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Psychology of Group and Collective Intelligence

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Introduction: What Is Collective Intelligence?

Imagine how many people are contributing to a plane's arrival at its destination. Over 4 billion passengers annually move on over 10,000 jets at all times. No one person controls all that activity, and no one person understands all the technology and has all the knowledge required to sustain the airline industry. Troubles such as flight delays are always occurring somewhere, but this huge system runs smoothly while absorbing such fluctuations. What makes this possible is that passenger movement is based on shared knowledge among cooperative and skilled staff of airlines and related industries, as well as by distributed processing by airport networks. And this is just one example of the fact that we are always running systems that exceed the intelligence of individuals.

Collective intelligence refers to a phenomenon in which intelligence (adaptability to the environment) that is greater than the sum of individuals appears in a group. Swarm intelligence is a form of collective intelligence. Ants and bees have a limited perception as individuals and no leaders, but they can build complex nests, divide tasks, and make collective decisions. We can see the collective intelligence created by humans in various scenarios as a phenomenon that synthesizes a combination of individual recognition, group cooperation, and distributed processing networks. In the past, crowds that caused economic bubbles and crowd avalanches in sync with misjudgment were thought to be stupid. But now, evolving internet-related technology has overturned that idea. When trying to get answers for translations and searches, it is more “intelligent” to aggregate the solutions of many people than to write the rules in a program. The intelligence brought by the crowd has been accepted as a surprise and has been actively studied. This phenomena is called collective intelligence, or the “Wisdom of the Crowd.”

On the other hand, collective intelligence that appears at higher levels does not necessarily lead to intelligent results. At times the crowd remains stupid, as seen in a quickly flaming net or extremist beliefs that divide society. Empowering a single leader and the upper class has brought a bitter experience to humanity, and many countries have chosen democracy in an attempt to avoid such outcomes. However, democratic procedures require long-term adjustments. To adapt to the accelerating speed of society's change in recent years, it might become to consider the necessity of re-empowering top management including national leaders.

Charismatic leadership, group deliberation, collective intelligence on the Internet, etc., and what is touted as the “secret of success” vary from time to time, which raises uncertainty about whether there is a single best approach. What should we rely on when faced with difficulty in getting closer to a solution?

People can be less intelligent and/or more intelligent depending on the conditions. This book aims to integrate research on collective intelligence that highlights the “wisdom of the crowd” and research on group processes that exaggerates “madness of the crowd.”

This book first overviews the psychology related to individual cognition (Chap. 1) and groups (Chap. 2) and summarizes research on collective behavior (Chap. 3). In the first three chapters, I introduce the factors related to cognitive level, group level, and structure level. In the latter three chapters, I summarize research on collective intelligence (Chap. 4) and collective intelligence related to organizations (Chap. 5) and, finally, introduce knowledge on collective intelligence on the Internet (Chap. 6). Reference numbers that indicate where to find each term will help readers understand, wherever they begin. To that end, basic scientific terms are summarized in a glossary at the end of the book. Readers interested in a particular field may follow up with specialized literature for deeper learning. In each chapter, I have touched on only a small part of the vast research in the topics covered and have introduced fields that exceed my specialty (group process). For ease of understanding, I have summarized many topics on the basis of a small number of research cases. I would be grateful if experts in each field would join this conversation by pointing out errors in the contents of this book.

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Author's Bio

Yoshiko Arima Ph.D. is a professor at Kyoto University of Advanced Science, Faculty of Humanities, Department of Psychology. Yoshiko Arima received her B.A. degree from Graduate School of Human Sciences,Osaka University, Japan, in 1981 and her M.A. and Ph.D. degrees from School of Human Sciences, Osaka University, Japan, in 1983 and 2003, respectively. From 1985 to 1992, she was a technical officer of Osaka University, and from 1992 to 2000, an associate professor at Poole Gakuin University, Japan. Since 2000, she has been a professor at Kyoto University of Advanced Science, Kyoto, Japan. Her research interests are in Group Processes and Collective Intelligence. As an author and co-author, she published books, papers in Japanese and other international scientific journals. She has teaching experience in the Social Psychology field and working ability in statistics using SPSS and machine learning using MatLab.

Chapter 1
Social Cognition

Please imagine that the people at the airport are moving individually for their own individual purpose. Some people may have come to the airport for the first time, and others may be on the plane for the first time, but most people find their way without trouble. Humans can efficiently process enormous amounts of environmental information. When observing and communicating with others, you can use the knowledge of others. This is possible because of the innate ability and cognitive ability developing according to the environment.

1.1 Cognitive Psychology

In the human brain, neural networks are connected together to form information processing units called columns, and modules aggregate the columns further to organize cognitive functions (cognition) capable of working independently to some extent. Various types of information processing can be performed by connecting the modules via a network.

Neural networks are formed immediately at birth to adapt to and to optimize performance in the environment. The most influential environmental factors are interpersonal interaction and language. Human beings can become humans by taking a shower of cultural information.

The extent to which intelligence is due to innate abilities is a subject of debate. We can see common structural characteristics unique to humankind such as functional localization of the brain (e.g., the visual cortex is in the occipital), global network (e.g., the neural circuit connecting the remote part of the frontal lobe to the occipital lobe), and neural development (e.g., the critical period of language acquisition). These structural features imply inherent limitations to human intelligence. Yet we know that neural networks differ slightly among individuals. Even in twins,

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the neural networks formed after birth vary significantly. However, the common part will appear during development.

Since genes have an on/off switch which is activated/deactivated by environmental factors, gene-environment interactions also affect intelligence. For instance, one experimental example to explain this lies in reflex behavior (heat shock response time of tail contraction) in mice. These differences have been demonstrated to depend on genetic factors (27%), environmental factors (42%), and genetic environment interactions (19%). Interestingly, the most influential factor was the "social" environmental factor, the "who the experimenter is "(Chesler et al., 2002).

1.1.1 Pattern Recognition

Pattern recognition, which emerges shortly after birth to adapt to the environment, is an ability to identify and classify meaningful patterns of information with repeated learning. This learning progresses by correct feedback, yet pattern recognition itself is possible without feedback. The following two processes work simultaneously.

Bottom-up processing: Feature extraction from data.
Top-down processing: Select features that fit knowledge.

The reason you can make a snap judgment about the gender of the person in front of you is that the classification created by previous empirical learning. As a person watch others, bottom-up processing begins, and it selects a classification that fits the top-down processing. Such processing ends without being aware of it. However, if the appearance is female, but the voice is male, the process begins with bottom-up processing again.

There is a model to explain the pattern recognition without assuming innateness. Among these, the connectionist (neural network) model of cognitive psychology has contributed significantly to the recent development of artificial intelligence (See Glossary G-4). Figure 1.1 illustrates handwritten input pattern recognition using machine learning.

1.1.2 Attention

Imagine a scene in a large airport terminal again. Our sensory organs receive an enormous amount of information, such as complex passages, signs, storefront products, people, and announcements. Which information is consciously processed is not determined solely by bottom-up. If you are about to leave, but you are distracted by the children running around and the architectural style of the airport, you will overlook the information you need. You should focus your attention on the information important to your purpose of action, such as an announcement that tells you the departure time and an electronic bulletin board. The only information that

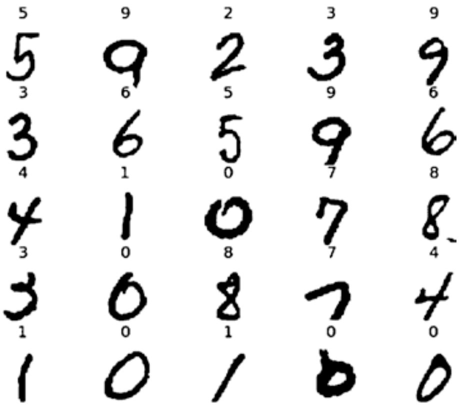


Fig. 1.1 Example of category classification using pattern recognition by machine learning of handwritten digits

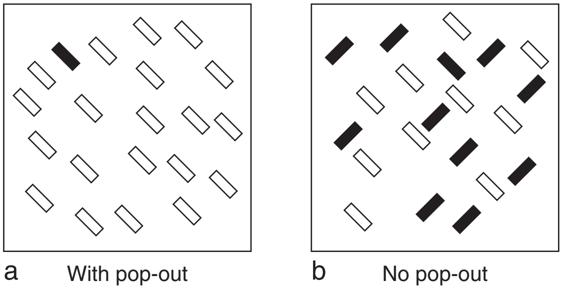


Fig. 1.2 Feature extraction

synchronizes with the higher-level neural network (the neurons fire at the same timing (Sect. 3.4.1.1)) is conscious. That is, "attention" is what selects stimulus called the attention filter model.

In feature extraction, "attention" is directed to only one feature at a time. For example, as shown in Fig. 1.2a, if the color is the only point of attention, it can be quickly identified even if the number of elements increases. However, as the number of features to be distinguished increases (e.g., Fig. 1.2b, find things that differ in both angles and colors), the reaction time will be delayed. Although this is the inherent limitation of our intelligence, whether people pay attention to the whole or details depends on their cultural background (Sect. 5.4.3). Humans develop intelligence to adapt to the environment with genetic constraints.

In humans, attention control ability develops from 7 to 13 years old (Hakoda et al., 2010). This ability can be measured with a Stroop color-word interference test. In this test, participants are asked what color the word "blue" is drawn in, and the time required for the answer is measured. For example, if the word "blue" is written in the color red (word-color incongruent), participants take longer to answer than if "blue" is written in blue (congruent).

Attention capacity has a limit; hence, it is referred to as "attention resources." Information processing is also limited and is called a "cognitive resource." Cognitive resources can be saved by proficiency through repeated learning. Suppose you are going along a path that you use every day. You arrive at your destination without thinking. Such processing is called *automatic processing*. Conversely, information processing that consumes large amounts of cognitive resources and proceeds consciously is called control processing. Top-down processing corresponds to automatic processing; meanwhile, bottom-up processing corresponds to control processing.

Humans are cognitive misers and tend to save cognitive resources. Therefore, top-down processing is preferred when the learned top-down process is available. It may be an innate characteristic that has evolved information processing speed while suppressing the energy consumption of the brain.

Joint Attention

Joint attention is being aware of other's interests in the ternary relationship of the self, the other person, and the object and directing attention to the same object. Joint attention is considered a natural ability based on the ability to recognize others' faces and gaze, and also leads to the ability of imitation (Sect. 3.3). In patients on the autism spectrum, acquiring joint attention may be delayed. Ikegami (2017) conducted sociological participation observations while suggesting patients with autism spectrum are more likely to communicate on the Internet than the real world. Conversely, normally developing people often face difficulties in communication on the Internet. This is because even if virtual reality is used, it is difficult to ensure natural joint attention based on gaze.

Give It a Try: "Selective Attention Task"

You can access YouTube videos of the selective attention test with the keyword search for "basketball gorilla." Let's count how many passes occur during the video. If you have done this test, try similar tasks.

Brain imaging research has revealed that the effects of attention range from higher brain function to the primary visual cortex. Even if the scene is inputted to the optic nerve through the retina, the stimulus you are not paying attention to are not "seen" Conversely, even subliminal stimuli may affect subsequent cognitive automatic processes (Sect. 1.1.4.1).

1.1.3 Memory

How does the brain store enormous information?

The memory of information received by the sensory organs (sensory memory) itself lasts only a few hundred milliseconds; nevertheless, the information to which attention is paid lasts longer. This is called short-term memory. In one model of understanding of short-term memory, working memory has a phonological loop, visuospatial sketchpad, and central executive. Short-term memory is transferred from the hippocampus to the cortex by rehearsal and stored as long-term memory. Long-term memory can be divided into episodic memory (memory of events) and semantic memory (knowledge). Even with episodic memory, one scene is not stored alone but is stored in association with various information.

When people are exposed to strong emotional stimuli, even if it is a one-time event, neurohormones and neurotransmitters continuously activate the hippocampus and store that as long-term memory. This is called long-term augmentation and can cause symptoms of PTSD.

In the experiment procedural terms, the memorizing of the presented stimulus as a representation is called encoding, the recollection without clues is called recall, and answering whether there is a memory when prompted stimulation is called recognition. The process of making linkage to other memories is called elaboration.

Relevance to other memories affects the process of retrieval from long-term memory.

Implicit Memory

Implicit memory is part of long-term memory, which is acquired and used unconsciously and capable of recall without an explicit request. There are two types of implicit memory: procedural memory and semantic memory. Procedural memory is memory related to physical sensations and exercise, such as riding a bicycle. Semantic memory (Sect. 1.1.4.1) also subliminally affects our cognition. These influences can be measured by the priming effect (Sect. 1.1.4.1) or false memory.

When retrieving memories, false memories (Sect. 1.1.3.2) are often mixed. Imagine a kindergarten you attended in your childhood. The details of the scene are often intermingled with memories of the photograph or other places. Collective memory (common memory remembered by people such as major incidents and disasters Sect. 5.4.4) is also often stored with information obtained from recorded images. When we recall memories of the past, we do not retrieve past episodes as they were but reconstruct the scene from memory fragments.

