered as a process of managing people (staff), aimed at achieving the goals of the organization through the implementation of powers, carried out by the head (Krasnov, 2020). In turn, leadership is a process of influencing a group of people in order to lead them to achieve certain goals (Kudryashova, 1996; Northouse, 2022); accordingly, a leader (informal leader) is a person who influences a group of people, as a rule, without implementation of powers (Murray, 2020; Kotter, 1990). Thus, a leader manages people by virtue of the fact that they trust him, in contrast to an official head who manages personnel in an organization (group) by virtue

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of his official position (Kotter, 1990; Aronov & Melnikova, 2021). Sun Tzu, the great Chinese strategist of the 5th century BC, spoke figuratively on this topic (Sun Tzu, 2018): The leader (leader) leads not by force, but by example. It should be noted that the definition of the term "leadership" varied significantly over the period of more than a century: in the first third of the 20th century this term was de-fined as "the ability to inspire the will of the leader to the followers and induce obedience, respect, loyalty and cooperation", recently it has been defined as "a process whereby a person influences a group of people to achieve a common goal" (Northouse, 2022). So, leadership (mainly at the psychological level) and management (at the social level) focus on solving the group's tasks and on reaching consensus (Krichevsky & Dubovskaya, 1991). Bennis Warren, an American leadership theorist, gave more detailed and comprehensive description of the differences in management styles (Warren, 2009) (see Table 1).

Table 1. Differences in management styles of an official head and a leader

Management style of a head	Management style of a leader
Focuses on the present	Focuses on the future
Focuses on obedience	Focuses on trust
Uses official influence	Uses personal influence
Maintains routine	Develops organization

The leader directs the team by organizing its activities and motivating, and does not force the members of the team to take any action and does not impose his/her own position, unlike the official head. It is known that when the size of the group increases, the role of management in the formation of collective opinion rises. The relation between management and leadership and its effect on decision-making is in the focus of many studies, since in many organizations' leadership displaces the need for authoritarian management that has been developed over decades. In the process of making a group decision, a special place is occupied by interaction of people in situations of concluding transactions and negotiating. This interaction results in the development of an agreed decision, since the presence of a time element makes it necessary for individuals to search for a mutual choice (Krichevsky & Dubovskaya, 1991). This is especially evident in a situation when the functional approach of management is transformed into the process approach in accordance with the international standards ISO 9000 series. Further in the present work we discuss the following questions: what can a leader do in terms of influencing a group to achieve consensus and what specific features will a consensus decision have if there is a leader in a group, in contrast to a group decision made in the presence of an authoritarian head. Here, by "consensus" we mean "general agreement, characterized by the absence of serious objections on essential issues from the majority of interested parties and achieved as a result of a procedure that seeks to take into account the views of all parties and bring together diverging opinions" (ISO/IEC, 2004). Let us investigate how group management styles affect the time to reach consensus using the consensus model (Aronov et al., 2015). So, the aim of the article is a comparative analysis of the time to reach consensus and its variability, as well as the structure of the consensus decision in the case of an official head in the group (in the text we will use the word "head") and in case of a leader. It should be emphasized that this simulation complements field studies of social dynamics in groups, since, as noted in (Krasnov, 2020; Moscovici & Zavalloni, 1969), carrying out a real research is possible only in small groups (no more than five people), and most often under laboratory conditions. The complexity of such a study is evidenced by the fact that the analysis of various aspects that affect the consensus and cohesion of operators (cosmonauts) is still being carried out using software and hardware tools developed on the basis of the Gorbov Homeostat electronic device, proposed for small groups (Aronov & Maksimova, 2021). It is also important to note that the study of consensus in social psychology raises many questions related to the reproducibility of research results. The fundamental research of the collaboration of evidence-based psychologists ("Estimating the Reproducibility," 2015) showed that out of 100 original experimental studies in the field of social psychology, other groups managed to reproduce no more than 39 experiments. These facts do not allow organizing socio-psychological research to study the nature of consensus in large groups. In connection with the above, it is advisable to study the phenomenon of consensus in social groups using a modelling methodology that is not constrained by the number of group members. A "good" mathematical consensus model using simulation modelling is free from these systemic defects.

