Closed-mindedness and insulation in groupthink: their effects and the devil's advocacy as a preventive measure

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Abstract

This paper's purpose is to clarify groupthink phenomena and to assess the devil's advocacy as a groupthink prevention measure. An agent-based model is presented to formalize group closed-mindedness and insulation in a group decision making setting. The model was validated by showing that groupthink results in the decision with low quality and the group's inability to explore more alternatives. Besides that, the devil's advocacy also formulated in the model. The simulation results of different conditions of the devil's advocacy support Janis' suggestion to utilize the devil's advocacy to alleviate groupthink. It is also found that the utilization of devil's advocacy depends on the group's condition and the desired amount of conflict to produce the best decision.

Keywords Groupthink · Devil's Advocate · NK Model · Agent-based Model

Introduction

Group decision making is frequently employed in social life. One motivation to use group decision making is the complex and ambiguous nature of real-world problems which is very hard to be solved by a lone individual. Group decision making makes it possible to utilize both capabilities and knowledge from the group members to explore different possibilities and then find the best decision. But as promising as it sounds, group decision making also prone to failures that caused by group members' biases or other factors. One of such group decision making failure is groupthink. Despite its popularity, the mechanism on how groupthink yields non-optimal

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decisions is still unclear. The purpose of this paper is to clarify this issue by focusing on group closed-mindedness and insulation in groupthink. This is achieved by groupthink formalization in an agent-based model and analysis of the model simulation result.

Groupthink was first introduced by Irving Janis as “a mode of thinking people engage in when they are deeply involved in a cohesive ingroup, when the members striving for unanimity, override their motivation to realistically appraise alternative courses of action” [22]. In his model, Janis asserted that groupthink is caused by the groupthink antecedents. A group that affected by the groupthink antecedents will show the symptoms of groupthink and the symptoms of defective decision making which ultimately lead to failure in a group decision making. Janis demonstrated the usefulness of the groupthink model by using it to explain fiascos such as the decision on Bay of Pigs invasion, failure to prevent Pearl Harbor attack, and escalation of Viet Nam war [22].

Groupthink has been widely used but there are still debates regarding its validity. For decades groupthink has been widely used in various area such as history [1], health care [23], foreign policy [3, 12], and management [11, 36]. Contrast to its popularity in application to analyze decision making cases, there are still little efforts in clarifying the groupthink model itself especially the nature of group cohesiveness as one of the groupthink antecedents [4, 40]. Currently, some theories to clarify groupthink has been proposed by Turner et al. [50], Hogg et al. [21], and Baron [4] which incorporate the social identity [20] as a groupthink antecedent instead of group cohesiveness. There are two rooms for improvements on these theories [4, 21, 50]. First, these theories have established the relation between the groupthink antecedents and the groupthink symptoms but they could not explain how the groupthink produces defective the decision making symptoms such as the non-optimal decision and the low number of the explored alternatives. Such an explanation is important to assess groupthink countermeasures. Second, these theories could not take into account the structural faults in the groupthink such as impartial leadership and insulation. Structural faults are important because, for example, insulation is found to be an important and consistent predictor of groupthink [13, 30, 42].

There are two main contributions of this paper. The first contribution is clarifying how the groupthink leads to the defective decision making symptoms while also take into account the structural faults in a group decision making. The second contribution is to assess Janis’s recommendation to prevent groupthink by asking one or some group members to take the role of the devil’s advocate [22]. This paper is focusing on the group closed-mindedness and the insulation in the groupthink. Group closed-mindedness is the group members’ bias regarding information and knowledge from the outgroup members which motivated by the ingroup favoritism [20]. The ingroup favoritism is reflected by the beliefs on the group morality and the stereotyping of the outgroup members in the sense that ‘we’ are more peaceful, trustworthy, friendly, and honest than ‘they’ [7, 8, 14]. This bias hinders the group members to accept the outgroup members’ views [4]. Insulation also operates in the same manner as the group closed-mindedness in the sense that group members don’t access outside information but their ingroup views. Existing findings point out that group insulation is the most predictive groupthink antecedent [13, 30, 42].

Different from the previous models that utilize verbal language to describe the groupthink, this paper offers an agent-based model of groupthink. The proposed model is intended to be an alternative model to explain the groupthink mechanism in the middle of the experiments scarcity in testing groupthink. This scarcity is caused by the difficulty of the antecedents creation [4] and the difficulty in the measurements caused by the insensitivity of the group decision making task [50]. In the agent-based model, a group decision making is abstracted as a search task in a solution space. The decision makers generate alternatives as decision candidates from which the group decision is decided by consensus [33, 35]. The solution space is adapted from the NK model [24] which is deemed suitable because it depicts the interdependent variables in managerial problems [5, 9, 15, 17]. Besides, the NK model also has been proven to be empirically relevant and plausible not only in explaining but also in predicting decision making under realistic situations [5, 17].

This paper is organized as follows. Reviews regarding the groupthink, the devil's advocacy, and the utilization of the NK model are introduced in "[Literature review](#)". The agent-based model definitions are introduced in "[Model](#)". The simulation settings are presented in the "[Simulation](#)" with results presented in the "[Simulation result](#)". And finally, the implications of the model and simulation results are discussed in "[Discussion](#)".

Literature review

The Groupthink theory: concept, issues, and reformulations

Janis's groupthink formulation consists of the groupthink antecedents, the symptoms of groupthink, and the symptoms of defective decision making [22]. The groupthink antecedent conditions are namely the group cohesion, the organizational structural faults, and the situational factors. The structural faults are namely the insulation of the group, the lack of impartial leadership, the lack of methodical procedure of group norms, and the homogeneity of group members. While the structural faults refer to the group composition and norms, the situational factors refer to the adverse conditions such as high stress from the external threats and the temporary group low self-esteem. The existence of such groupthink antecedents will yield in the symptoms of groupthink such as the overestimation of the group, the closed-mindedness, and the pressure toward uniformity. Not only that, but the group also exhibit symptoms of defective decision making such as the incomplete survey of alternatives, the incomplete survey of objectives, the failure to examine risks, and the poor information search.