False Memory

False memory means the recall or recognition of an event that has never happened or recall that is distorted. The existence of false memory has become known to people through false charge cases in which the memory of the victim's sexual abuse was incorrect. The experimental procedure of false memory was designed using the phenomenon that, when using a word list with a strong semantic relevance, items can be easily associated are likely to be mistakenly recalled (Deese, 1959). The DRM (Deese-Roediger-McDermott) experimental paradigm (Roediger & McDermott, 1995) uses a trap word (known as a "lure"), which is a related word to the word list but not included in the initial word list. The results using DRM have been shown to be high repeatability, reaching 0.50–0.80 probability of recalling a lure word. One explanatory theory for this phenomenon is the spreading activation hypothesis (Roediger III et al., 2001a).

Spreading Activation Hypothesis

The spreading activation hypothesis is an idea that not only a specific nervous system corresponding to a particular stimulus is excited, but that neural excitation spreads around a semantic network (Fig. 1.3). As the related words are stored, the lure word in the place where the links overlap is primed; thus, it becomes easier to recall. The same concept can also explain the "priming effect" (Sect. 1.1.4.1).

Regarding false memory, cognitive neuroscientific evidence has accumulated to explain its occurrence. For example, fMRI images showed that hippocampal activation by list words (correct answers) and trap words is similar. P300, which is a semantically related brain wave, peaked faster in lure words than in list words. This result shows that the activation of lure words increased the same as the accessibility (Sect. 1.1.3.4) was increased by the primer. Of note, in patients with dementia or Alzheimer's disease, both correct recall and false recall simultaneously declined. These studies suggest there is a neural basis for virtual memory (Gallo, 2006).

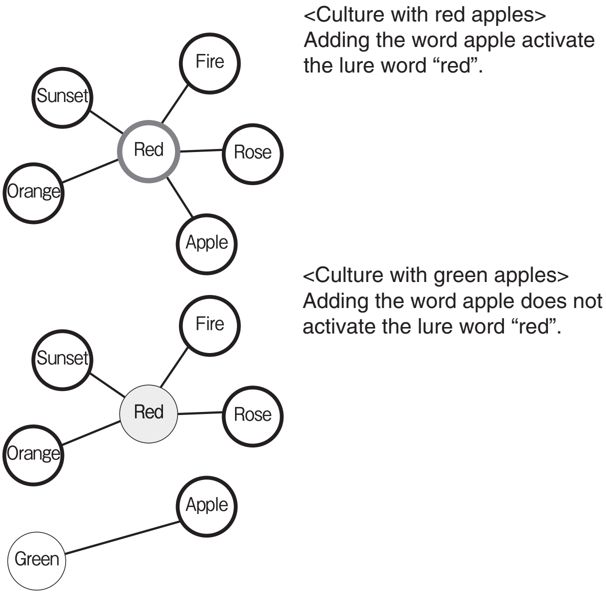


Fig. 1.3 Example of the word list
"Red" is a lure word, and apple, orange, sunrise, and fire are word lists. The lure word "red" has different levels of activity in the cultures where apples are linked to red and cultures where apples are linked to green. People in a culture with red apples are more likely to find the lure word "red."

In the DRM experiment, a word list is provided from the lists created from the free association. This list varies by the participant's cultural background (Fig. 1.3). The participant's false memory rates decrease with the second language word list. Thus, the DRM experiment paradigm uses culturally formed knowledge structures, which are thought to use shared associative semantic memories (Sect. 2.4).

Accessibility

When a word is recognized, the activation level of the "adjacent node (See Glossary G-2-1)" increases. This propagation of activity occurs more easily between concepts whose links have been strengthened by repeated learning, etc. Such a state that is easily recognized by the context and proximity experience is called "high accessibility." Attention is easily directed to higher accessibility concepts. It is difficult to control accessibility. When we consciously control thinking, we begin to monitor it, which makes it easier to recall the objects we have suppressed. The goal of "do not think" is prone to failure.

1.1.4 Knowledge Structure

The information (See Glossary G-1) stored in one's brain is called mental representation. There are individual differences in mental representation. When one hears the word "airport," some people will soon think of the local airport, while others will imagine the airport as seen in a movie. Even a single word may have a variety of representations depending on the context. The term "terminal" can mean an "airport" or a "computer command input screen."

Concepts, such as "apples are red and round fruits," are stored in long-term memory storage in association with other representations. Knowledge is an association among concepts such as "harvested from apple trees and sold over the counter."

There are various cognitive models in the framework defining the association of concepts, such as schemas, categories, mental models, and semantic networks. In this book, these are called "knowledge structure."

Priming Effect

The priming effect is a phenomenon in which the preceding stimulus "primer" facilitates the perception of the subsequent stimulus "target." Suppose the word "pear" is given as a subject to determine whether it is a meaningful word. If the word "apple" was presented before that, the judgment would be faster than when the word "violet" was presented in advance.

This is the semantic priming effect caused by accessibility (Sect. 1.1.3.4). The priming effect demonstrates the existence of implicit memory working (Sect. 1.1.3.1).

Figure 1.4 shows an example of a semantic network obtained from the priming experiment. If the primer duration time is 17 msec to 30 msec, although it is almost impossible to be aware of what was presented, it still affects the following task. This subliminal priming effect is also observed in amnestic patients. Neuroscientific evidence shows that different brain regions are activated by affective priming.

Category

"Category" is a concept with multiple elements in one group. Sparrows, pigeons, swallows, robins, etc. fall into the category of birds. A typical case within that category is called a prototype. For exsample, the sparrow is closer to the prototype than the penguin. Prototypes are not fixed to specific cases. When you hear the word "bird," you will have a generalized image of a small bird.

The category concept is naturally acquired during the language acquisition period of 2 and a half to 3 years old. It has been partially confirmed that there is a processing unit corresponding to the category concept in the brain column structure. Certain category concepts may be lost after brain damage.

Because we are cognitive miser (Sect. 1.1.2), we tend to use categories already learned rather than creating new categories. Since the top-down processing starts automatically, it is difficult to control consciously. Such cognition without conscious control is memorized with a lack of detailed information.

For example, if you find an unusually shaped table light, you will wonder—"What is this?" —and then, after comparing the detailed shape with your memory

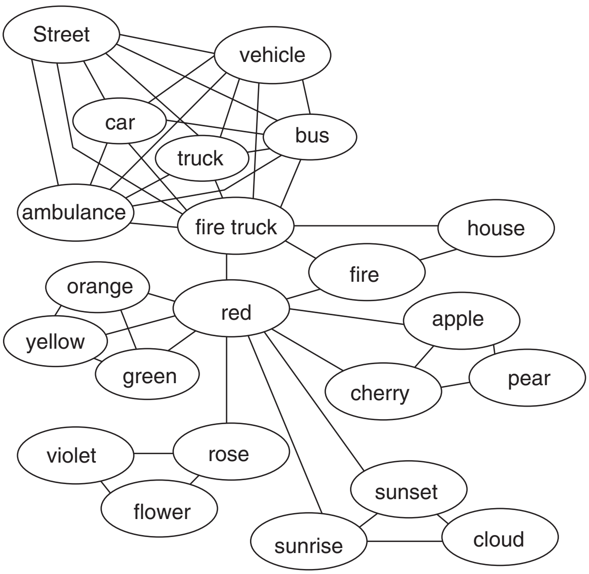


Fig. 1.4 Semantic network based on spreading activation model (Collins & Loftus, 1975) Individual concepts are represented as nodes, and associations between concepts are represented as links. Nodes with higher semantic association are closer to each other

of the category, you will recognize it as a table light. In such cases, its features are clearly stored. However, a prototype of a stand on an office desk is recognized without paying attention to details, and the memory is easily recalled as the prototype. Such category recognition leads to prejudiced recognition called "stereotype (Sect. 2.3.5.1)".

If there are several categories already learned, the recognition may switch among them. If you hear "people in the kitchen" in the context of a home kitchen, you might imagine "female," but if you ask in the context of a restaurant kitchen, you might imagine "male." This is an example of a stereotype related to the categories of males and females, while it also serves as an example of how schema works to fill in missing information by default.

Schema

When you hear the word "bird," not only the category but also knowledge such as "fly and have wings" is automatically recalled. Unless an exception such as a "penguin" is presented, "bird" is understood by applying the default value that it will have wings and will fly. Such top-down processing is called "cognitive schema."

Cognitive schema always works subconsciously along with categories. The schema also causes stereotypes (Sect. 2.3.5.1) so that if you hear "doctor," you might automatically come up with the image of a man; meanwhile, "nurse" you might think of a woman. If the information obtained from the environment does not fit the schema, the schema is updated through learning. To update the schema to adapt to new information is called "coordination." Adjusting the schema after becoming an adult requires an effort to use cognitive resources. For example, if the concept of "transgender" is generalized, the classification "androgynous" may be made automatically, but it takes time to learn. If you already have multiple schemas, the same information is processed by different schemas due to changes in accessibility (Sect. 1.1.3.4). Therefore, if you have a complex knowledge structure, you can understand it flexibly by switching schemas. Nontheless, context switching cannot be done automatically unless accessibility is changed by external stimuli and requires cognitive resources.

Mental Model

"Mental model" is a model constructed in the mind during problem-solving, especially in the inference process. It is thought to manipulate images or iconic representations, as when a chess player thinks of tactics (Hinterecker, Knauff, & Johnson-Laird, 2016; Johnson-Laird, 1980). Note the "shared mental model (Sect. 4.6.1)" used in organizational psychology is a broader concept that includes schemas and categories. Applying the acquired inference process to a new task situation is called transfer. Tasks that require more mental models are more likely to be mistaken because they need more cognitive resources.

If you are in a familiar environment, you can act without being aware of the flow of getting on the train or making payments. Such a mental model of a behavioral procedure is called a “script.”

1.1.5 Inference Process

Inference is the thinking process to solve problems. The method of deriving general rules from cases is called “inductive reasoning,” while the method of acquiring conclusions from preconditions is called “deductive reasoning.” Inductive reasoning, such as category classification (1), is considered to be based on the ability gained by pattern recognition. It is known that deductive reasoning and judgment of probability have several common biases mistaken by humans.

The “Monty Hall problem” is one of the probability judgmental tasks. In the task of choosing one hit from three boxes, the question is whether to change the selection if you receive information that one box you did not pick after choosing is empty. The subjects stick to the first choice, but the probability of hitting is higher if the first decision is changed (See Glossary G-5).

A well-known example of deductive reasoning is the Wason selection task (four-card problem), in which a responder is asked to confirm supposed governing rule among four cards, each with a letter or picture on one side and a number on the other. The responder may turn over only the two cards in four. For example, if the rule is “If the front is even, the back is a vowel,” the responder must turn over the even card and consonant card to see if the rule is correctly adopted. The average accuracy rate for this problem is low, about 10%. Most participants cannot check violations of the rules, and the confirmation bias could be its cause. However, the correct answer rate rises to about 80% when resetting to a familiar problem (who violates the rule of “prohibition of drinking under 18”). This is because it is easy to understand that the cards of those under 18 and those of drinkers can be turned over.

This is called thematic materials effect, and giving a specific image to the task improves the correct answer rate. Through the accumulation of these experimental results, it was proposed that intelligence evolved according to specific tasks. The bias from rational judgment is called “cognitive bias.” Many experiments have shown that various cognitive biases are commonly seen in humans.

Confirmation Bias

“Confirmation bias” is seeking information that supports one’s expectations and hypotheses while ignoring the contradicting information. The tendency for confirmation bias to appear in communication to support each other’s expectations is called “confirmative communication,” while the tendency to act following one’s or other’s expectations is called “behavioral confirmation.” The phenomenon in which the hypothesis becomes a reality through such a process is called “self-fulfillment of prophecy.”

Heuristics

Humans are not always able to make reasonable judgments. Why is that? One reason is that people use “heuristics.”

There are two procedures in solving the problem: “algorithms” and “heuristics.” The algorithm always obtains a correct result in a precise process. Heuristics are intuitive solutions based on individual experience. Humans who are cognitive misers (Sect. 1.1.2) prefer heuristics rather than algorithmic thinking.

Even though the “Wason selection task” and “Monty Hall problem” shown above are problems that are difficult to intuitively solve, the correct answer can be reached by following the prescribed procedure.

However, it is difficult to determine the correct answer for many issues because of the complexity of the interaction among various factors including unknown ones. Think of the question, “What time should I go to bed to allow me to smoothly falling asleep?” The answer “If you live a regular life, you can sleep at a certain time” would be an approximate answer (a solution close to the correct answer); however, the exact time varies depending on the individual condition based upon their daily physiological and psychological factors. If you calculate everything, it may be closer to the correct answer, but it takes much more effort. Therefore, it would be judged based on past individual experiences. Such a judgment method is “heuristics.”

Most everyday problems cannot be solved by algorithms. Considering human cognitive resources are limited, heuristics are indispensable. The ability to make use of many heuristics gained from experience makes it possible to make quick decisions and adapt to society. But these heuristics often cause simplistic thinking. Therefore, smart people don’t always make better decisions. This is one reason collective intelligence is more intelligent than experts. Collective intelligence can go beyond the limits of handling complexity by individuals.