2. EXPERIMENTAL

A mathematical model for achieving consensus in a social group based on Markov chains was proposed by DeGroot (DeGroot, 1974). The model is based on the assumption that participants exchange opinions and influence the opinions of other group members during the discussion. The process of group functioning is considered as a solution to the group's problem. The detailed description of the theoretical model for reaching consensus in the work of technical committees for standardization aimed at evaluating international or national projects, where decision is made on the basis of consensus, was given in (Aronov et al., 2015). Let us present the main provisions of this model. Let the group consist of n members who participate in the discussion; let $S(0) = (s_{01}, \ldots, s_{0n})$ be the initial opinions of the group members, where s_{0i} is the initial opinion of the i-th member. The group members exchange opinions among themselves regarding the values of S. As noted, before, their opinions may change in the process of agreement. Introducing the probability of trust of the i-th participant to the opinion of the j-th participant of the discussion through $0 < p_{ij} < 1$ ($i = 1,\ldots, n$; $j = 1,\ldots, n$), we obtain

a square confidence matrix P = (p_{ij}), that changes at each stage of the negotiation process. Thus, the opinion of each participant in consensus-reaching process is a linear combination of all the opinions of the group members at a given moment, i.e. the model characterizes the mutual influence of group members on each other. The presented probabilities of the confidence matrix P for each member of the group can be obtained by normalizing rows of the matrix, each element of which was obtained by expert evaluation of the components developed by F. Fiedler and later tested on a variety of laboratory experiments (Fiedler, 1995). The described model is consistent with that set out in the work of the social psychologist D. Homans, who proposed a scheme for the functioning of social groups based on the exchange of values and information (Homans, 1984). In social psychology, the negotiation process is described as "...a specific type of communicative interaction. Within the framework of this interaction, the most important is the achievement of an agreement between the parties resulting from an exchange of views through effective feedback, which should normalize the relations of the parties in the future" (Homans, 1950). The confidence matrix P is stochastic, i.e. the sum of probabilities p_{ij} in each of its rows is equal to 1. For each stage of interaction, the vector of opinions of group members is calculated by the formula $S^T(1) = P \cdot S^T(0) = (s_{11},\ldots,s_{1n})^T$. After the *k*-th step of interaction, the opinion vector is calculated by the formula

$$S^T(k) = (s_{k1}, \ldots, s_{kn})^T = P \cdot S^T(k-1) = P^k \cdot S^T(0) \quad (1)$$

The iterative process ends at some *m*-th step, when all rows of the matrix P^m become the same. The confidence matrix P after *m* iterations reaches the final matrix F. Due to the fact that the final matrix F does not change during subsequent iterations, the vector of opinions of group members $S^T(m) = P^m \cdot S^T(0) = (s_{m1}, \ldots, s_{mn})^T$ will not change too, i.e., a consensus has been developed.

3. RESULTS

Let's build a model for a group when there is one member who and only, he is trusted by all other members of the group (except for themselves). This member of the group, trusting only his own opinion, is absolutely authoritarian. Then the confidence matrix is formed from the conditions:

$$\exists\, i_0 = \overline{1;n}:\ p_{i_0 i_0} = 1;\ \ \forall i \neq i_0 : 0 < p_{ii} < 1;\ \ \forall j \neq i_0 : p_{ij} = 0.$$

We will connect this case with *authoritarian management* as one of the types of dominance: a group member is absolutely authoritarian; all members of the group trust him through submission. The second case of management in a group is characterized by the fact that there is one member who and only he is trusted by all other members of the group (except as themselves), while this member of the group is not authoritarian, trusting the rest of the group members. Then the confidence matrix is formed from the conditions:

$$\forall i = \overline{1;n}: 0 < p_{ii} < 1;\ \exists\, i_0 = \overline{1;n}\ \ \forall i \neq i_0, j \neq i_0 : p_{ij} = 0.$$