Groupthink reformulations [4, 21, 50] have been proposed to adopt the social identity [20] as one of the groupthink antecedents instead of the group cohesion. These reformulations were motivated by two findings. First, the analysis of Janis's description of the group cohesion concludes that Janis formulated the group cohesion as the interpersonal friendship [21] which associated with the improved decision making instead of the groupthink [21, 27]. Second, the experiments to reproduce the groupthink presented diverging results with supports [30, 32, 41] and

rejections [16, 19, 27]. In these reformulations [4, 21, 50], the existence of a salient social identity results in the group members' depersonalization which further produces conformity, concurrence, agreement, and ethnocentrism which relate to the symptoms of groupthink. Turner et al. [50] asserted that the groupthink is a product of a group's effort to maintain the positive group images attributed to a social identity that shared among the group members. In doing so, the group members are inclined to discriminate the outgroup members and to enhance the ingroup characteristics. Hogg [21] clarified the difference between personal attraction and social attraction. It was asserted that the personal attraction, i.e. the friendship, does not related with groupthink while the social attraction, i.e. the self-identification by the group membership, causes ethnocentrism, stereotypic perception, and outgroup discrimination which are related to the symptoms of groupthink. Both Turner et al. [50] and Hogg [21] established the correlation between the social identity, the symptoms of groupthink, and the symptoms of defective decision making by experiments. The groupthink concept, which was limited to the small group process in a decision making, has been expanded by Baron [4]. Baron [4] asserted the 'ubiquitousness' of groupthink which means that groupthink is not only limited to cases that imagined by Janis and it could be encountered in the everyday lives such as the phenomena of opinion conformity, decision polarization, pluralistic ignorance, and outgroup vilification.

The groupthink reformulations [4, 21, 50] has established the relationship between social identity and groupthink symptoms. But a clarification is needed to explain how the groupthink produces the defective decision making symptoms which will be answered in this paper. Different to Baron [4] which asserted the ubiquitousness of groupthink, this paper limits groupthink to the decision making within a small group or a workgroup [13, 39, 40] which typically comprised of three to twelve individuals [49]. A workgroup, as an organization, has the group knowledge that is shared among group members as tacit or explicit knowledge [25, 31]. These knowledge are materialized as the organizational routines in which the group operates [25]. If a group is susceptible to groupthink, then it is expected that the group reject outside knowledge and tends to stick with their routines.

The devil's advocacy to program conflict

The devil's advocacy is a method to program conflict in a group decision making especially for ill-defined problems [28, 43, 44] in which one or some team members take the role of the devil's advocate. The devil's advocates take the opposite position against the alternative solutions presented by the other group members. This opposition triggers the other group members to reflect on the issues from different perspectives and to avoid the premature solutions [29].

Some studies recommended the devil's advocacy to prevent groupthink [28, 29, 47]. The analyses by Lunenburg [28] and Sims [47] asserted that the implementation of the devil's advocacy to a group decision making will result in a decision with better quality and accuracy. MacDougall [29], on the other hand, confirmed the benefit of the devil's advocacy in a group decision making by conducting an

experiment. The experiment was conducted by dividing the participants into four groups in which one devil's advocate is assigned to each group. The experiment confirmed that the operation of the devil's advocacy opened up new alternatives but it was unclear whether the final decision quality was improved or not.

A review on the landscape modeling using the NK model

NK model was originally used in evolutionary biology to illustrate the organism adaptation in a fitness landscape [24]. An organism's fitness is determined by its genomes which modeled as N -loci composition. The loci are interdependent which tuned by the parameter K with the value from 0 (no interdependence) to $N - 1$ (full interdependence). A high loci interdependence means a more complex landscape with more local minima.

NK model has been widely used in the agent-based models to study the complex adaptive systems (CAS) such as the organizational adaptation [38, 46] and the collective problem solving [18, 48, 51, 53]. The proposed model in this paper is a model on collective problem solving. In the collective problem solving models simulation, typically, each agent is assigned with a loci string which represents a candidate solution. After that, during the simulation, agents generate new solutions in the search for ones with better fitness based on the defined learning mechanism.

Existing models of the collective problem solving have analyzed the effect of dynamic network [26, 48], the problem decomposition [18], the number of individuals [51], and the individual's level of bounded rationality [53]. There is currently no work that tests the effect of the group closed-mindedness, the group insulation, and the devil's advocacy on collective problem solving. Thus the constructs of those concepts in the proposed model are new. Besides that, different from previous works that focus mainly on the solution fitness, the number of explored solution and the number of iteration in the group decision making also measured in this paper. The number of explored solution is measured to capture one of Janis' symptoms of defective group decision making namely "incomplete survey of alternatives" [22]. While the number of iteration in group decision making is measured to capture the relation between groupthink to a quick decision that shown in experiments [21].

Model

Model overview and agent-based model definitions

The model's purpose is to abstract group closed-mindedness and insulation in the groupthink and how the devil's advocacy is used to prevent it. In the model, a group decision making is abstracted as a problem solving in which decision makers search over the best solution in an NK fitness landscape. Each decision maker, through social learning, generates a new solution with better fitness. The social learning takes into account existing solutions by both ingroup and outgroup individuals. If the decision makers are not biased against outgroup solutions then it

is said that there is no groupthink. But if the decision makers are closed-minded or insulated from the outgroup then they are inclined to only consider ingroup solutions. The decision making process ends when decision makers come to a consensus on a single solution. The complete model descriptions are arranged as sets and functions presented in Tables 1 and 2 respectively.

The set individual denotes the individuals in the model i.e. agents. There are two groups in the model that $\text{Group} = \{\text{DM}, \text{OB}\}$. DM denotes the decision makers that involved in the group decision making committee. OB denotes the observers, experts or qualified organization members that are not involved in the committee. Each individual either belongs to the DM group or the OB group which determined by f_{Group} .