Collaborative Problem-Solving

In cognitive psychology, research on “collaborative problem-solving” in which two or more people solve problems is being conducted. In these experiments, insight tasks allow subjects to discover new strategies or creative tasks. For example, the “Tower of Hanoi” (Fig.1.5) is a puzzle that moves all the disks from left to right according to the rules in the figure. If an appropriate algorithm can be found, it can be solved with minimal operation. Such puzzles require the ability to gain a new perspective without sticking to one solution. Therefore, problem-solving ability increases by gaining a novel perspective of others. If they were thinking from the same viewpoint, they are prone to a lack of flexibility (Miyake, 1985, 2000).

In creative tasks, such as “find new ways to use matchsticks,” participants must have divergent thinking to explore the possibilities of various solutions, rather than convergent thinking that seeks to explore the only precise answer. The method of

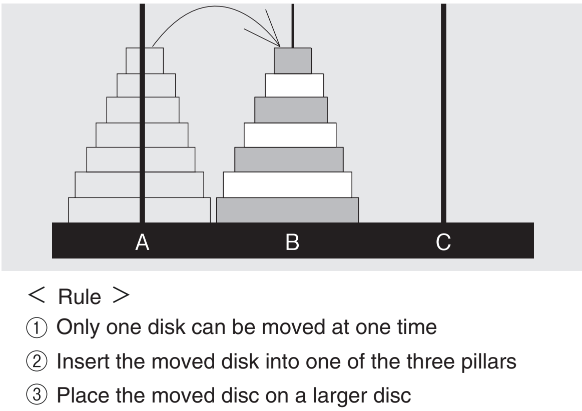


Fig.1.5 Let’s challenge the Tower of Hanoi

using divergent thinking and convergent thinking in a team is called “design thinking” and is recommended for scenes such as planning meetings.

1.1.6 Metacognition

“Metacognition” means awareness of one’s thoughts and perceptions. Metacognition is the “knowing” in the phenomenon “one struggles to recall something that one knows” that we often experience. The monitoring function of working memory (Sect. 1.1.3) is related to this recognition.

Two Neural Signalings of Emotion

One reason humans do not always make reasonable judgments is emotional influence. There are two types of emotion recognition: fast and slow routes (Fig. 1.6). In the rapid route, stimuli are sent directly to the amygdala via the thalamus that aggregates the input signals, and it unconsciously evokes emotions. In slow signal transmission, the stimulus passes through the thalamus and then through the cerebral cortex to determine “what the stimulus is” and eventually reaches the limbic system that controls emotion.

The involvement of fast signaling in decision-making processes has become known through gambling task experiments. In the gambling task, participants compete by picking cards from a deck of cards (Bechara et al., 1994). There is a disadvantage deck mixed with dangerous cards. When selecting a deck of disadvantaged cards, an electrical skin reflex reaction, which is an index of tension, appears from a premonition period before being aware of the danger. However, such reflexes are not observed in brain-injured patients shown on the right side of the graph. The graph on the left shows the control conditions (Fig. 1.7).

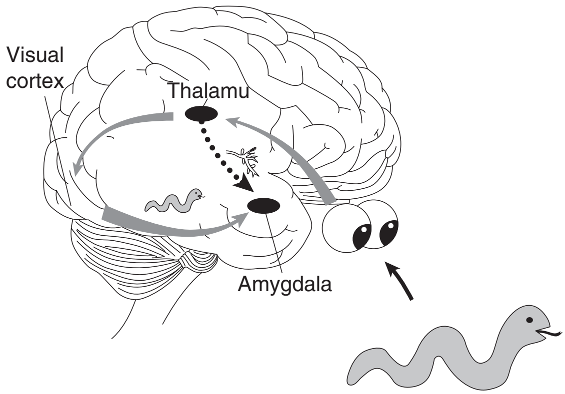


Fig. 1.6 Two neural routes of emotion (modified from Hakoda et al. 2010)
The dashed arrow indicates the direct route, and the grey arrow indicates the indirect route.

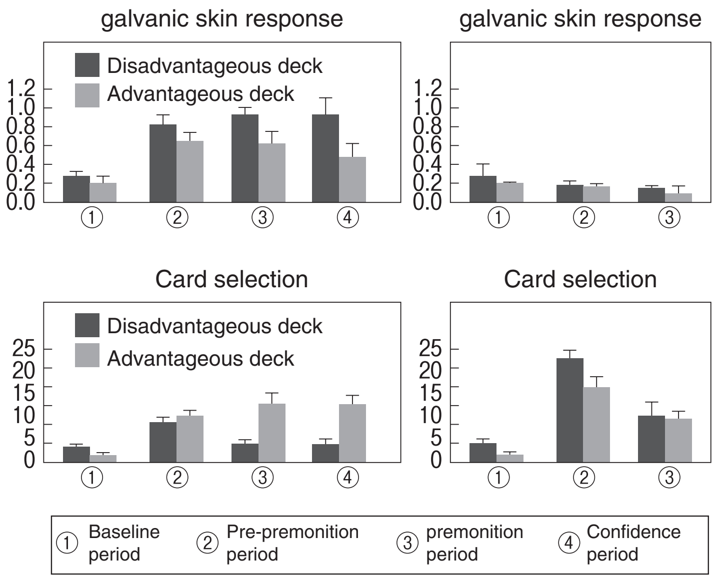


Fig. 1.7 Relationship between Orbitofrontal area and gambling task (Okada et al., 2015 modified from Bechara et al., 1994)

As observed in gambling task experiments, emotional responses that are not obvious appear in metacognition. Within the index of emotional reactions, confidence in the answer is available. Although confidence does not correlate with actual accuracy rate, if the more confident answer was selected from one's multiple responses, the accuracy rate will increase. Although emotions often lead to unreasonable human judgments, this feature has been preserved from the need for our survival. Such emotional reactions generate collective intelligence (Sect. 5.2.2), however, while as a group, people recognize each other's wrong answers, facilitating their confidence and causing false beliefs.

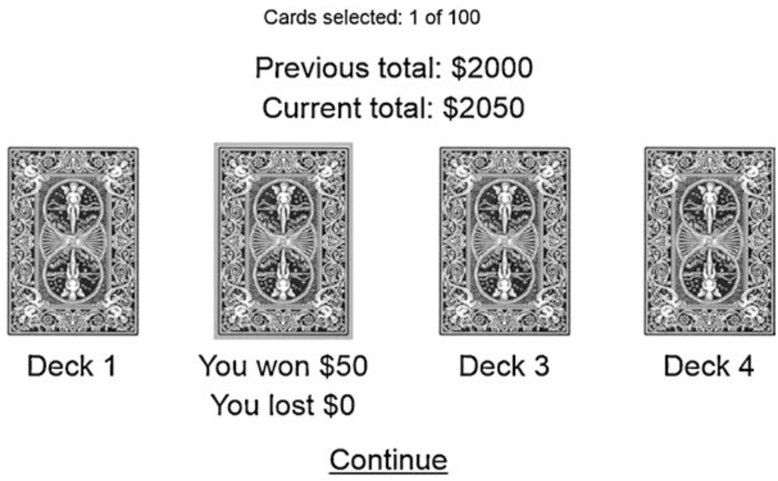


Fig. 1.8 The Iowa Gambling Task

Give it a Try: "The Iowa Gambling Task"

You can experience "The Iowa Gambling Task" with the program provided by Inquisit.

The Fig. 1.8 is a program image for kids (Bechara, et al., 1994, Garon et al., 2006). Let's try it with a free trial version of Inquisit. If you have a galvanic reflex (GSR) device, you can try it.

Misunderstanding of Agreement

When judging a problem (Sect. 4.2.4) for which there is no correct answer, cognition of the opinion distribution of "how others think about it" also affects metacognition. There are various biases in the perception of opinion distribution. One of them is "false consensus" (Ross et al., 1977), which overestimates the percentage of people with the same opinion. False consensus is measured as follows: After asking subjects whether they agree or disagree with an idea, they are asked how often others agree with that question. Here, bias is observed that overestimates the ratio of the number of people answering the same as self.

1.2 Game Theory

The action to select from the choices is called "decision-making." For example, when thinking about which restaurant to dine (e.g., Fig. 1.9) the "value" (utility [See Glossary G-3]) for the person has multiple attributes such as taste, price, and

Fig.1.9 Two-person zero-sum game. Alice's score on the left and Bob's score on the right. See G-3-4-1 for a detailed explanation of this table

		BOB	
		A	B
ALICE	A	0, 0	3, −3
	B	2, −2	1, −1

Fig.1.10 Prisoner's dilemma game (Prisoner A's score is shown on the left, and Prisoner B's score is shown on the right)

		B	
		Silence (cooperation)	Confession (competition)
A	Silence (cooperation)	−1, −1	−5, 0
	Confession (competition)	0, −5	−3, −3

atmosphere. The value obtained by multiplying the utility by the occurrence probability is the "expected value." Deciding with a high expectation is called "strategy" (See Glossary G-3-4). The preferences of the people you go with may differ from yours. However, if it is more beneficial to eat with two people rather than by yourself, your utility changes depending on the choice of others. The "game theory" is a field that attempts to mathematically express interpersonal relationships—from two-party relationships to society, with the assumption of such a situation.

In game theory experiments, participants choose to cooperate or compete as "players." The table showing the resulting utility is called the "pay-off matrix." A two-player zero-sum game like chess where one wins (one player's score is the other's negative point) (e.g., Fig. 1.10) or both are profitable; the so-called win-win pay-off matrix can also be considered. The game may be one-time or repeated. In a mixed strategy, a player who repeats will probabilistically change his choice so that the opponent does not read his strategy.

In the game theory, first, a pay-off matrix is set. If players with various strategies play, it is predicted that its equilibrium point (the combination of strategies that neither attempts to change the strategy) will be reached. The founder of the game theory, Von Neumann, showed that even in a two-person zero-sum game, there is an equilibrium point that minimizes both losses (See Glossary G-3-4-1).

1.2.1 Prisoner's Dilemma

In reality, the player behaves unexpectedly. The fact that humans are not rational decision-makers is now widely recognized not only in psychology but also in economics. The "prisoner's dilemma" game highlights it.

Give it a Try: Prisoner's Dilemma

Try the prisoner's dilemma game and experience the dilemma situation.

Two suspects who are being interrogated separately are given the choice of confessing or not. Confession is a "betrayal (competition)" for the partner, and silence is the "cooperation" for the partner. Figure 1.10 is an example. The one who confesses earlier will go free, whereas the other will receive 5-year sentence. If both confess, both will receive 3-year sentence. Considering the sum of their sentences, it will better for no one to confess. However, people tend to confess because we can't stand the situation when we don't know when we will be betrayed (this method is actually used when incriminating evidence is lacking); the name of the "prisoner's dilemma" is derived from this cover story. In a one-time prisoner's dilemma game, no matter what choice the other makes, it is more profitable to confess, so the betrayal is the strictly dominant strategy (See Glossary G-3-4). However, when we actually experiment, we can see that humans do not necessarily make "rational choices."

Let's be a pair of two people, and prepare red and blue poker chips. Based on the premise that red is "cooperation" and blue is "competition," the game is played about ten times in one session according to the pay-off matrix. If the number of sessions is known, noncooperators appear at the end, so the recorder stops at the appropriate time and calculates the average score. Try different strategies for each session, and discover which strategy has the highest score. Besides, let's try a "mixed strategy" that can change the strategy within one session.

1.2.2 Tragedy of Commons

The "prisoner's dilemma" is a two-party game. What will happen if this is extended to the society? Let me introduce one story that illustrates social dilemmas—"The tragedy of common land." It originates from the anecdote that the "shepherd grazed many sheep (in the original paper, cattle) at once to grab more profit from the common grazing land, and eventually, he made the land unusable." A social dilemma situation implies a situation in which the rational behavior by individuals results in a decline in social benefits.

There is a "public goods game" as a multiplayer game. Private tokens contributed to the public pot when players are added up after being summed up, and then distributed equally. Players who did not contribute tokens can also get the payoff of "public good," so some people who just ride will appear. When this game is played, there are three strategies: "coordinationism (cooperates even if other people don't contribute)," "free riders (ride without contribution money)," and "reciprocity (cooperates if other people contribute money)." As more people do not cooperate, reciprocity people will not contribute.

Nash mathematically proved there is an equilibrium point (See Glossary G-3-5) in a multiplayer game with a mixed strategy. Equilibrium points are the points where profits do not vary with strategy. The combination of strategies is expected to stabilize society. It is known that in the repeated dilemma game in which various strategies are rearranged, "tit-for-tat strategy" results are better eventually. The tit-for-tat strategy requires initial cooperation with others but thereafter imitates other's behavior: Cooperation is met with cooperation, competition with the competition. If everyone uses this strategy, it does not mean they will be stable in a cooperative relationship. In a dilemma situation, cooperating strategies are not equilibrium points. Therefore, even if they cooperate, there is a high possibility that they will be competing as a result.

Shared rules can improve the social dilemma situation, but the larger the group size, the higher the cost of monitoring free riders. So how can we build a low-cost system? Humans do not necessarily behave as predicted by the game theory. Even a one-time prisoner's dilemma game does not necessarily result in betrayal. In the current game theory, research is progressing on the premise that humans are not wholly rational. A genetically defined tendency is hypothesized as one cause of irrational human judgment.