We will interpret this case as *leadership* (From the point of view of social psychology, we consider a democratic type of leadership, which has advantages over others due to the highest satisfaction of the group, the desire for creativity and the most favorable relationship with the leader (Krasnov, 2020)) (one participant is trusted by all members of the group, and he, in turn, trusts them). In the first case, when the group member is absolutely authoritarian, the trust matrix P has an absorbing state that the iterative process cannot leave (Amyaga et al., 2014). This means that the opinion of such a participant does not change as a result of interaction (in the final matrix F, it is the element $p_{i_0 i_0}$ that remains equal to 1): the consensus decision takes into account only the opinion of this authoritarian group member – the head. Let us consider a case with one of the possible initial confidence matrices P, when there is a head in the group:

$$P = \begin{pmatrix} 0.5 & 0 & 0 & 0 & 0.5 \\ 0 & 0.4 & 0 & 0 & 0.6 \\ 0 & 0 & 0.3 & 0 & 0.7 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}. \quad (2)$$

As a result of the iterative process described above, the initial confidence matrix P will converge to the final matrix F of the form $F = (\bar{0}, \bar{0}, \bar{0}, \bar{0}, \bar{1})$. In such a group, consensus is achievable. It is important that in this case the consensus decision takes into account only the opinion of the head, the opinion of the other members of the group is not taken into account in the final decision. In other words, the head forms a collective opinion based on his own. This authoritarian type of management can be described by a short bitter saying literally translated from Russian: "I'm the boss, you're the fool". Matrix F mathematically illustrates this situation. Let us analyze how the structure of the consensus decision will change if the head in this group is replaced by a leader who is trusted by the members of the group, and at the same time he trusts the members of the group (the last line of the matrix (2)). Matrix P characterizes not only the mutual influence of the group members on each other, but also the mutual influence of the leader on the group members and vice versa. This is consistent with the opinion of the sociologist J. Homans who stated that the right to influence others is acquired at the cost of allowing others to influence yourself (Homans, 1984). Consider the following confidence matrix:

$$P = \begin{pmatrix} 0.5 & 0 & 0 & 0 & 0.5 \\ 0 & 0.4 & 0 & 0 & 0.6 \\ 0 & 0 & 0.3 & 0 & 0.7 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0.2 & 0.2 & 0.2 & 0.2 & 0.2 \end{pmatrix}.$$

In this case, the final matrix will look like $F = (\overline{0.18}, \overline{0.15}, \overline{0.12}, \overline{0.11}, \overline{0.44})$. This matrix F indicates that a collective opinion was formed due to the contribution of each member of the group, and the leader's contribution prevailed, but was not decisive. As noted in the work (Homans, 1950) devoted to the theoretical analysis of group behavior, promotion to a leadership position is eventually defined by the effectiveness of the contribution of a group member to the solution of the group problem. It is clear that in this case the consensus becomes more balanced (harmonized). Further, we are going to discuss the analysis of changes in the time to reach consensus in the presence of a head (absolute dominant) in the group and a group leader.

3.1 Time to reach consensus if there is a leader in the group.

Let us build a mathematical model of dominance for groups where the number of members varies from 5 to 20. It was shown in (Zazhigalkin et al., 2019) that the number of members in a group greater than 20 is not optimal in terms of the number of agreements before reaching consensus (all other things being equal). In particular, if a group has already 50 people and there are authoritarian members in it, the number of agreements may reach 200 or more, which is poorly implemented in practice due to time constraints allotted to solve the task. Let us estimate the convergence time of the opinion matrix P to the final matrix $F = P^m$. This time is determined by the necessary m number of iterations (discussions within the group) to form a consensus. Mathematically, m is defined as the power of the matrix P for which in the final matrix F the elements inside each column j satisfy the condition $|p_{ij} - p_{kj}| < \varepsilon$ for all i, k $(j, i, k = \overline{1, 20})$. The value of m will be calculated from the condition $\varepsilon = 0.01$. For the modeling, we take the following initial data: $n = 20$ – the number of members in the social group, m – the number of agreements among the members before reaching a consensus (i.e., the time to reach a consensus), there is one absolutely authoritarian participant (head). Modeling consisted of several stages.

At the *first stage*, several levels of n were chosen indicating the change in the number of group members:
1st: $n = 5$;
2nd: $n = 10$;
3rd: $n = 20$.

At the *second stage*, the probability p_{ii} was selected, which sets the probability of the participant's trust in himself (let us call it the level of authoritarianism). For the head in the conditions of dominance $p_{nn} = 1$. Therefore, the following levels of authoritarianism p_{ii}were distinguished for the rest of the group participants at $i = \overline{1, n-1}$:
1st: $p_{ii} = 0.20 \div 0.30$;
2nd: $p_{ii} = 0.45 \div 0.55$;
3rd: $p_{ii} = 0.65 \div 0.75$;
4th: $p_{ii} = 0.85 \div 0.95$.