The NK model fitness landscape is used as a representation of the problem faced by the decision makers. The fitness landscape is constructed by the solution set *Solution* with the solution fitness function defined by f_{SFitness} . The *Solution* is a set of all possible solution that is the set of N-tuples in which each tuple s has elements $(s_1, s_2, \dots, s_N)$ in which every s_i is either 0 or 1. Thus $|\text{Solution}| = 2^N$. Each individual has a solution regarding the problem specified by the f_{Solution} . The individuals' solutions at the start of the simulation are generated randomly. In the generation process, the decision maker group knowledge or routines are taken into account which represented by the shared loci among decision makers with the length determined by f_{CBelief} .

Individuals are embedded within a social network which represented as a non-directed graph G . During the simulation, individuals generate solutions through social learning from their respective neighbors in the social network. There are two types of behaviors:

1. *Normal behavior* An individual with this behavior generates a solution that is closer to the best neighbor solution. The solution preference function $f_{\text{SPreference}}$ is taken into account in selecting the best neighbor solution.

Table 1 Set definitions

Notation	Description
Time	Time set, $\text{Time} = \{1, 2, \dots, T\}$, $T \in \mathbb{N}$, with 1 denotes the start of simulation while T denotes the end of simulation
Individual	Individual set, $\text{Individual} = \{i_1, i_2, \dots, i_P\}$, $P \in \mathbb{N}$, with P is the number of individuals
Group	Group set $\text{Group} = \{\text{DM}, \text{OB}\}$
Solution	Solution set $\text{Solution} = \{(s_1, s_2, s_3 \dots s_N) i \in \{1, 2, \dots, N\}, s_i \in \{0, 1\}\}$ with N is the NK model parameter. Solution denotes the set of all possible solutions in the NK fitness landscape
DAdvocate	Devil's advocate set $\text{DAdvocate} = \{da da \in \text{Individual}, f_{\text{Group}}(i) = \text{DM}\}$ with $da \in \text{DAdvocate}$ if and only if da assigned as a devil's advocate. DAdvocate denotes the set of decision makers that assigned with devil's advocate behavior
G	Communication network $G = (\text{Individual}, \text{Channel})$ as an undirected graph with edges $\text{Channel} = \{\{i_i, i_j\} i_i, i_j \in \text{Individual}\}$ with $\{i_i, i_j\} \in \text{Channel}$ if and only if i_i is connected with i_j

Table 2 Function definitions

Notation	Description
f_{Group}	Group membership function $f_{\text{Group}} : \text{Individual} \rightarrow \text{Group}$. $f_{\text{Group}}(i)$ denotes the group in which the individual $i \in \text{Individual}$ belongs
f_{Solution}	Individual's solution function $f_{\text{Solution}} : \text{Individual} \times \text{Time} \rightarrow \text{Solution}$. $f_{\text{Solution}}(i, t)$ denotes a solution proposed by an individual $i \in \text{Individual}$ at time $t \in \text{Time}$
f_{Locus}	Solution variable function $f_{\text{Locus}} : \text{Solution} \times \{1, 2, \dots, N\} \rightarrow \{0, 1\}$. $f_{\text{Locus}}(s, i)$ denotes i -th solution variable of the solution $s \in \text{Solution}$
f_{SFitness}	Solution fitness function $f_{\text{SFitness}} : \text{Solution} \rightarrow [0, 1]$. The fitness of a solution $s \in \text{Solution}$ is defined as $f_{\text{SFitness}}(s) = \frac{1}{N} \sum_{i=1}^N f_{\text{SVFitness}}(s, i)$ with N is the NK model parameter and $f_{\text{SVFitness}}$ is a function which returns fitness contribution of the i -th solution variable drawn from the normal distribution. $f_{\text{SVFitness}}$ assumes the Kauffman's adjacent neighborhood [2] to determine the interdependencies among the solution variables
f_{CBelief}	Common belief function $f_{\text{CBelief}} : \text{Group} \rightarrow \{0 \dots N\}$. $f_{\text{CBelief}}(g)$ denotes the number of solution variables that shared among members of the group $g \in \text{Group}$. Let $f_{\text{CBelief}}(g) = i$ then the first i solution variables for each group member of g is set as 1 at the start of simulation. $f_{\text{CBelief}}(g) = 0$ means there is no shared belief among group members of g
$f_{\text{SPreference}}$	Solution preference function $f_{\text{SPreference}} : \text{Group} \times \text{Group} \rightarrow [0, 1]$. For $g_i, g_j \in \text{Group}$, $f_{\text{SPreference}}(g_i, g_j)$ determine how members of g_i weigh solutions from members of g_j . High score in $f_{\text{SPreference}}(g_i, g_j)$ means group g_i members will be more likely to adopt solution from members of g_j and vice versa
$f_{\text{Neighbors}}$	Neighbors function $f_{\text{Neighbors}} : \text{Individual} \rightarrow \mathcal{P}(\text{Individual})$. Neighbors of an individual $i_i \in \text{Individual}$ is denoted by $f_{\text{Neighbors}}(i_i) = \{i_j \{i_i, i_j\} \in \text{Channel}\}$
$f_{\text{EXSolution}}$	Explored solution function $f_{\text{EXSolution}} : \text{Time} \rightarrow \mathcal{P}(\text{Solution})$. $f_{\text{EXSolution}}(t)$ return the set of explored solutions by the decision makers until time $t \in \text{Time}$ which defined as $f_{\text{EXSolution}}(t) = \{s f_{\text{Solution}}(\text{dm}, u) = s \wedge u \leq t, \text{dm} \in \text{Individual}, f_{\text{Group}}(\text{dm}) = \text{DM}, \text{dm} \notin \text{DAdvocate}, u \in \text{Time}, s \in \text{Solution}\}$. For any $t_1, t_2 \in \text{Time}$ if $t_1 < t_2$ then $f_{\text{EXSolution}}(t_1) \subseteq f_{\text{EXSolution}}(t_2)$

2. *Devil's advocate behavior* An individual with this behavior generates a solution as the opposite of ingroup solution.