1.2.3 Give it a Try: NetLogo

NetLogo web (http://www.netlogoweb.org) offers various free educational programs related to social science (Wilensky, 2002). Let's run PDN-person iterated, and see what strategies are likely to survive in the repeated prisoner's dilemma game with many players. Five strategies have been set: "random" to be randomly selected, "cooperate" to always cooperate, "defect" to always betray, "tit for tat" to return according to the opponent, and "unforgiving" that is not forgiving once betrayed. You can set your own strategy into "unknown." Initially, the traitor's profit is better, but the situation changes with repetitions. Try changing the ratio of unforgiving, etc., and start by changing the population ratio of people who take a specific strategy and seek a stable society.

1.3 Evolutionary Psychology

Strategy in evolution is the selection of genes that determine the body and behavior patterns. Genes are not merely duplicated, but mixing gametes by sexual reproduction. The evolutionary psychological research is the back-engineering that investigates the process of "irrational" strategies, such as cooperation in dilemma games.

Humans can express "empathy" (Sect. 3.3.1) for others who are in pain. If you jump into the water to help someone, you may die early before you have your offspring. Individuals with altruistic characteristics are more likely to die before passing on their genes. But herds are observed to help each other. Considering many of these behaviors are found in close relatives, this could support the preservation of their own genes. This is called "inclusive fitness" (See Glossary G-3-7).

1.3.1 Evolutionary Game

The state corresponding to Nash equilibrium is called an evolutionally stable strategy. It is a combination of strategies that cannot be invaded by other strategies.

Suppose two birds are competing for the same food. Fighting hawks are at risk of injury if they meet the same hawk, but peaceful pigeons are at risk of being deprived of food. Unfortunately, however, a peaceful society where everyone can be pigeons is unstable. As pigeons increase, hawks increase because they are ready to take food without fighting. If birds decide the strategy after looking at the opponent's strategy, more birds will pretend to be hawks, because it will be a disadvantage if it seems to be a pigeon. This shows that in human society, there are many struggles to maintain a reputation when there are onlookers (Fig. 1.11).

However, in the human society, behavior that hurts the other is rare. It would be more common to help someone drowning who is not your relative. This behavior is

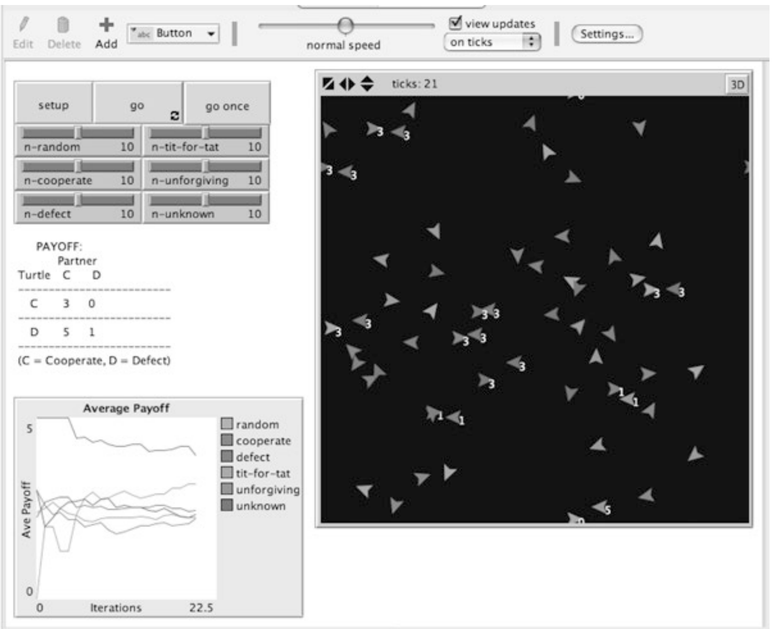


Fig. 1.11 Prisoner's dilemma game with NetLogo

thought to have evolved as "reciprocal altruism" (helping others because they will help each other: indirect reciprocity). Indirect reciprocity can also be the reason cooperative behavior is observed in a one-time dilemma game.

Not only genes but also representations (strategies, behaviors, meme (See Glossary G-1-8), etc.) are replicated through generation. Our behavior is replicated through learning and imitation and is examined by simulation for each generation (See Glossary G-7-3-4).

Influence of Culture

The "irrational" trend does not necessarily rely on genes. An anthropological study on the ultimatum game shows that. In this experimental game, one player A, the proposer, is endowed with $100, and A decides how much to give to responder B. Responder B only decides whether to accept or reject it. There is only one chance. If B refuses here, B will lose the rewards, so it would be better for B to receive even $10. The proposer A knows it; consequently, it is beneficial for A to reduce the distribution to B. However, as a result of the experiment, on average A distributes about 40% to B. If the distribution was less than that, B is more likely to refuse to receive it. This is not a genetically determined trend, but the results of the ultimatum game were different in ethnic groups. The ultimatum game was tried with various ethnic groups; some ethnic groups allowed low distribution, while others did not. Whether people cooperate can be related to feelings of unfairness, emotional responses to betrayal, and the tendency of others to react.

Relational Mobility

The distribution of ultimatum games tends to be fairer in ethnic groups with trade experience between societies. This can be thought of as a cultural custom influenced by the interpersonal network. There is relational mobility (Yuki et al., 2013) as an explanatory concept related to interpersonal networks. Relational mobility increases as the rate of a job change or residence mobility increases. Besides, relational mobility is thought to affect the cooperation rate in games, fairness perception, and reputation (Sect. 5.3.2).

Yamagishi (1998) reports survey results that the reliability to generalize others (unknown people) was lower in Japan than in the United States. This is thought to be because in a society with high relational mobility, the ability to read the strategies of generalized others develops. Contrary, Japanese people with low relational mobility are thought to be poor at speculating generalized other's strategies.

1.4 Social Cognition

Besides the application of cognitive psychology, studies of social cognition have widely influenced sciences.

1.4.1 Perspective in Social Cognition

Fiske and Taylor (2008) classified the framework of social cognition into these five viewpoints, consistency seeker, naive scientist, cognitive miser, motivated tactician, and activated actor, representing the basic views of humans. "Consistency seeker" is one human nature seen mainly in attitude research conducted in the 1950s to the 1960s. The effect of consistency being expressed through attitudes to others has been demonstrated based on balance theory and cognitive dissonance theory and is still influential today. However, since the 1970s, motivation-oriented theories had declined and changed to cognitivism.

"Naive scientist" is a viewpoint of causal attribution research that assumed a naïve person could think like a scientist. However, attribution studies have found they are prone to making mistakes rather than using rational thinking. The reason is that the human being is a "cognitive miser" (Sect. 1.1.2). Saving cognitive resources has been shown to cause various errors and biases. Currently, it has been shown that motivation changes the cognitive process (motivated strategist) and that subliminal priming (Sect. 1.1.4.1) changes the purpose of action (driven actor); hence, the once-declined motivation process regained attention. Motivations, emotions, and cognitions that run in the mind before being aware are also referred to as the "nudge" effect in behavioral economics.

1.4.2 Dual Process Theory

There are two processes of human thinking: an automatic/implicit processing that does not require attention and control/explicit, conscious processing that needs attention. The terminology for distinguishing the two processes varies depending on the fields. This book uses the terms of automatic processing and control processing (Sect. 1.1.2). It also called conscious/subconscious processing for a brief understanding.

Automatic Processing and Control Processing

Since there is still no clear answer to what "conscious" is, control processing research is more ambiguous than automatic processing. The difference between control processing and automatic processing is whether it is "intentional" or not. The intention is considered to be the thought paid when it was necessary to make a decision in automatic processing. For example, usually driving is almost automatic, so there is no problem even if you are thinking (Sect. 1.5.3). Similarly, stepping on the brake after seeing the brake light of the preceding vehicle is also automatic. However, if you are considering avoiding traffic jams and changing your route, control processing is started by intentional action.

Previously, it was thought that either automatic processing or control processing was activated preferentially, depending on the situation or motivation. Currently, the model that starts with automatic processing is the mainstream. This is considered as appropriate from the neuroscientific evidence that neural activity changes before being conscious of acting (Libet, 2004). Following this idea, all processes, including control processing, are started from a process under consciousness, so the "concept of free will" requires reconsideration. There is another idea that automatic processing and control processing always proceed simultaneously.

In the past, it was thought that automatic processing was responsible for the low-order cognitive process (perception/cognition). However, social cognitive research revealed that automatic processing was also involved in high-order cognitive processes such as inference, judgment, and motivation.

Misattribution

We do not always accurately capture the cause of our cognition and emotions. A striking example of this can be seen in neuropsychological studies of epilepsy with patients who had received separation surgery of the callosal connection between the right and left brains. According to Gazzaniga (2011), the left brain, which could not see the stimuli cue shown in the right visual field, tried to explain the action taken by the right brain. Gazzaniga himself did not claim that "consciousness could be divided into two." However, this study suggests that the left brain observes and explains their own actions as if they were others.

Even a healthy person can make errors when trying to explain automatic processing that began with a conscious stimuli. For example, the suspension bridge effect (Dutton & Aron, 1974) is an example of the misattribution of arousal. This indicates the phenomenon of neural excitement due to fear of a suspension bridge and is mistaken for romantic arousal. The phenomenon of misinterpreting one's feelings is called "emotion misattribution." Misattribution is triggered even without awareness of excitement. Schachter and Singer (1962) showed that participants who have received epinephrine injection in the guise of saline increased their empathy for others.

"Self-concept" can also be influenced by presenting it to others. For example, when an introverted person roleplays an extroverted person in front of the public, the self-concept shifted toward extroverted (Tice, 1992). We may have observed ourselves as if we were others and live with the story to keep our self-concept consistent.

Give it a Try

One of the social cognitions studied from an early stage is "attribution research." When we see a particular action, we automatically infer its intention. You can watch the experimental video on YouTube that Heider et al. used in their experiments

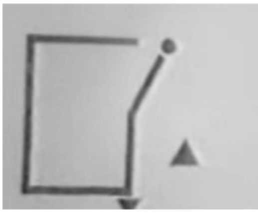


Fig. 1.12 Heider's experiment stimulus

(Fig. 1.12). The figure is just moving around, but you notice you are reading the intention of the movement as you watch. Cognition to seek the existence of the subject in a moving object and read its intention is considered an automatic processing process. These general cognitive trends allow us to share information and collaborate with others.

1.4.3 Self-Regulation

Achieving long-term goals requires efforts to suppress emotions and maintain attention. However, when people are faced with problems, people tend to respond intuitively to issues that they can solve, or even if they are confident that they will get better long-term benefits, they will often choose short-term gains. The tendency to do so has been shown in many experiments.

Continuous control of attention and emotion is called "effortful control." As with "cognitive resources" (Sect. 1.1.2), effortful control is considered as having limited resources and is called self-regulation resources. The "marshmallow experiment" (Michel, 2014), which showed that the time children endure eating marshmallows in front of them extends with age, shows that control resources increase with development. Children with higher self-regulation abilities are thought to be more likely to succeed in their life.

1.4.4 Motivation

There is accumulating evidence in theories that are classified as extrinsic motivation (acting for rewards) and intrinsic motivation (acting for self-interest and growth). Intrinsic motivation is essential for creativity and is known to decline when rewarded. This is called the undermining effect (Ryan & Deci, 2000).

It is difficult to determine if the behavior is purely due to intrinsic motivation. While spending a long time to gain rewards in the game seems to be an extrinsic motivation, it may be due to intrinsic motivation to discover the pattern of reward appearance. It is the nature of human beings that sometimes wants to continue exploring when encountering rare treasures rather than always being given the same reward. Therefore, various random changes are put in the game programs and are designed to attract the player's interest. Such a game design technique has had applications in learning and tasks to maintain motivation and is called "gamification" (McGonigal, 2011).

Dopamine, a neurohormone, is deeply involved in motivation and is also known as the "reward hormone." If a person achieves better than expected results, dopamine secretion increases, and happiness increases, but if a person obtains worse results than expected, it decreases. It is the "utility" of neurotransmitters (Siegfried, 2006). Dopamine is also involved in learning about identifying conditions for rewarding (Enomoto et al., 2013). Dopamine has the role of promoting learning to adapt to unknown environments.

1.4.5 Goal Contagion

Automatic processing also affects motivation. For example, if an image of dirty shoes is inserted into subliminal priming, the target word "shoeshine" related to stimuli is quickly recognized.

Since a single priming stimulus cannot initiate the learning of a new concept, it is assumed that actions and goals are linked in advance. This is called a goal route. If you use a bicycle to go to university, "bicycle" works as a primer and leads you to go to university. Interestingly, this priming effect has been reported to better work subconsciously than consciously (Aarts & Dijksterhuis, 2000; Aarts et al., 2004).

Even if there is no motivation, if the goal-behavior link is used, it can be started by automatic processing without wasting control resources (Sect. 1.4.3). For example, after your favorite habit (e.g., making coffee), it is a good practice to start working on something you don't want to do (e.g., start-up a computer). The priming effect is thought to last until the goal is achieved, yet it is difficult to restart if there is an intervention by control processing (e.g., check the email first because the smartphone was noticed) on the way. The more habitual and the stronger the goal-behavior link is, the influence of the control processing intervention is less. Indeed, you would have sat unconsciously in front of your computer while having a cup of coffee.

The more habitual the stimuli are, the better the reaction to the goal. In some cases, recognizing a person acting toward some goals can be a primer (Sect. 1.1.4.1) for the same goal. This is called "goal contagion," and, remarkably, the goals of others can infect unconsciously.