The level of authoritarianism p_{ii} close to 1 characterizes the behavior of a person who is almost not suited to compromise, and the value of p_{ii} close to 0 characterizes the behavior of a conformist with the absence of his own solid position in negotiations and, accordingly, trusting more in someone else's opinion than his own. The behavioral traits of different members of the group were reflected in the modeling conditions, $0.20 \le p_{ii} \le 0.95$.

At the *third stage*, for each level n, the elements p_{ii} of the matrix P were simulated using a uniform distribution law with the parameters indicated at the second stage of modeling for p_{ii}. The remaining elements of the matrix were calculated as follows: $p_{ij} = 0$ for $i \neq j \neq n$ and $p_{in} = 1 - p_{ii}$ for any $i = \overline{1, n-1}$. Thus, the condition of equality to unity of the sum of probabilities is reached, taking into account p_{ii} within each row, i.e. matrix P becomes stochastic

$$P = \begin{pmatrix} p_{11} & 0 & 0 & 0 & 1 - p_{11} \\ 0 & p_{22} & 0 & 0 & 1 - p_{22} \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & p_{n-1,n-1} & 1 - p_{n-1,n-1} \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

In order to obtain firm conclusions regarding the average number m of agreements under the changes of other parameters, 100 simulations were carried out in Microsoft Excel for each fixed level of factors (Efron & Tibshirani, 1991). Figure 1 shows the dependence of the number of approvals (iterations) m on the number of group members n in the presence of the head in the group. It is interesting that the number of group members in this case has little effect on the number of agreements, all other conditions being equal. However, in conditions when the average authoritarianism of the group is high and practically is comparable to that of the head, the average number of approvals increased sharply (upper curve in Figure 1). At the same time, if at least one of the group members, apart from the head, is authoritarian, then they form coalitions, and consensus is unattainable (Maksimova & Aronov, 2021). The authoritarianism of the group members has a strong influence on the average number of agreements before reaching a consensus (Figure 2). It can be seen that when the authoritarianism of the group members is close to 1, the number of agreements increases (the dependence has a power law). It is important to note that the simulation results showed a weak variability in the number of agreements at low average levels of group authoritarianism (the standard deviation (SD) was about $0 \div 0.4$ agreements per 100), but a stronger variability with high average level of group authoritarianism (the SD reached 16.8 agreements per 100) (T'yuki, 1981).

Thus, in the presence of an authoritarian head in a group of no more than 20 people, the time to reach consensus is little dependent on the size of the group. The average

authoritarianism of the group members has a greater impact on the average number of agreements, especially when $p > 0.7$.

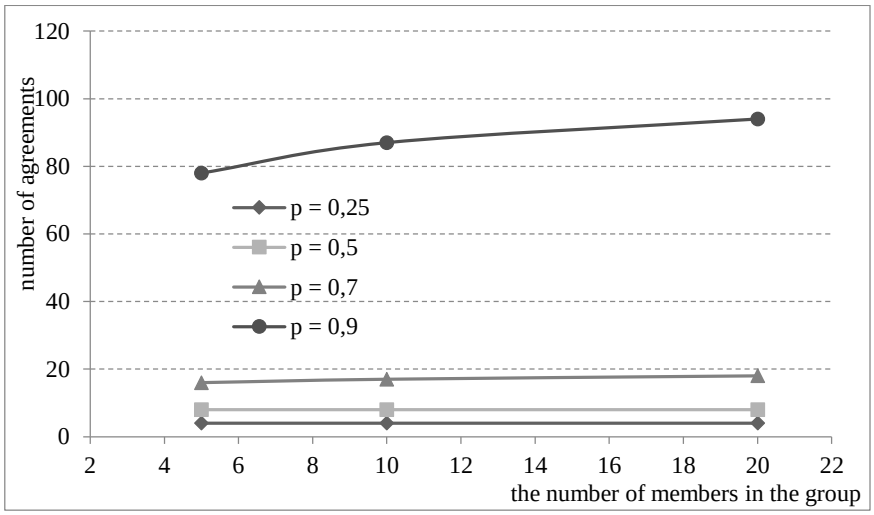

Figure 1. Dependence of the average number of agreements *m* on the number of group members *n* at various average authoritarianism of the group members *p* in presence of the head in the group