More details on the individual behaviors are presented in Sect. 3.2. Observers are assigned with normal behavior. Decision makers that included in the *DAdvocate* set are assigned with devil's advocate behavior otherwise normal behavior.

Agent interaction

Normal behavior

An individual with normal behavior learns from the best neighbor solution and then adopt it by changing one of its non-matching solution variable(s). Consider an individual $i \in \text{Individual}$ with normal behavior. The individual then determines the best neighbor solution to adopt, adopted solution AS , given initial solution $IS = f_{\text{Solution}}(i, t)$ at current time $t \in \text{Time}$. For any neighbor $n \in f_{\text{Neighbors}}(i)$ the AS is selected as the neighbor solution with the highest utility which defined as

$$\begin{aligned}
\Delta \text{Fitness} &= f_{\text{SFitness}}(f_{\text{Solution}}(n, t)) - f_{\text{SFitness}}(\text{IS}) \\
\text{Utility}(n) &= \Delta \text{Fitness} \times f_{\text{SPreference}}(f_{\text{Group}}(i), f_{\text{Group}}(n)) \\
\text{MaxUtility} &= \operatorname{argmax}_{n \in f_{\text{Neighbors}}(i)} \text{Utility}(n) \\
AS &= \begin{cases} f_{\text{Solution}}(n, t) & \text{in which} & \text{if MaxUtility} > 0 \\ n \in f_{\text{Neighbors}}(i), \text{Utility}(n) = \text{MaxUtility} & & \\ \text{IS} & & \text{otherwise} \end{cases} \quad (1)
\end{aligned}$$

where $\Delta \text{Fitness}$ is the fitness difference and $\text{Utility}(n)$ is a function that returns the utility for adopting the neighbor n 's solution. The $f_{\text{SPreference}}$ in the Utility function determines the weight of adopting n 's solution. If $f_{\text{Group}}(n) = f_{\text{Group}}(i)$ then the individual i will not bias against n 's solution. But if n is i 's outgroup i.e. $f_{\text{Group}}(n) \neq f_{\text{Group}}(i)$ then there are three cases of $f_{\text{Preference}}(f_{\text{Group}}(i), f_{\text{Group}}(n))$:

1. Equals to $f_{\text{Preference}}(f_{\text{Group}}(i), f_{\text{Group}}(i))$. The individual i does not discriminate against any solution by n 's group members, i.e., no groupthink. In this case the AS will always be the neighbor's solution with the highest fitness regardless of n 's group membership.
2. Between 0 and $f_{\text{Preference}}(f_{\text{Group}}(i), f_{\text{Group}}(i))$. The individual i discriminates against solutions by n 's group members and inclined to adopt fellow ingroups' opinions. This case represents the individual i 's group closed-mindedness in which the individual discounts information from the outgroup [22]. The same bias also shown in experiments on the evaluation of ingroup and outgroup solutions in a problem solving situation [4].
3. Equals to 0. The individual i omits any solution by n 's group members such that the ingroups' solutions are the only candidates for AS. This case represents the individual i 's group insulation from the outgroup judgements [22].

Once the AS is selected, the individual i sets his/her solution to be closer to AS as follows. Define a function f_{NMVIndex} which returns the set of non-matching variable indexes between any two solutions $u, v \in \text{Solution}$ as

$$\begin{aligned}
f_{\text{NMVIndex}} &: \text{Solution} \times \text{Solution} \rightarrow \mathcal{P}(\{1, 2, \dots, N\}) \\
f_{\text{NMVIndex}}(u, v) &= \{idx | f_{\text{Locus}}(u, idx) \neq f_{\text{Locus}}(v, idx), idx \in \{1, 2, \dots, N\}\} \quad (2)
\end{aligned}$$

then the individual's updated solution $US = f_{\text{Solution}}(i, t + 1)$ is constructed by adopting the first non matching solution variable from AS as follows

$$\begin{aligned}
\text{NMIndex} &= f_{\text{NMVIndex}}(\text{IS}, \text{AS}) \\
US &= \begin{cases} \text{IS} & \text{if } |\text{NMIndex}| = 0. \\ (US_1, US_2, US_3, \dots, US_N) & \text{otherwise, with} \end{cases} \quad (3) \\
\text{for } idx \in \{1, 2, \dots, N\}, US_{idx} &= \begin{cases} f_{\text{Locus}}(\text{AS}, idx) & \text{if } idx = \min(\text{NMIndex}) \\ f_{\text{Locus}}(\text{IS}, idx) & \text{otherwise} \end{cases}
\end{aligned}$$

Devil's advocate behavior

A devil's advocate takes an opposite position against alternative solutions that presented by fellow ingroup members [28, 29]. The devil's advocate may raise issues by saying "Haven't we perhaps overlooked ...?" or "Shouldn't we give some thoughts to ...?" [29]. Based on this insight, the devil's advocate behavior in the model is implemented as the following two steps. The first step is for the devil's advocate to identify the most common solution among fellow decision makers. The second step is to formulate a solution by calculating the least common value for each solution variable.

Define the function $f_{SV\text{Peek}}$ that check whether the value of a certain solution variable matches with the given value and the function $f_{SV\text{Count}}$ that returns the number of solution variables that match with the given value within a given solution set as follow

$$\begin{aligned} f_{SV\text{Peek}} &: \text{Solution} \times \{1, 2, \dots, N\} \times \{0, 1\} \rightarrow \{0, 1\} \\ f_{SV\text{Count}} &: \mathcal{P}(\text{Solution}) \times \{1, 2, \dots, N\} \times \{0, 1\} \rightarrow \mathbb{N} \\ f_{SV\text{Peek}}(s, idx, v) &= \begin{cases} 1 & \text{if } f_{\text{Locus}}(s, idx) = v \\ 0 & \text{otherwise} \end{cases} \\ f_{SV\text{Count}}(\text{SSet}, idx, v) &= \sum_{s \in \text{SSet}} (f_{SV\text{Peek}}(s, idx, v)) \end{aligned} \quad (4)$$

with N is the NK model parameter. Consider a devil's advocate $da \in \text{DAdvocate}$. Let at time $t \in \text{Time}$ the ingroup neighbor set INeighbors and the ingroup neighbor solution set INSolution to be defined as

$$\begin{aligned} \text{INeighbors} &= \{\text{in} \mid f_{\text{Group}}(\text{in}) = \text{DM}, \text{in} \in f_{\text{Neighbors}}(da)\} \\ \text{INSolution} &= \{\text{ins} \mid \text{in} \in \text{INeighbors}, \text{ins} \in \text{Solution}, \text{ins} = f_{\text{Solution}}(\text{in}, t)\} \end{aligned} \quad (5)$$