1.4.6 Relationship Schema

"Relationship schema" is a schema that affects interpersonal relationships and a schema that affects motivation. For example, it has been demonstrated that the insertion of Pope's grimaces as subliminal priming stimuli raises anxiety among Christians (Baldwin et al., 1990), showing the impact of relationship schema.

According to Przybylinski and Andersen (2015), stimuli that evoke significant others activate the knowledge structure shared with the others and cause confirmation behavior (Sect. 1.1.5.1). Predicting that a newly met person will be your friend if the person recalls a good friend, and if the person reminds you of a bully, predicting that person should be avoided. The prediction causes confirmatory communication and "confirmation bias" (Sect. 1.1.5.1) and results in the prediction occurring, the so-called self-fulfillment prophecy. The relationship schema works as if the important past relationships were transferred to new relationships.

1.4.7 Attitude

"Attitude" is a positive or negative cognition, emotion, or action for a specific object. If you feel that a particular brand of hamburger is delicious and you are satisfied, this indicates that you have an attitude toward that brand. In classical research, the effect of making the attitude consistent has been examined by balance theory (Sect. 3.4.2) and cognitive dissonance (e.g., smokers ignore health warnings that tobacco is harmful). However, attitudes measured by questionnaires (e.g., political support) cannot always predict actual behavior (e.g., voting). Therefore, the conditions for matching the behavior and attitude have been investigated in automatic and controlled processing (cf. Cacioppo et al., 1986).

Implicit Attitude

We are not aware of our genuine attitude. Therefore, research interest is directed to the implicit attitude hidden under consciousness. Implicit attitude is measured in a way that does not rely on language reporting. Especially developed by Greenwald, Nosek, and Banaji (2003), implicit association test (IAT) is famous. IAT is a test which consists of a category judgment on words and images (e.g., subjects are asked to make a judgment based on the categories shown on the left and right of the screen) (Fig. 1.16). In subjects with a strong link between the concepts of "young-good" and "aged-bad," if the words "young-bad" and "aged-good" are displayed in the same place, judgment is delayed. A series of studies using IAT (Gawronski & Bodenhausen, 2006) revealed there was a difference between implicit and explicit attitudes. In social cognitive research, simulation research using machine learning would be promising. Attitude studies are also being examined in relation with simulations and empirical data (e.g., Dalege et al., 2016).

Mere Exposure Effect

In an experiment to measure the likability of a face after looking at facial photographs, the likability was higher in the more frequently presented face (Zajonc, 1968). This phenomenon called "mere exposure effect" is explained by the perceptual fluency hypothesis. This implicates that the more frequently people see it, the easier it is to recognize. This is the effect of misattribution of the ease of recognition to favor (Sect. 1.4.2.2). The mere exposure effect indicates that we can not be aware of the cause of our true attitude.

Later, Zajonc observed the same result in subliminal perception and hypothesized that emotions could occur without intentional memorizing, and hence being cognition and emotion could occur separately. Although this idea is still controversial, if it is considered to correspond to fast and slow routes (Sect. 1.1.6.1), it can be a valid hypothesis.

Online Processing and Memory-Based Processing

Garcia-Marques, Santos, and Mackie (2006) conducted a time series analysis of attitudes and found that attitude stability is lower than expected. Petty, Torrmala, Pablo, and Jarvis (2006) showed that even after the attitude changed, the memories of the previous attitude remained and maintained an implicit influence. It is a state where there is an implicit conflict in the knowledge structure (Priester & Petty, 2001). Such a conflicting knowledge structure is not unusual. For example, a neutral word "red" can be associated with a positive image of "warmth and activity" or a negative image of "danger and fire" depending on the context. The attitude toward "red" can change according to the context.

Attitude stability depends on whether it is memory-based, based on one's memory, or online processing that faces the subject (Hastie & Park, 1986). Attitudes are more consistent with behavior when asked online (Bizer et al., 2006). In particular, once the attitude is expressed and then asked again, the initial attitude becomes extreme, even if the conflicting information is presented (Jern et al., 2014). But the memory-based attitude is inconsistent. Memory-based attitude is considered to be easily affected by the previous event and the emotional mood. Therefore, memories invoked by a questionnaire will be reconstructed under each circumstance. This process results in a low consistency of attitude (Fabrigar et al., 2006).

Associative Network Model of Emotion

In the relationship between cognition and emotion, Bower (1981) proposed emotion-network theory that assumed a link relationship similar to the semantic network (Fig. 1.13). The network model of emotion helps us intuitively understand the attitude. Figure 1.14 hows an example.

Emotions for a particular object vary due to automatic processing started by environmental cues. If it changes immediately depending on the situation, it is not an attitude. An "attitude" is when the link always causing positive or negative emotions is strengthened by episodes that generate strong emotions. Strengthening the link between disgusting emotions and the concept of Tokyo leads to an attitude of "I do not like Tokyo."

Even if we intend to think without emotion, emotions subconsciously affect attitude. If you have a subject with strong emotions, think about what kind of episode it is associated with it. Further, if you need to change your attitude, elaboration through verbalization of emotions may help to cut off automatically occurring

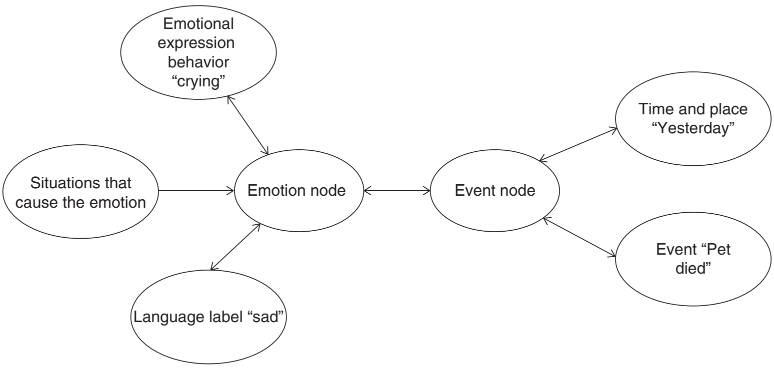
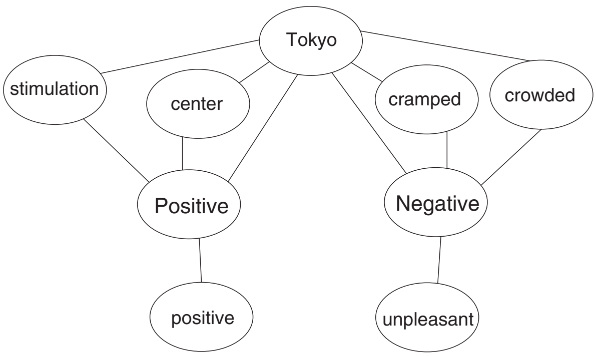


Fig. 1.13 Emotional network model (from Mori & Nakajo, 2005)

Fig. 1.14 Example of explanation of attitude by emotional network and semantic network



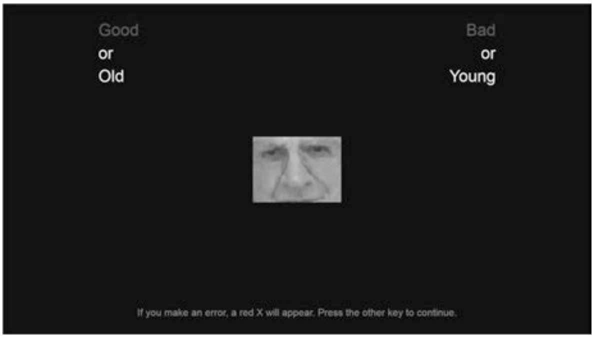


Fig. 1.15 IAT to measure prejudice against age (Nosek et al., 2007)
This is an image of a free program provided as an IAT (Nosek et al., 2007) that measures the strength of prejudice against age. When presented with a portrait of an older person or a youth, one decides whether it is a youth or an older person. On the other hand, when a word is shown, one determines whether it is a good word or a bad word. The test has about 10 facial photographs and words, which are presented randomly. This measures whether one has an implicit attitude of associating young with good or old with bad.

emotions. A phenomenon that supports the emotion network model is the "emotional Stroop effect" (Sect. 1.1.2) (Williams & Taormina, 1993). When a word that arouses emotion (e.g., "bullying") is displayed, and the character color is judged, the reaction is delayed compared to when a neutral word (e.g., "shelf") is displayed. It is thought that the greater the delay, the stronger the association with emotion. This implies that emotions affect as early as attention process.

Give it a Try

There is a site where you can easily study your implicit attitude (Fig. 1.15). Here you can measure your implicit attitude related to race, gender, body type, etc. Choose your favorite subject and experience it. You'll be surprised to discover a prejudice that you never realized you had. Even in a category where yourself are subject to prejudice, the effect of the acquired knowledge structure will appear. This test also shows the limits of psychological tests measured with questionnaires.

Most IAT pages require you to answer several questions and provide data first. If it's difficult, search for "Inquisit" and install a free 1-week trial. The Inquisit website offers a variety of free social psychology experiment programs.

1.5 Social Neurosciences

Psychology has changed with the progress of statistical science and cognitive science but is now strongly influenced by neuroscience. Physiopsychological studies use indicators such as EEG, stress hormones, and electromyograms. Furthermore, since the 2000s, brain imaging research such as fMRI has become widespread, and knowledge of global networks activated during various tasks has accumulated—a field called "cognitive neuroscience." "Social neuropsychology" is the application of these research methods to social cognitive tasks.

Many neurotransmitters and neurohormones are involved in emotional expression. Emotions are created by the interaction of numerous neurotransmitters, nervous system, and endocrine hormones, so it is difficult to determine the causal relationship. However, for example, it has been experimentally observed that cortisol and testosterone in saliva increase when males in the Southern United States are insulted, indicating that the amount of hormones secreted varies depending on conditions. Cortisol is a stress-related hormone, while testosterone is related to male aggressiveness. Dopamine (Sect. 1.4.4) and oxytocin are known as neurotransmitters involved in social behavior. Oxytocin is secreted in large quantities during childbirth and is thought to encourage mother-infant bonding.

1.5.1 Cognitive Neuroscience

Not all of the various cognitive models mentioned as models of cognitive psychology have been elucidated by neuroscience. For example, priming effects and false memories have mostly supported the presence of semantic networks and category concepts. However, mental models or schemas are models in cognitive psychology, in which the neuroscientific basis for their existence has not yet been clarified.

Cognitive neuroscience has shown that unconscious automatic processing (Sect. 1.1.6.1) exists as the subcortical route. The presence of the subcortical pathway introduces the possibility that the behavior of biocoenosis discussed in Chap. 3 may apply to humans (Sect. 3.3.1). In recent years, following the establishment of a neural network model, a novel model has been studied, in which a semantic network directly affects judgment without using concepts such as schemas (Bhatia, 2017).

1.5.2 Empathy

How do you feel when you see others being humiliated?

People sometimes share the same feeling by seeing such a sight. This is due to our high level of empathy.

There are antisocial human images such as psychopaths who lack empathy, but conversely it doesn't mean that people with high empathy will always help others. If a person synchronizes with the feelings of others seeking help, the person will avoid them and will fail to help.

Batson (2009) divided empathy into "cognitive empathy" and "emotional empathy."(Fig. 1.16) Cognitive empathy is via the cortical pathway, and emotional empathy is via the subcortical pathway (Eisenberg & Eggum, 2009). Emotional

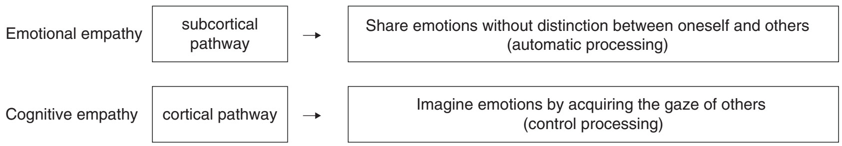


Fig. 1.16 Two pathways for empathy

empathy is one of the automatic processes that unconsciously mimic the mental state of the target person. People who experience moderate emotional empathy and with high cognitive sympathy are expected to have high aid capacity.

Embodied Cognition

Representations including physical movements are called "behavioral representations." It is one of the implicit memories that are automatically activated, such as when the behavioral representation of "grasping the doorknob" when a doorknob is visible is recalled. According to the perceptual symbol system theory, the environment and body reaction are simulated in the working memory at the moment the object is perceived (Fiske & Taylor, 2008) and occur just by looking at images and photos.

The simulation hypothesis explains why physical responses to perception are seen both in online processing (while performing tasks) and also in memory-based processing (recalling in one's mind) (Sect. 1.4.7.3). Perception-cognition-body response is linked in both directions; for example, when reading a comic book, holding a pencil in your mouth to contracting the smile-related facial muscles makes the reader feel more humorous. This is called "embodied cognition" (Strack et al., 1988) and is thought to be a phenomenon caused by the link between muscle reaction and cognition. A process in which the facial muscle reacts when perceiving the smile of another will unconsciously infect the emotion of others (Sect. 3.3.1).

Innateness of Empathy

Pfeifer and Dapretto (2009) mapped infants' perceived behaviors to their own behavioral representations and found that infants began mimicking within hours of birth. In monkeys, specific regions imitating others' actions have been identified, while in humans, several regions are assumed to be involved. Lieberman (2013) called this the mirror neuron system and considered it located near the working memory. Iacoboni (2008) considers the mirror neuron system to partially overlap the language field.