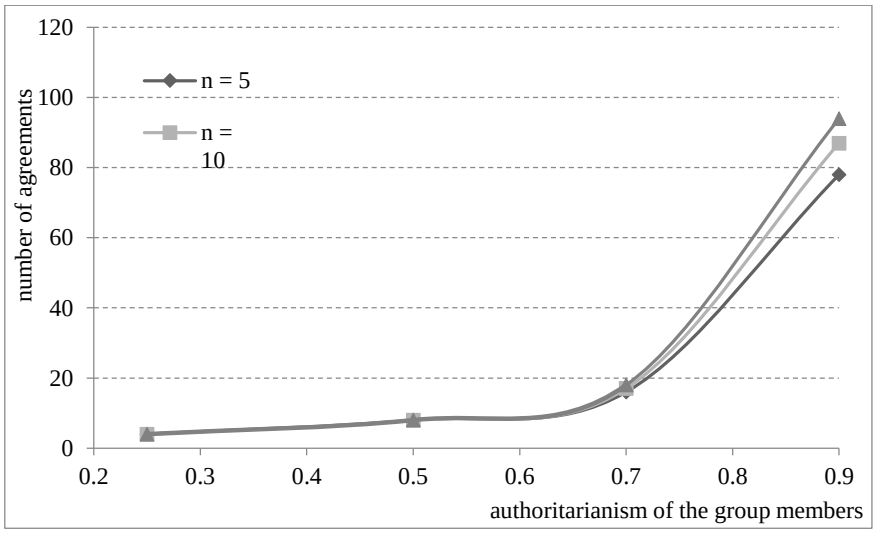

Figure 2. Dependence of the average number of agreements m on the average authoritarianism of the group members in groups with a different number of members n in the presence of the head

3.2 Time to reach consensus if there is a leader in the group.

The conditions and stages of modeling were given above, which we will follow when modeling the case of the presence of a leader in a group. We will assume that he/she gives equal trust to all members of the group, i.e. the simulation matrix P has the form

$$\mathrm{P} = \begin{pmatrix} p_{11} & 0 & 0 & 0 & 1-p_{11} \\ 0 & p_{22} & 0 & 0 & 1-p_{22} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & p_{n-1,n-1} & 1-p_{n-1,n-1} \\ 1/n & 1/n & 1/n & 1/n & 1/n \end{pmatrix}.$$

In this case, the number of agreements is on average higher than that in presence of a leader (Figures 2, 3).

Just as in the case of a leader in a group, there is a power-law relationship between the number of agreements and the average authoritarianism of the group members (Figure 3). The simulation results showed a higher variability in the number of agreements when there is a leader in the group, not a head, all other factors being equal. Under the conditions of an authoritarian head, the standard deviation was about 1.7 ÷ 1.8 agreements per 100, and under the leadership, the standard deviation reached 23.8 agreements per 100. Thus, on average, with a leader, the time to reach consensus is delayed, although not significantly, compared to the situation with an authoritarian head and is susceptible to greater variability. In social psychology, it has been known that leadership as a phenomenon, even in small groups, is less stable than authoritarian management, and depends on

the group (Krasnov, 2020). The results of our modelling showed that the authoritarianism of the participants in a group is one of the most important indicators that significantly affects the variability in the number of agreements: the high authoritarianism of the group members leads to a decrease in leadership positions in relation to the team, thereby setting a less predictable number of agreements leading to the formation of a collective opinion. But, as noted above, if there is a leader in the group, a collective consensus decision is formed taking into account the opinions of each member of the group. So, it is confirmed that leadership is a more complex system of relations in a group, in contrast to authoritarian management, which was reported earlier in the field studies performed for small groups (Krasnov, 2020).