The devil's advocate da constructs the updated solution $\text{US} = f_{\text{Solution}}(da, t + 1)$ by assigning each solution variable with the least occurred value that is for $idx \in \{1, 2, \dots, N\}$

$$f_{\text{Locus}}(\text{US}, idx) = \begin{cases} 0 & \text{if } f_{SV\text{Count}}(\text{INSolution}, idx, 0) < \frac{|\text{INeighbors}|}{2} \\ 1 & \text{otherwise} \end{cases} \quad (6)$$

Simulation

The goal of the simulation is to explore the groupthink phenomena and to assess the effectiveness of devil's advocacy to improve group decision making. The groupthink exploration is done by varying the degree of decision makers' tendency to bias against observers' solutions. The result of the groupthink exploration establishes the model's behavioral validity. On the other hand, the assessment of devil's advocacy is done by varying the number of decision makers that assigned with devil's advocate

Table 3 Simulation parameters

Description	Value
N	7
K	2, 4, 6
Communication network	As shown in Fig. 1
Decision makers common belief	4
Observers common belief	0
Outgroup preference	1.00, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30, 0.25, 0.20, 0.15, 0.10, 0.05, 0.00
Devil's advocate set	As listed in Table 4

Fig. 1 Decision makers (grey) and observers (white) in the 7×7 lattice

behavior in the group decision making. Further details on the simulation setup and measurements are available in the following sections.

Simulation parameters

Simulation parameters are listed in Table 3 which run 1000 times for each parameter combination. The solution preference $f_{\text{SPreference}}$ returns 1.00 except for $f_{\text{SPreference}}(\text{DM}, \text{OB})$ which determines the decision makers' preference in adopting solutions from the observers. The outgroup preference $f_{\text{SPreference}}(\text{DM}, \text{OB})$ returns values that ranged from 1.00 to 0.00. Outgroup preference with value 1.00 means the decision makers are not discriminating observers solution (no groupthink) and value 0.00 means decision makers are insulated from observers solution. The decrease of the outgroup preference value from 1.00 to 0.00 means the increasing degree of decision makers' closed-mindedness against the outgroup. A single communication network is used in which individuals are placed in a 7×7 lattice as shown in Fig. 1. There are a total of 9 decision makers in the middle of 40 observers.

Five devil's advocate sets are introduced which specified in Table 4. The higher number of decision makers that assigned to the devil's advocate set corresponds to the higher level of programmed conflict during the group decision making process. Not only that, the devil's advocate set also affects the number of the decision makers that participate in the consensus making. When $DAdvocate_0$ is used in a simulation, all nine decision makers participate in the consensus making. When $DAdvocate_4$ is used only five decision makers participate in the consensus making.

Simulation stages

The simulation is started with an initialization and then followed by iterations. Each iteration consists of two stages: observers interaction and decision makers interaction. At the end of an iteration, the consensus among decision makers is checked to decide whether to start the next iteration or to stop the simulation. Details of the procedures are explained as follows.

1. Initialization. Set time $t = 1$ and then initialize groups and individuals according to the simulation parameters. For any individual $i \in \text{Individual}$, the individual's solution is constructed in two steps:
 - (a) Initialize shared loci. Let $c = f_{\text{CBelief}}(f_{\text{Group}}(i))$, if $c > 0$ then the first c solution variables are set as 1.
 - (b) Initialize random loci. Each solution variable with index between $c + 1$ and N is assigned either as 1 or 0 with equal probability.
2. Observers interaction stage. All observers learn from their respective neighbors based on the normal behavior (Sect. 3.2).
3. Decision makers interaction stage. One decision maker with devil's advocate behavior is selected to execute the devil's advocate behavior (Sect. 3.2). After that, one decision maker with normal behavior is selected to execute the normal behavior (Sect. 3.2).
4. Consensus check. The group reach consensus if every decision maker with normal behavior has the same solution i.e. the Hamming distance between their solution tuples is zero. The solution thus becomes the decision makers' decision. If the decision makers have not reached consensus then the next iteration is started with time $t + 1$.

Table 4 Devil's advocate set parameters

Devil's advocate set	Value
$DAdvocate_0$	{ }
$DAdvocate_1$	{DM1}
$DAdvocate_2$	{DM1, DM3}
$DAdvocate_3$	{DM1, DM3, DM7}
$DAdvocate_4$	{DM1, DM3, DM7, DM9}

Measurements

1. Number of explored solution. The number of explored solution by decision makers at the end of simulation which defined by $|f_{\text{EXSolution}}(T)|$. The higher number of explored solution means that the decision makers consider more solution alternatives before coming to a consensus. The number of explored solution is available in Figs. 2 and 6.
2. Decision fitness. The fitness of the decision makers' decision defined by $f_{\text{SFitness}}(f_{\text{Solution}}(\text{dm}, T))$ for any decision maker with normal behavior $\text{dm} \in \text{Individual}$, $\text{dm} \notin \text{DAdvocate}$. At the end of the simulation, each decision maker with normal behavior comes to the same solution i.e. a consensus. This solution is treated as the decision maker group decision and its fitness value becomes the decision fitness. A high decision fitness means that the decision makers come to a solution with high quality thus the decision making process was a success. It is expected that the groupthink result in a faulty decision making which means the decision makers come to a decision with low quality thus a low decision fitness. Decision fitness is available in Figs. 3, 7 and Tables 5, and 6.
3. Number of iterations. The number of iterations needed by the decision makers to reach a consensus defined by T . The higher number of iterations means that decision makers need longer time to reach a consensus. The number of iteration is available in Figs. 4 and 8.