Suggesting humans are born with the ability to infer and share the intentions of others, the mirror neuron system is not activated by the unintentional actions of others. Around 2 years of age, humans acquire an objective viewpoint that differentiates themselves and others and avoids duplication of the self-perspective and others' views. This ability is the basis of the theory of mind (Baron-Cohen, 2008), which enables us to guess the reasons for other behavior.

Give it a Try: Rubber Hand Illusion

Neural circuits that create body mapping in the brain are formed over time; however, in online processing, they reform flexibly according to the environment. Although you can experience it using upside-down glasses, you will need some equipment, so let's do a rubber hand illusion that can be easily realized. You can see the procedure on YouTube videos, etc.

1. Participants with their arm inserted place the mannequin's hand on the cuffs of their jacket and place their own hand under the desk or in an invisible position.
2. Two experimenters tap the same place on the mannequin hand and the experiment participant's hand simultaneously. Tapping it to the rhythm of the music will work well.
3. Participants in the experiment stare only at the mannequin's hand.

It is a success if the participant gets the feeling that his or her hand position is confused. Through such a body illusion, a simulation of the body corresponding to perception is being performed. In my experiments, about 10% of participants had an illusion sensation. By introducing a VR system such as the Oculus Rift, the body placed in a virtual space can experience a sense of danger more vividly. Note, long-term immersion may risk the degeneration of your nervous system.

1.5.3 Self-Regulation and Brain

Are you spontaneously thinking about other topics while following the text of this book? I often find that after reading a few pages, I was thinking of something completely unrelated. But if you read here and returned to the book again, probably you noticed the content at being automatically processed.

Such a phenomenon is called "mind-wandering." It is a condition in which thinking does not remain focused on the task at hand but across another topic. Self-regulation (Sect. 1.4.3) is required to prevent mind-wandering. Self-regulation needs multiple abilities, such as control of attention, suppression or activation of behavior, and the ability to integrate planning and information. These abilities are related to the central executive function of the working memory in cognitive psychology and to the attention-related dopamine system frontal lobes in neuroscience. In recent years, the relationship with the default-mode network has become a hot topic.

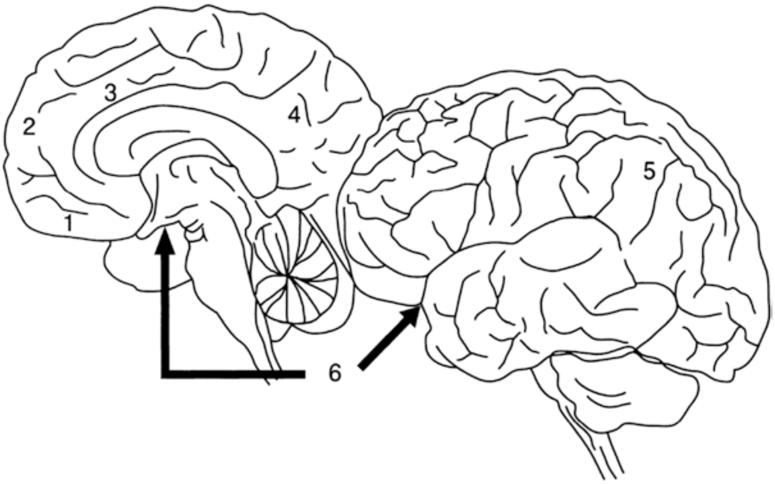


Fig. 1.17 Brain default mode network (modified from Immordino-Yang et al., 2012)
The DMN is composed of the following main regions. 1. Ventromedial frontal cortex, 2. Dorsolateral frontal cortex, 3. Anterior cingulate gyrus, 4. Posterior medial cortex, 5. Posterior cingulate cortex, 6. Hippocampus

1.5.4 Default-Mode Network

The default-mode network (DMN) is a large-scale brain network that activates at wakeful rest with closed eyes (Fig. 1.17). In brain imaging, the activation of the cingulate gyrus and frontal lobe is observed; meanwhile, EEG analysis observes slow remote brain synchronization δ wave (4 Hz or lower), especially in the 0.06–0.2 Hz band (Omura, 2013). Brain pathology has shown that amyloid deposition in Alzheimer's patients was observed in the default-mode network region. The default-mode network deactivates when attention is focused on some work, while it is activated when attention is departed, and the mind wandering (Sect. 1.5.3) begins. In depressed patients, the deactivation of the default-mode network is not observed even when the work is started, suggesting a problem with attention control. For this problem, certain effects have been recognized in mindfulness-based cognitive behavioral therapy (See Glossary G-6), which trains attention.

Nervous System Responsible for Social Cognition

Lieberman (2013) distinguished the nervous system responsible for interpersonal cognition from the mirror neuron system and the mentalizing system. The mentalizing system, which is activated at resting rather than working, is related to social cognition. For example, when we looking at another person's behavior, the mirror system responds to the question, "how did the person act?"; while the mentalizing system responds to the question, “why did the person act?” Lieberman supposed that thinking about social relationships is a default status for a human brain.

Social Exclusion

The Cyberball game task is a computer program that experiences “social exclusion” (bullying) (Williams et al., 2000). In this virtual ball-tossing game, only one of the three participants is ignored, and the ball is not passed (Fig. 1.18). Analyzing the brain image during this task, the responsible region for recognizing physical pain was activated. Isolation due to social exclusion not only impairs self-regulation ability and resilience (ability to recover from stress and adapt) but also directly affects physical conditions (Cacioppo & Patrick, 2008).

Lieberman (2013) suggests that regarding human empathy, processing differs for humans and inanimate objects. Even in inanimate objects, if they behave as if they have intentions (e.g., Fig. 1.12), they are processed in the same brain region used for recognizing humans. But there are reports that the brain function of processing as a human has stopped for homeless photographs. Occasionally, humans show

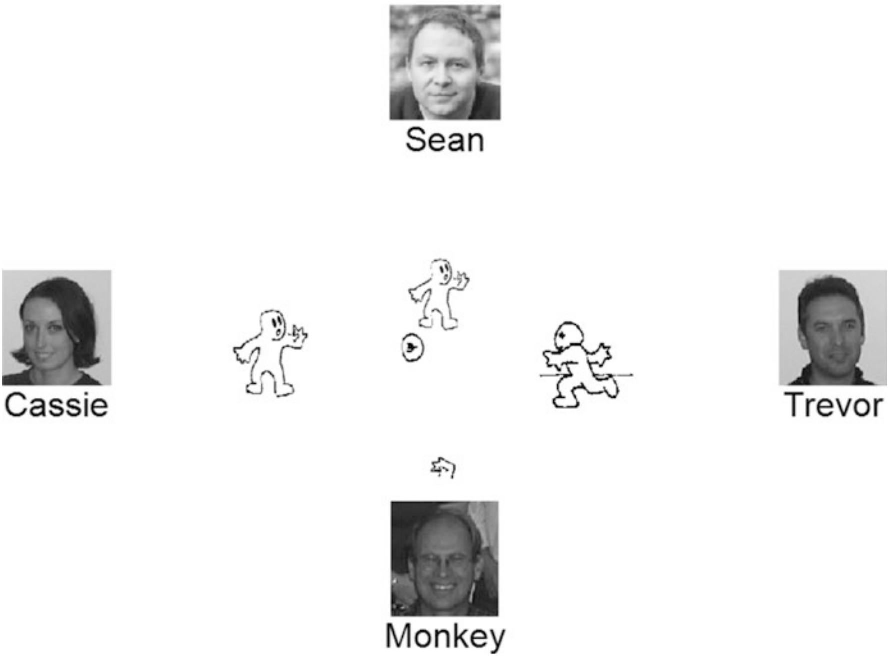


Fig. 1.18 Image provided by Inquisit program (Williams et.al, 2000, Williams & Jarvis, 2006). Monkey is a program simulating a participant, and the program runs the other members. Participants experience a situation where no one passes him the ball. Compare fMRI of the brain before and after that experience

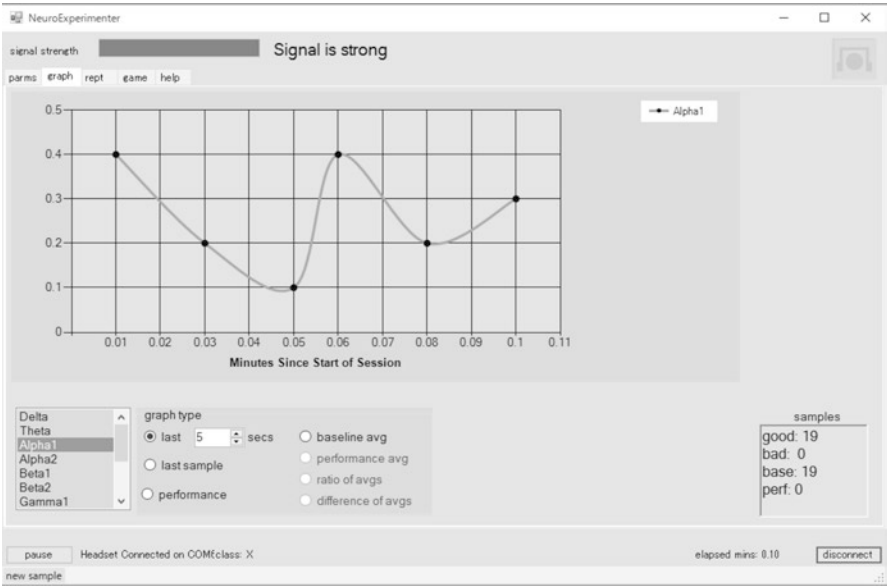


Fig. 1.19 Neuroexperimenter
Shows the display screen of the Mindwave software called "Neuroexperimenter." Since it performs the optimal t-test, you can easily compare the EEG of the work and rest conditions. This software is available at https://sites.google.com/site/fredm/neuroexperimenter.

aggressiveness to humans, such as genocide. In such a situation, the brain region related to empathy could have declined.

Give it a Try: "Mobile Electroencephalograph Device"

Currently, mainstream cognitive neuroscience uses diagnostic imaging using fMRI, and electroencephalography (EEG) in clinical settings such as epilepsy diagnosis (Fig. 1.19). However, they are all expensive and cannot be used easily. A mobile EEG device can be purchased for around $100. EEG has the advantage of high temporal resolution, and hence many apps have been developed for use as biofeedback and game consoles. Analysis software for researchers is also provided free, so simple experiments can be performed. Although it cannot be expected to be as precise as scientific papers, its use is recommended for educational purposes.

https://sites.google.com/site/fredm/neuroexperimenter

Experimental Example
Self-regulation ability can be inferred to some extent from brain waves. Generally, α waves decrease during cognitive tasks but increase during breaks between tasks. However, it is known that α waves are suppressed during a break after feedback on a poor task performance. This is presumed to be due to the continued emotional

response to failure. This phenomenon is called error-related α suppression. Compton et al. (2013) reported that participants who tended to have lower α-waves exhibited lower performance in the next tasks. Besides, they have pointed out the correlations of their tendency with stress hormone levels (cortisol) and depressive symptoms. I (Arima, 2017) applied this phenomenon in an educational program to compare the appearance patterns of α and β waves during mindfulness (See Glossary G-6) meditation after pleasant or unpleasant stimuli. Please refer to the paper for details on the results and methods.

1.6 Common Sense

In the one-time prisoner's dilemma, competition is a more rational choice, but in practice, many people will cooperate. This is thought to be the nature of humanity that has evolved with the group's cooperation.

But consider, however, that participants merely did not know how to behave. Participants are often confused because they lack understanding of their situation. Under an unusual situation where communication is prohibited, and there is no information other than the pay-off matrix, participants will be in a state of combinatorial explosion (See Glossary G-4-1) where a robot falls in; "Is it better to cooperate?" "Should we excite the game here according to the experimenter's intention?" "Shouldn't I think?" etc.

In game theory, all information should be given by the pay-off matrix, but in reality, when people do not know what to do, they search for rules in contexts beyond the pay-off matrix, and implicitly it is established. That is the "common sense" (Watts, 2011), "the power of the situation" in social psychology (Sect. 2.2.4).

Milgram experimented on a train to examine the relationship between invisible social rules and daily behavior; he let his students ask a stranger for their seat (Blass, 2004). Almost all of the people who are suddenly asked to give up their seats by unknown students gave up their seats. Considering seating to be a one-time game with strangers, asking to give up is strategically correct, but contrary to common sense. Milgram students who were forced to act insanely are reported to have experienced an intense emotional burden. Behavior against common sense created guilt in the students.

Common sense implies an "implicit interaction rule" (Sect. 4.6.1). Having a common sense in itself is adaptive. A robot without common sense (See Glossary G-4) cannot decide unless it is given a purpose in advance. With humans, the options embedded in the situations automatically activate appropriate schemas and scripts, so we can act according to familiar procedures without being concentrated. If we were always gathering information and making decisions as if in a foreign country, we will be exhausted. We can act because common sense (how other behave) provides rules. And when we come across situations that we can't handle with common sense, we try different options and try to understand patterns.

What kind of game do we live in during our life? To find it out, we are seeking rules that are shared with others while depositing unchanging rules in the subconscious. We are being driven to find new rules from changing situations.