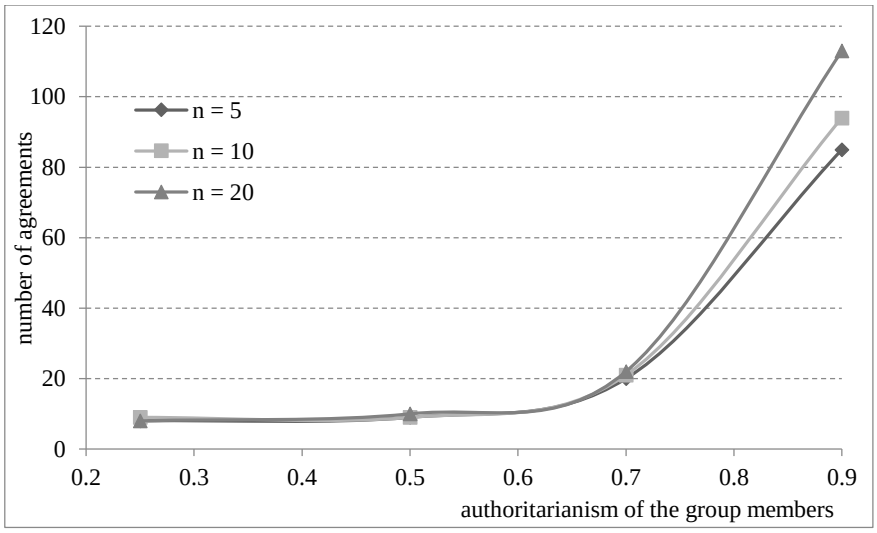

Figure 3. Dependence of the average number of agreements m on the average authoritarianism of group members in the groups with different number of members n in the presence of the leader

4. DISCUSSION

The simulation results for comparative analysis, summarized in Table 2, are presented for the following cases: 1) authoritarian management: there is one participant who and only he is trusted by all members of the group, while he does not trust anyone in the group; 2) leadership: there is a participant who and only he is trusted by all members of the group, while he, in turn, trusts the members of the group; 3) a homogeneous team: all members of the group trust the rest with equal probability (there is no head and leader). The simulation results are presented in Table 2.

Table 2. Simulation results for the average number of agreements *m* for the cases: an authoritarian management (presence of a head), a leadership (presence of a leader) and a homogeneous team

The number of members in the group, *n*	**Average authoritarianism of the group members**	**The average number of agreements**		
		authoritarian management	**leadership**	**homogeneous team**
5	0.25	4	8	4
5	0.5	8	9	7
5	0.7	16	20	15
5	0.9	78	85	65
10	0.25	4	9	5
10	0.5	8	9	10
10	0.7	17	21	20
10	0.9	87	94	90
20	0.25	4	8	7
20	0.5	8	10	13
20	0.7	18	22	26
20	0.9	94	113	116

In a small group (n = 5), the presence of a head to some extent reduces the speed of achieving consensus compared to a homogeneous team. The presence of a leader further diminishes the speed of reaching consensus. An increase in the average authoritarianism of the group members increases the time to reach consensus. The increase in the number of group members affects the time to reach consensus in such a way that the presence of a head increases the speed of reaching consensus compared to a homogeneous team; the speed of reaching consensus in the group in the presence of a leader does not affect significantly the number of agreements.

Additional analysis showed that the presence of a head in the group significantly reduces the variability in the number of agreements before reaching the consensus. In this case, the variability in the number of agreements is minimal, but the consensus decision, as noted earlier, is provided only by the opinion of the leader. Therefore, from a practical point of view, the arrival/development of a leader in a group provides a high-quality and relatively fast consensus decision (in comparison with a homogeneous team).

5. CONCLUSION

This study demonstrates the well-known in psychology (for small groups) divergence between the behavior of a head and a leader in a group (an organization). Based on the modeling of a consensus decision, it is shown that the leader provides a more balanced, more harmonized decision that takes into account the positions of other members of the group. A consensus decision in a group with the head in it can be obtained for a smaller number of agreements (other things being equal), but consensus is based only on the opinion of the head himself, i.e. the quality of the solution is low. The presence of a group member with a leadership position contributes to the formation of a collective opinion: the leader influences the opinions and actions of the group members, and does not simply try taking advantage, as in the case of authoritarian management. The leader directs the team, organizes its activities and motivates, rather than forces participants to take any action and does not impose his/her own position. Thus, as the size of the group increases, the role of leadership in shaping the collective opinion increases too.

The authoritarianism of the group members affects the speed of reaching consensus (in both cases: in the presence of a head or a leader). The higher the authoritarianism of the group, the greater the number of agreements is required to reach the consensus.

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