Simulation result

The effect of insulation and group closed-mindedness in group decision making

This section presents the effect of the group closed-mindedness and the insulation in groupthink by comparing the measurements taken from simulations in which the outgroup preference value is set from 0.90 to 0.00 against the no groupthink case

Fig. 2 Mean and standard deviation of the number of explored solution for given outgroup preference

Fig. 3 Mean and standard deviation of the decision fitness for given outgroup preference

Table 5 Decision fitness mean difference for given outgroup preference calculated against no groupthink case (outgroup preference = 1.00)

Outgroup preference	K = 2		K = 4		K = 6	
	Mean diff.	St. Dev.	Mean diff.	St. dev.	Mean diff.	St. Dev.
0.90	0.0001	0.0557	0.0003	0.0431	0.0006	0.0413
0.80	0.0004	0.0553	− 0.0001	0.0442	− 0.0021	0.0420
0.70	− 0.0011	0.0570	− 0.0017	0.0452	− 0.0052**	0.0443
0.60	− 0.0037	0.0582	− 0.0059**	0.0490	− 0.0130**	0.0485
0.50	− 0.0085**	0.0601	− 0.0173**	0.0574	− 0.0261**	0.0558
0.40	− 0.0207**	0.0682	− 0.0357**	0.0652	− 0.0450**	0.0606
0.30	− 0.0363**	0.0744	− 0.0598**	0.0717	− 0.0622**	0.0645
0.25	− 0.0491**	0.0811	− 0.0717**	0.0751	− 0.0747**	0.0658
0.20	− 0.0716**	0.0911	− 0.0875**	0.0754	− 0.0866**	0.0625
0.15	− 0.0908**	0.0918	− 0.1000**	0.0759	− 0.0968**	0.0661
0.10	− 0.1158**	0.0937	− 0.1146**	0.0760	− 0.1040**	0.0664
0.05	− 0.1468**	0.0966	− 0.1301**	0.0782	− 0.1121**	0.0680
0.00	− 0.1757**	0.0950	− 0.1463**	0.0797	− 0.1225**	0.0701

t test of means was conducted with ** $p \leq 0.01$

(outgroup preference 1.00). Figures in this section display the simulation results in which there is no devil's advocate among the decision makers ($|DAdvocate| = 0$).

Figure 2 shows the mean and the standard deviation of the number of explored solutions before reaching consensus with the x-axis corresponds to the outgroup preference. The number of explored solutions is decreasing in line with outgroup preference. This is because when the outgroup preference is lower, the decision makers are more likely to only consider the ingroup solution and explore the NK landscape only based on those solutions. The standard deviation of the number of explored solution also decreasing in line with the outgroup preference.

Fig. 4 Mean and standard deviation of the number of iteration for given outgroup preference

Figure 3 shows the mean and the standard deviation of the decision fitness with the x -axis corresponds to outgroup preference. Just like in term of the number of explored solution, decision fitness is decreasing in line with the outgroup preference. As the outgroup preference is lower, decision makers are less likely to learn from outgroup solution. Consider a case where there is an observer with a higher solution fitness compared to the decision makers. If the outgroup preference is low enough to 'ignore' the solution then decision makers are unable to learn from the solution. Regarding the standard deviation, different from the trend in the number of explored solution in which lower outgroup preference results in the smaller standard deviation, the trend in the decision fitness is the opposite. The standard deviation is wider as the outgroup solution preference is lower. This is because when the outgroup preference is low, the final decision maker solution is more similar to the initial solution. Thus the final decision fitness also closer to the initial solution fitness which is randomized. When the outgroup preference is higher, then decision makers are more likely to learn from the outgroup solution thus more likely to reach a final solution with better fitness. The decision fitness mean differences for different outgroup preferences are presented in Table 5.

Figure 4 shows the mean and the standard deviation of the number of iterations needed to reach consensus with the x -axis corresponds to outgroup preference. The number of iteration is decreasing in line with outgroup preference. Different to the trend in the mean, the relationship between outgroup preference and the standard deviation is curvilinear. When the outgroup preference value is low it is expected that the decision makers only consider solutions from among themselves thus the decision making process took fewer iterations. But when the outgroup preference is neither high nor low the number of iteration becomes less predictable.

Figure 5 shows the effect of the landscape ruggedness to the three measurements. The trends are different depending on the group condition whether there is no groupthink (outgroup preference 1.00), insulated (outgroup preference 0.00) or in between.

When there is no groupthink (outgroup preference 1.00) increase in landscape ruggedness means an increase in decision fitness, number of explored solution,

Fig. 5 Mean of decision fitness, number of explored solution, and number of iteration across landscape ruggedness

and number of iteration. To explain how decision fitness increased, consider a case in which an individual learns from a neighbor's solution. When the individual learns, the individual's solution is changed to get closer to the neighbor's solution. During this 'walk', the individual is more likely to 'stumble' upon a solution with a higher fitness compared to the neighbor's solution when the landscape ruggedness is high. The increase in the number of explored solution and the number of iteration is because when the landscape ruggedness is high it is more possible for observers to identify more maxima from which the decision makers can learn thus a wider landscape search area.

When the group insulated (outgroup preference 0.00) increase in landscape ruggedness means an increase in decision fitness but there is no change in the number of explored solution and the number of iteration. The reason for the increase in decision fitness is the same as in the case of no groupthink, that is the possibility for an individual to discover a better solution when learning from a neighbor's solution. No change in the number of explored solution and the number of iteration is because the decision makers are not learning from observers so they are limited to the number of unshared loci. In the simulation the shared loci, i.e. the group knowledge, among decision makers are set as 4, so the maximum number of explored solution in the insulated case is $2^{N-4} = 2^3 = 8$ which is independent of K.