1.7 Summary

In an airport where people pass by, we can move smoothly. This is possible because it is an automated process that works in the subconscious. When common sense predicts the right course, they move according to their own knowledge, but when the situation changes, they seek information to reach a decision. These cognitive functions enable appropriate information gathering and quick and adaptive behavior.

Because the human brain consumes enormous amounts of energy, it is impossible to process all surrounding information by the bottom up processing. Thus, the information is compressed and stored for quick processing. In cognitive psychology, the processing system has been examined as various models such as schema, category cognition, and mental model, and some of them have begun to be demonstrated in neuroscience.

Despite the recent accumulation of cognitive psychological knowledge, the definition of consciousness is still uncertain. There is a concept that the "society of mind," a network of modules that perform all kinds of automatic processing, creates awareness and another concept that there is a hierarchical structure such as a central execution system. In any case, most of the enormous activities are performed automatically, and only a small part goes into conscious processing. Our adaptive behavior is not necessarily genetically determined. Both genetic influence and cultural influence work behind the behavior of cooperating without taking the "noncooperation" strategy predicted by the Nash equilibrium (Sect. 1.3.1.1). Culture is one of the environmental factors created by human beings. As the culture changes, the fitness landscape (See Glossary G-7-3-5) also changes, so the criteria for what is intelligent will change accordingly.

If the criterion of intelligence is regarded as the speed of information processing, the ability to compress more knowledge is needed. This is the case for knowledge structures that compress and simplify details such as schemas. However, the speed of information processing does not always lead to wisdom. Most tasks that humans have to solve are complexity events (See Glossary G-7-1) that have not been mathematically solved. Solving such tasks requires the ability to recognize complicated things as complex. Because there is a limit of individual cognition, we must utilize the brain of another person as an external storage/information processing device. Therefore, the intelligence required is considered as not only the speed of information processing but also the complex knowledge structure with various viewpoints and the ability to share it with others.

The presence of others also creates human cognition and behavior as one of the environmental factors. Just as the imitation reflex appears shortly after birth, humans naturally have an ability to empathize with the emotions of others and imitate their behavior. Every human is born as a social being.

This ability causes unconscious conformity to the behavior of others. Since conformity occurs naturally, even your own goal-directed behavior that you recognize as intentional may have been influenced by someone. Others, who influence individual consciousness and behavior, are sources of our foolishness and our wisdom.

The next question is, how do we share the knowledge we need to live with others? To approach this answer, in the next chapter, I will introduce studies related to group processes, focusing on conformity in groups.

Chapter 2
Group Process

It is hard to explain exactly how an aircraft flies. However, for most this is not a concern because people trust the experience and knowledge humankind has accumulated. Also of little concern to people is how the toilet flushes. Our knowledge is full of gaps, but Sloman and Fernbach point out if someone knows, they can become the "knowledge illusion" (Sloman & Fernbach (2018). It would be surprising that such people lacking knowledge can run complex systems.

Unfortunately, groups of experts can also make mistakes. The Challenger project, which gathered NASA's best and brightest, overlooked the dangers of the project resulting in an accident. The Fukushima nuclear power plant in Japan suffered a meltdown due to power loss while claiming it was "99.99% safe."

The group process is a social psychological approach to examine the interactions within or among groups. Here, the main interest is to find emergent phenomena occurring only as a group which cannot be explained by the sum of individuals. This can be applied to the concept of collective intelligence. Groups can accomplish what people cannot do individually, and although the history of group process studies have emphasized that people can be stupid when in groups, how can this opposite phenomenon be integrated?

2.1 What Is a Group?

First, we need to clarify the differences between crowds, groups, and organizations. Kugihara (2011) defined people existing in a particular space sharing their attention as crowds, while people made up of individuals existing geographically distant and without sharing their attention was defined as a collective.

In collective intelligence research, the concept of the crowd is a collective which attention is not sharing; collective intelligence is also called "wisdom of crowd."

Y. Arima, *Psychology of Group and Collective Intelligence*,
https://doi.org/10.1007/978-3-030-84698-5_2

In this book, for simplicity, the term "crowd" is used for the horde of people, and the term "collective" is used for an abstract concept representing the aggregate of multiple elements. "Crowd" refers to the extent of the chain of influence through sensory organs, but its membership is unclear due to the free joining property.

Think about what a group is. Various requirements, such as interdependency and entitativity, have been considered in the definition of a group, yet this book takes into account the ideas of social identity theory (Sect. 2.3) and defines two or more people who share their group names as a group. In social identity theory, the sharing of knowledge of one's "own position" is the minimum requirement for the definition as a group, and communication is not necessarily required. If a person who watches a video streamed on the Internet thinks that he or she is a member of IS, it means that he is a member of the IS group.

2.1.1 Organization and Group

An organization is one form taken by a group. *APA Psychology Encyclopedia* (APA, 2007) defines an organization as "a structured entity consisting of various components that interact with each other to perform functions." Here, no distinction is made from a group other than the emphasis on being an entity.

However, there are apparent differences between groups and organizations. In fellow groups, roles and norms often change as members change. However, in organizations, the task performance ability should not change with the members. The minimum requirement for groups to be established is sharing the name of the group, while organizations need to share knowledge about role and task structures.

2.1.2 Cooperative Actions

Interactions within a group can be categorized into three categories: cooperate, coordinate, and collaborate. Interpretations of each term may differ in fields. Of the three terms, "cooperate" has the broadest meaning. "Coordinate" represents a behavioral concept, while "collaborate" represents coordination, with shared cognition (Table 2.1).

Table 2.1 Classification of cooperative actions

Cooperate	In interactions involving costs and rewords, the choice to obtain higher rewords than others is called competition, and the choice to increase mutual benefits is called cooperation.
Coordinate	Group members coordinating behavioral sequences to solve problems
Collaborate	Combining the knowledge, knowledge structure, and technology of group members to solve problems

To avoid confusion, this book will mainly use the term “cooperate” in the context of game theory and collaborate in the context of group problem-solving. Cooperative actions require shared cognition. Shared cognition is a concept shared with others. Here, the relationship among concepts, the knowledge structure (Sect. 1.1.4), is shared as well. In this book, when the latter is emphasized, it is called a shared knowledge structure.

Emergence Delivered from Cooperative Activities

The term emergence broadly means that the interaction between factors can create more than simple addition. In complex system science, it means that the interaction of multiple elements induces a phase transition (See Glossary G-7-1). In collective research, emergence means that a group performs better than the sum of its individual abilities. If emergence is observed through collaboration, collective intelligence at the group level has been brought. In social psychology research, few studies have shown groups to have emergence. Usually, collaborative outcomes are better than the individual average yet do not reach those of the best member in the group (Laughlin et al., 1998). In experiments using tasks with correct answers, Laughlin and Hollingshead (1995) showed that 82% of the group would reach the correct solutions if one individual achieved the correct answers. This result means that 18% of the groups failed to answer, even if one member grasps the correct answers for tasks having the correct answers being able to logically inferred. If no one found the correct answers, 98.4% of the groups remained incorrect. As these indicators show, the probability that emergence appeared in groups is only 1.6%, hence being almost by accident.

Whether a group can bring about emergence, in other words, whether a group can work beyond the best member, is a common theme in group process research and collective intelligence research.

Process Losses

Process losses refer to a group’s performance falling below the best member. Steiner (1972) suggested that three factors can promote process losses: coordination losses, diffusion of responsibility (social loafing), and the demonstrability of correct answers. Here, coordination losses refer to situations in which the opportunity to discuss and intervene is lost.

The causes of process loss depend on the tasks. Steiner (1972) categorized the group tasks into three categories, as shown in Table 2.2. In additive tasks and disjunctive tasks, individual responsibilities are prone to being diffused. In conjunctive tasks when unanimity is required, the lack of demonstrability causes process losses, because members find it hard to understand the correct answer.

Table 2.2 Task classification

Conjunctive task	The member with the worst performance restricts the performance of the group. Ex. - flow work that cannot be completed if someone's assembly work is delayed
Additive task	The total performance of each member determines the performance of the group. Ex. - Split up into group members and picking up and collecting garbage.
Disjunctive task	The task can be completed when the member with the best performance in the group finds the solution. Ex. - thinking about a solution to a puzzle or problem, etc.

Social Loafing and Social Facilitation

Social loafing (Latane et al., 1979) refers to the phenomenon that individuals' performance is reduced when working in groups compared to working alone. Even if the person is not aware of it, performances decline when they're working as members of groups. This phenomenon often occurs in tasks where individuals task is not distinguishable. Contrary, there is also a phenomenon that individual performance is improved by the presence of others—social facilitation.

For instance, the phenomenon of cyclists' performances improve under race conditions compared to cycling alone.

Not only do rewards determine whether social loafing or social facilitation occurs. Zajonc (1965) suggested that the presence of others improves individual performance in learned tasks, yet contrary, the performance decreases in unlearned tasks. This is because the nervousness of competing with or observed by others accelerates the response in learned behaviors while hindering the learning of unlearned behaviors. Similarly, positive mood promotes thinking via automatic processing such as heuristics (Sect. 1.1.5.2) while disturbs thinking via control processing that requires careful consideration.

Demonstrability of Correct Answers

Demonstrability of correct answers here is whether a member who found the correct answer can persuade other members. The more difficult it is to explain the correct answer, the less likely the group's performance will reach that of the best member. In such tasks, it is necessary to share the knowledge structure used in the process leading to the correct answer, such as mental models and heuristics (Stasson et al., 1991). In tasks that allow members to share their attention in their sight, such as the Tower of Hanoi (Sect. 1.1.5.3), correct answers will increase.

However, the performance of the group is not always lower than that of the best members. Laughlin et al. (2006) showed that a group of three exceeded the best member using a cryptographic task. Such emergence may successfully occur due to the difference in knowledge structure (Sect. 1.1.4) among members. Therefore, emergence can occur in tasks that require trying various combinations of information, tasks that require many trials and errors within a limited time, and tasks that require the integration of knowledge that exceeds the storage capacity of one person.

Differences in knowledge structure among members affect group performance in opposing directions, while it reduces the demonstrability of correct answers and degrades the group performance; contrarily, the emergence of a new combination of concepts may eventually improve the group performance.

2.1.3 Collaborative Memory

Collaborative memory (Clark & Stephenson, 1981) studies focus on identifying how an individual's memory capacity and accuracy of recall changes when they store memories (e.g., being memorization or recall and recognition) when part of a collaborative group. The storage capacity of a group should be increased with the sum of the number of members; thus, the comparison is made between the collaborative group and a nominal group.

Collaborative Inhibition

The collaborative group has the effect of stimulating each member's memories and therefore performs better than individuals in tasks such as associating words (Clark et al., 2000). This is due to the variety in the knowledge structure within the group, expanding the range of word association. However, the storage capacities of the collective group is reduced by about 70% compared to the nominal group (Clark et al., 1990). This reduction in memory by collaborative groups is called collaborative inhibition (Weldon et al., 2000). It is thought that collaborative inhibition is not caused by social loafing (Sect. 2.1.2.3), but is due to differences in knowledge structure within groups causing retrieval disruption of memory (Basden et al., 1997). This comes from the fact that retrieval strategies for recalling memories differ among individuals (Basden et al., 1997, 1998). Unless there are explicit clues, people make their own categorization of the words, and hence differences in the knowledge structure among members affect the cooperative process (Meudell et al., 1995). For example, if the word list category is one or two (such as the name of a flower and the name of an animal), the influence of collaborative inhibition is small. The more complex the knowledge structure required for the task, the harder it is for the group to share it.

The phenomena of collective inhibition and retrieve disruption indicates restrictions for collaborative groups when they are sharing a complex knowledge structure. A simple knowledge structure maximizes the storage capacity but decreases as the complexity increases.

Knowledge Structure Sharing Process

One way to measure the sharing of knowledge structures is to measure how similar the order of freely recalled words is among members (Cuc et al., 2006). Congleton and Rajaram (2014) used this technique to explore how groups share knowledge structures. They found that the more the group cooperated to encode, the more their memory and search structure overlapped. However, when each member recalled alone, the amount of recall tended to decrease for those who used the shared knowledge structure.

This experiment shows that knowledge structures can be shared through collaborative work. However, on the other hand, sharing a knowledge structure causes a phenomenon—whereby the total memory capacity decreases—hereinafter, this phenomenon is called the capacity-complexity trade-off in the collective.

Distributed Cognition

Distributed cognition is a broad concept that has been used mainly in educational psychology, yet in this book, it refers to the form of cognition that is established based on environment information, including others. In the case of insects, physical and chemical information are used by accumulating information in the environment through actions such as secretion of pheromones. Even if the object is made by humans, looking at the lever will naturally evoke behavioral representations (Sect. 1.5.2.1), such as "turning and pulling it." The knowledge accumulated on the Internet and the memories of others are also an environment in this sense. Distributed cognition—that is, the knowledge that others have—expands individual possible cognition and behavior.

Distributed cognition can also be a solution for collaborative inhibition (Sect. 2.1.3.1). Finlay et al. (Finlay et al., 2000) found that cooperation during encoding reduces collaborative inhibition during recall. This is because sharing the framework of knowledge enables mapping of each area of the knowledge structure to one's knowledge structure, even if the content is not shared. If a group has such a shared cognition of "memory about their own and other's knowledge areas," it will break through capacity-complexity trade-off; as a result, the group will obtain collective intelligence. Distributed cognition is necessary for the group to exert the emergence.