When the outgroup preference is between 1.00 and 0.00 the trend is determined by the value of outgroup preference itself. The number of explored solution and the number of iteration are mainly decreased. This is because when the landscape ruggedness is high there are many local maxima thus the fitness differences between the observer solutions and the decision maker solutions are smaller. Low outgroup preference values make the decision makers ignore observer solutions. This also explains why the decrease is more significant in line with the decrease in outgroup preference. The decision fitness trend is similar to the no groupthink and group insulated cases.

The effect of devil's advocacy to group decision making

This section presents the effect of the devil's advocacy in group decision making. Different numbers of devil's advocates are operated from 1 to 4 devil's advocates. The effect of devil's advocacy is identified by comparing it to the case in which there is no devil's advocate ($|DA_{advocate}| = 0$).

Figure 6 shows the mean of the number of explored solution for a given number of devil's advocates with the x-axis corresponds to outgroup preference. When a decision maker takes the role of a devil's advocate he/she will challenge fellow member's solution instead of learning from neighbors' solutions. When there is no groupthink, making a group member to take the role of a devil's advocate reduces the number of explored solution because the decision maker group loses an individual that can learn from the observers' solutions. In this case, when there is no groupthink the 'explored solution gain' by employing the devil's advocacy is smaller compared to learning from observers' solutions. But a different trend is shown when the outgroup preference is low. The 'explored solution gain' is higher when the devil's advocacy is used. This is because the decision makers that assigned as devil's advocates disregard group knowledge instead of trapped by it. The effect of the devil's advocate is more significant as the outgroup preference is closer to 0.00.

Figure 7 shows the mean of the decision fitness for a given number of devil's advocates with the x-axis corresponds to outgroup preference. The trend is similar to the number of explored solution. It means that the increase in the number explored solution translated to an increase in decision fitness. It is also shown that as the outgroup preference is closer to 0.00, the decision fitness improvement as the result of the devil's advocacy is more significant. The operation of the devil's advocacy harms decision fitness for high outgroup preference but the opposite is true for low outgroup preference. The operation of the low number of devil's advocates starts to yield a positive effect in relatively higher outgroup preference compared to the operation of the high number of devil's advocates. This trend is shown more clearly in Table 6.

Figure 8 shows the mean of the number of iterations needed by decision makers to reach consensus for a given number of devil's advocates with the x-axis

Fig. 6 Mean of number of explored solution (by decision makers with normal behavior) for given outgroup preference and number of devil's advocate (DA)

Fig. 7 Mean of decision fitness for given outgroup preference and number of devil's advocate (DA)

Table 6 Decision fitness mean difference for given number of devil's advocate and outgroup preference calculated against no devil's advocate case

Number of DA	K = 2		K = 4		K = 6	
	Mean diff.	St. dev.	Mean diff.	St. dev.	Mean diff.	St. dev.
Outgroup preference = 0.60						
2	− 0.0019	0.0585	− 0.0071**	0.0520	− 0.0061*	0.0544
4	− 0.0109**	0.0689	− 0.0195**	0.0658	− 0.0218**	0.0661
Outgroup preference = 0.50						
2	− 0.0037	0.0634	− 0.0063*	0.0577	− 0.0050	0.0588
4	− 0.0152**	0.0738	− 0.0224**	0.0698	− 0.0238**	0.0684
Outgroup preference = 0.40						
2	− 0.0040	0.0688	− 0.0057	0.0648	− 0.0046	0.0607
4	− 0.0169**	0.0786	− 0.0211**	0.0717	− 0.0213**	0.0683
Outgroup preference = 0.30						
2	− 0.0048	0.0762	− 0.0028*	0.0690	− 0.0031	0.0649
4	− 0.0160**	0.0799	− 0.0081*	0.0717	− 0.0120**	0.0663
Outgroup preference = 0.20						
2	0.0050	0.0791	0.0088*	0.0700	0.0048	0.0628
4	− 0.0014	0.0832	0.0053	0.0715	0.0032	0.0657
Outgroup preference = 0.10						
2	0.0227**	0.0824	0.0194**	0.0702	0.0094**	0.0621
4	0.0247**	0.0835	0.0224**	0.0712	0.0131**	0.0655
Outgroup preference = 0.00						
2	0.0553**	0.0807	0.0340**	0.0700	0.0197**	0.0637
4	0.0682**	0.0793	0.0453**	0.0692	0.0264**	0.0652

t test of means was conducted with * $p \leq 0.05$ and ** $p \leq 0.01$

corresponds to outgroup preference. Assigning a decision maker as a devil's advocate means one less individual that involved in the group consensus. But when the outgroup preference is low, adding a devil's advocate could also

Fig. 8 Mean of number of iteration for given outgroup preference and number of devil's advocate (DA)

trigger the decision makers to explore more alternatives as has been shown in Fig. 6 which also translates to taking more iterations.

Discussion

An agent-based model featuring group closed-mindedness and insulation in groupthink and how the devil's advocacy is used to prevent it is presented in this paper. The model has been proven to be useful to explain groupthink phenomena by confirming and clarifying existing findings based on assumptions on the micro level i.e. capturing emergent phenomena [6]. Assumptions on the group closed-mindedness and the group insulation have been simulated and validated. Simulation results show groupthink results in the decrease in the number of explored solution, decision fitness, and the time needed to reach a consensus which is consistent with previous findings [21, 22]. Besides that, the simulation results also show the outcome of devil's advocacy operation to prevent groupthink. There are two focuses of the model simulation.

The first focus is to explore the effect of group closed-mindedness and insulation on the quality of decision making. Different scenarios featuring closed-mindedness and insulation and then the measurement results are compared against the base scenario in which there is no groupthink. The simulation was conducted by varying the outgroup preference which decreasing from 1.00 (no groupthink case) gradually to 0.00 (insulation case). Lower outgroup preference corresponds to a higher tendency for the decision makers to bias against the outgroups' solutions.

The second focus is to explore the effect of devil's advocacy on the quality of decision making. Different numbers of devil's advocates were simulated across different outgroup preference values. The operation of devil's advocacy was done by assigning 1 up to 4 decision makers as devil's advocates. A decision maker that assigned as a devil's advocate takes the opposite position against fellow ingroup members and is not involved in the group consensus.

The nature of insulation and group closed-mindedness in groupthink

The model explains how groupthink in group decision making leads to a lower number of explored solution and lead to lower decision quality. This is achieved by constructing group decision making as a search over the NK landscape. Simulation results show that group closed-mindedness and insulation will harm group decision making in term of the number of explored solution and the quality of the final decision. Besides that, it is also shown that the effect of insulation is stronger compared to group closed-mindedness.

The number iteration, which depicts how long time needed for a group decision making to reach a consensus, also captured in the simulation. The simulation result shows that both closed-mindedness and insulation result in a lower number of iteration. Just like in terms of the number of explored solution and decision fitness, the effect of insulation on the number of iteration also stronger compared to group closed-mindedness. Besides that, the standard deviation also smaller which means a group decision making in which the decision makers are insulated from outside influence consistently ends with lower discussion time. This finding invokes the possibility that the decision makers might voluntarily insulate themselves to limit discussion time. This possibility is open because in a crisis condition the decision makers are expected to make a quick decision [45]. Besides that insulation also presented in Janis original cases of groupthink where the decision maker was in the middle of a crisis and a huge responsibility was at stake [13]. Not only insulation, other structural faults such as directive leadership style also emerge within a group decision making process during a crisis condition [34].

The effectiveness of devil's advocacy to prevent groupthink

Devil's advocacy in the model is implemented as the decision makers' behavior that opposes the fellow ingroup solutions. Simulation results show that devil's advocacy is effective to trigger decision makers to consider more solutions before coming to a consensus thus avoiding a premature solution. In addition to that, simulation results also confirm the effectiveness of devil's advocacy in helping group to reach a better solution.

Assigning an individual a role of the devil's advocate comes with its advantages and disadvantages. The first advantage is that the individual will be freed from the bias caused by anchoring to existing group knowledge. The second advantage is that the individual will trigger other group members to explore more alternatives by challenging the existing group solutions. The disadvantage is the fact that converting one the individual to be a devil's advocate means fewer people in the group that learn from the outside solutions.

The decision of whether to employ the devil's advocacy or not is determined by whether the group is susceptible to groupthink or not. From the simulation results, it is found that employing the devil's advocacy is beneficial when the group is closed-minded or insulated i.e. susceptible to groupthink. Besides that, as the group is

getting more closed to the outside solutions, employing more devil's advocates is more favorable. When the group is not susceptible to groupthink, having more individuals to learn from the outside solutions is more beneficial.

Model validity

Validity is a requirement for an agent-based model which refers to the model's homomorphism compared to the referent system [10, 37]. In the proposed agent-based model case, the referent system is groupthink in a group decision making. The following model validity analysis follows the criteria proposed by Cioffi–Revilla [10]. There are other proposed criteria to assess the empirical validity of a model such as one introduced by Windrum et al. [52]. However, Windrum et al. [52] are focused on economic macro-phenomena in which empirical time series data are available thus less suitable for the proposed model in this paper.

Cioffi–Revilla [10] introduces two types of model validity namely structural validity and behavioral validity. Structural validity refers to the model's suitability in representing relevant individual attributes and interactions. It concerns the model's internal structures and mechanisms. The proposed model is based on the abstraction of group decision making as a search over the NK landscape which is suitable because it captures the interdependent variables nature of managerial decision problems [5, 9, 15, 17] and relevant to decision making in the realistic situations [5, 17]. Besides, the groupthink and devil's advocacy formulations are based on relevant findings. The group closed-mindedness in the model is formulated as the decision maker's low outgroup preference. It is consistent with one groupthink characteristic in which individuals discount solutions from the outgroup and less likely to adopt them [22]. The formulation of group insulation in which the outgroup preference is set to zero also consistent with the case in which the group completely blocks outgroup solutions [22]. And lastly, the formulation of the devil's advocate behavior is formulated as the agent's opposition against ingroup members' solutions instead of adopting them. This mechanism is consistent with the devil's advocacy role in which an opposite position is formed against alternatives presented by the other ingroup members [28, 29].

Behavioral validity refers to the simulation result's compatibility with empirical findings. It concerns with the patterns that emerge in the model simulation. The model's simulation results are consistent with existing findings on groupthink and devil's advocacy. The simulation of the group closed-mindedness and insulation shows that these conditions result in the lower number of explored solutions and the lower decision quality which is consistent with groupthink characteristics namely incomplete survey of alternatives and decision making failures [22]. Besides, simulation results also demonstrate insulation as a consistent groupthink predictor which conforms with existing findings [13, 30, 42]. In regards to the devil's advocacy's effectiveness to prevent groupthink, simulation results show that adding more devil's advocates increases the number of explored solutions during the group decision making. This result is consistent with findings on the effectiveness of the devil's advocacy in helping a group to identify more alternatives [29].

Limitations and future research

There are at least two limitations to this paper. First, the outgroup preference parameter range in the simulation is not derived from any empirical finding. Thus a careful consideration is needed in interpreting the simulation result into the real world setting. Second, the practicality of the devil's advocacy to prevent groupthink. In the simulation, the number of devil's advocates is ranged from 1 to 4 which assigned among 9 decision makers. These numbers can be designated the low number of devil's advocates and the high number of devil's advocates which depend on the team's size. As an example, if the group size is 5 then the low number of devil's advocates is interpreted as 1 and the high number of devil's advocates is interpreted as 3.

Future researches could extend the model to test other recommendations to prevent groupthink. As an example, Janis recommended splitting the group into smaller groups which work the problem in parallel [22]. This can be implemented by designing a communication network constructed from small cliques which connected by bridges as communication channels between the smaller-team leaders.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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