Group False Memory

Groups are superior to individual averages in memory accuracy (Tindale et al., 2001). This is because if even one member is aware of the correct answer, the decision rule (Sect. 4.2.2), this opinion will be adopted. Exceptionally, when using the word list having the high semantic association, as used in the DRM experiments (Sect. 1.1.3.2), groups may miss the error in the collaborative recall. When a group

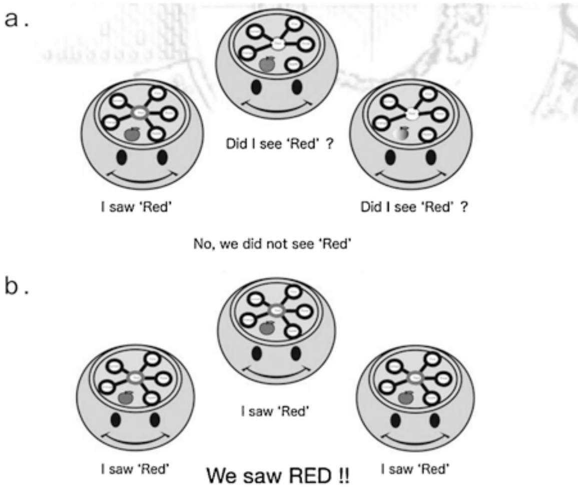


Fig. 2.1 False memory of the group
As shown in Fig. 2.1, if all members have a culture that associates "red" with apples, it is difficult to prevent false memories. However, if even one person who associates "green" with apples joins, they will be able to find mistakes and prevent false memories easily.
When the majority of people associate "green" with apples, the "red" lure word is hard to activate.
When all the members associate "red" with apples, the group cannot prevent misunderstanding.

collaborates on memorizing, false recalls are more likely to occur (Basden et al., 2002). In addition, hearing lure (trick) words from other members triggers false recognition within the group (Roediger III et al., 2001b).

Group false memory occurs when knowledge structures are well shared so that all members are unaware of their mistakes. Therefore, the amount of group false memory can indicate how much knowledge structure was shared (Fig. 2.1) (Arima, 2013; Arima et al., 2018).

Give it a Try: The Experiment for the Collective False Memory

After memorized the word list that induces false memory (e.g., Yukihiro et al., 2001) individually, let's measure recall in the order of "individual recognition" → " collaborative recognition" → "individual recognition." Will recalling the memory as a group increase or decrease false memory? Will the results change if the trial uses foreign language word lists?

2.2 Group Process Study

One of the achievements of the early group process studies is that it demonstrated that group decisions promoted individual attitude change. For example, when trying to change eating habits, group decisions are more effective than lectures alone (Lewin, 1953). The impact of such group decisions has been applied to training in organization development and group therapy for addiction. On the other hand, due to its high effectiveness, it has an adverse history, such as being used by cult religions and vicious traders.

In the 1970s and 1990s, there was a great deal of research comparing groups with individuals, yet since the 2000s, interest in group processes has gradually declined. As stated by the journal "Group Dynamics"—the analysis of the contents of published research articles—there were many studies on group counselling and group dynamics until 1997, yet now themes mainly focus on cognitive processes (Dennis et al., 2007).

2.2.1 Groupthink

How has the concept of "madness of the crowd" been formed in classical group studies?

A prominent groupthink study by Janis (1972) showed the foolishness of groups . It explored the pitfalls of group processes from historical cases where important group decisions have failed—e.g., the case studies of the Cuban crisis by Kennedy and the NASA committee discussing the safety of the Endeavor. In a highly motivated group led by influential leaders, an atmosphere that is difficult to disagree with is dominant.

Reconsideration of Groupthink

Gibson (2014) analyzed the recording of the meeting of President Kennedy during the invasion of Cuba. The analysis showed that he moved to a different topic, as though he had avoided discussion, despite others pointing out the difficulties of the invasion. The meeting record of the NASA Challenger accident also reported that the chair avoided in-depth discussion, despite reports of the possibility of the accident. Groupthink is one of an agenda failure; this "foolishness" is not always conscious. Both leaders and followers consciously or unconsciously focus their attention on the task-solving procedure, not noticing the importance of other information because understanding it requires cognitive resources. However, both scenarios could have been prevented if the leaders gave the group time to examine all the information. Groupthink is primarily driven by leadership. The next question is what is leadership?

2.2.2 *Leadership*

The foundation of experimental social psychology research was laid by Kurt Lewin, who fled the United States from Germany. The researchers' awareness at the time was how Nazi Germany could easily incite people to undertake genocide. Lewin, a Jew, did not attribute the reason to the character or national character of a particular individual but sought to interpret it as the "power of social situations" common to humankind. His fair and scientific approach reinforced this academic attitude in social psychology.

Previous leadership studies have attempted to capture the essence of leadership by following the footsteps of charismatic individuals in history. Lewin's research team (Lippit & White, 1943) used field experiments to show that changing the behavior of the same person could alter the mood and outcomes of the group. Since then, leadership can be described as an action that can be performed by anyone, rather than by one personality.

Leadership Research

The word leadership itself does not refer to the qualities and abilities of a particular person. Chemers and Ayman (1993) viewed leadership as a social influence process. Brown (1988) also defined that "one can influence others in a population more than is affected by others."

Bales and Slater (1955) examined the process of generating leaders from the first meeting of discussion groups and found that it is difficult for one person to be both a task-oriented leader and a relationship-oriented leader and that several people are responsible for each leader.

On the other hand, leadership scale development indicated that task orientation and human relationship orientation were independent factors for leaders. In line with this, a leadership two-factor theory (assuming the highest group performance under leaders with high relationship-oriented and task-oriented factors) was proposed. The approach tended to be somewhat simplified, so researchers gradually turned to study situational factors and cognition. The author found that for the one to have both relationship-oriented and task-oriented factors, he or she needs to plan (clarifying task and role structures) leadership (Arima, 1989).

In recent years, leaders have been required to combine strong top leadership that can flexibly change and allow the organization to adapt to the environment and servant leadership that mediates between the top and teams (Sect. 5.2.3). Diring this process, task-oriented leadership has been at the top, and relationship-oriented leadership has been divided into middle managers.

The source of the leader's power may be due to the abundance of resources (including abilities and information) that he or she can provide or may have been appointed by an authority. In any case, the leader's power is not the individual's resources or authority itself, but the consensus among members that the leader has the resources or authority. Ultimately, even a person who lacks abilities can exert a strong influence by merely sharing past histories and anecdotes. As the consensus of members changes, so does the leader's influence. In essence, leadership is not cognition or situation of an individual, but a shared cognition within a group.

2.2.3 Social Influence Process

A major factor that makes group decisions foolish is conformity, whereby people synchronize with the opinions of many without carefully reviewing the information. This is the image of the "foolishness" of groups.

The group of Lewin et al. conducted many experimental studies using small groups and found essential research topics such as leadership, intergroup conflicts, conformity, and networking. Among them, conformity has become the central subject of classical group research. Conformity refers to aligning one's judgment and actions to others. The premise of conformity here is that the individual attitude is not fixed as a consistent personal attitude and changes depending on informational circumstances. The effects that cause conformity are called social influence.

Social influence is divided into two types: normative influence and informational influence (Deutsch & Gerard, 1955).

Informational Influence

We will refer to the opinions of others when we can't find a correct answer, or for questions where the correct answer is determined by agreement. The influence occurring in such situations is informational influence.

Sherif's conformity experiment (1936) showed the existence of informational influence. Sherif used an illusion that when staring at a light spot in the dark, it looks like the light spot is moving due to eye movements. Subjects do not know that the light spot has not actually moved, but in the experimental room, the other participants report how many centimeters the light spot has moved. At first, the answers differed greatly between each subject, but as the task was repeated, the answers converged near the group average (Fig. 2.2).

In Sherif's experiment, even if the subjects were to answer alone after the group experiment, they continued to answer based on the average of the group. Even after one leaves the group, the lasting group's influence is called private acceptance, being a feature of informational influence. On the other hand, conformity that occurs only in the situation when one is in front of others is called public compliance, being a feature of normative influence.

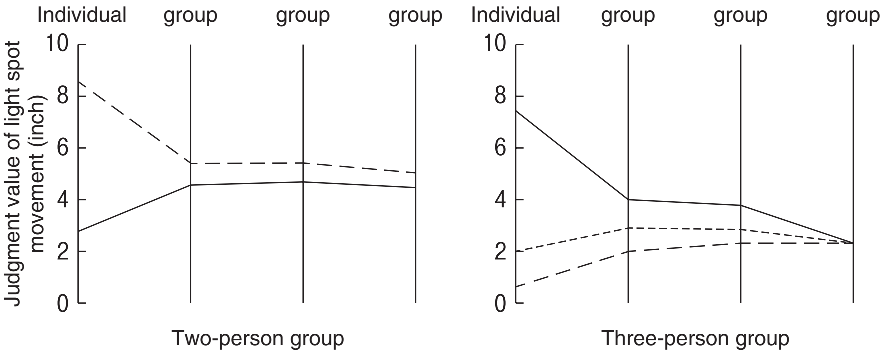


Fig. 2.2 Sherif's conformity experiment (Saito, 1987a)
(Each line shows the average judgment value by an individual)

Normative Influence

Normative influence is the influence that emerges with the aim for an individual to be accepted as a group member. Many of the norms that we follow are not particularly conscious (Sect. 3.1). This is another form of conformity, yet one can only notice the presence of a normative influence if one feels the need to break it.

A typical experiment that showed the existence of normative influence is the conformity experiment by Asch (1956). Here, seven participants answered a simple perceptual judgment task, i.e., comparing the lengths of three line segments. This experiment aimed to demonstrate how extent subjects can make their own decisions in the following situations: Six of the seven participants are experimental confederates, and the genuine experimental participant answers sixth. Experimental confederates agree and select the wrong answer in 12 of the 18 trials. As a result, more than 60% of the experiment participants followed the wrong answer at least once. Asch also noted that the effect of normative influence reached the ceiling effect in a four-group trial (Fig. 2.3).

The number of people who induce conformity in an individual is called the conformity threshold. Milgram asked experimental confederates to stand in the main street and look up and then measured pedestrians' conformity. In this experiment, the ceiling effect was reached in a trial with five confederates, and about 80% of people followed the confederates and looked up (Milgram et al., 1969). The threshold of conformity and the conforming rate vary depending on the situation, and the easier the demonstrability, the higher the conforming rate (MacCoun, 2012).

As in the case of Sherif's experiment, informational influence is defined operationally using tasks that do not have the correct answer. In contrast, normative influence is defined operationally as "following the wrong majority." The latter has given people the impression of "foolish groups," including groupthink, and has reminded people of social "foolishness," such as the bubble phenomenon. However, actually, bubbles occur in situations where the "correct answer" changes depending on the behaviors of others; thus, informational influence can also be a source of foolishness.

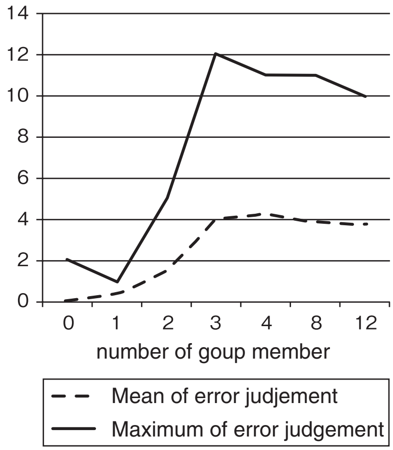


Fig. 2.3 Asch's conformity experiment (modified from Asch, 1951)
When the majority was three for one of the minority, a significant influence was shown, and the influence did not change even if the majority was further increased. However, if the number of minorities is two or more, the influence of the majority will weaken (2-2-5 influence of minorities).

Influence of Conformity on Memory

According to a study examining brain activity during an Asch-type experiment (conformity to incorrect visual judgment), when subjects conform to others, brain regions related to vision and spatial recognition were activated. When subjects were not followed, it was observed whose amygdala had been activated (representing an emotional load) (Berns et al., 2005). Based on these observations, conforming to the group behavior is thought to be a default state for our brain, and social exclusion (Sect. 1.5.4.2) causes physical and mental stress responses.

Conformity has also been shown to affect memory (Edelson et al., 2011). In this experiment, a group of five people watched a witness-type documentary, and 3 days later, they answered a memory test individually. Four days later, participants underwent a memory test while recording neural activity with fMRI. At this stage, a collective condition group and a control group were introduced. In the collective condition group, subjects were presented with false answers by four others during each memory test, and in the control group, no presentation was given. One week later, the subjects were told that the other's answers were fake, and then the memory tests were performed again.

As a result of the experiment, about 70% of participants followed the wrong answers of the majority (the rate of wrong answers in the control group was 15%). Approximately 60% of participants who followed the wrong answer returned a week later to the original correct answer, while 40% of participants remained with the other's answers. fMRI captured that the amygdala and the global network connecting the amygdala to the hippocampus had been activated in the subjects who changed their own answers.

This result indicates that some people recognize the answer was true even if they conformed to others' wrong answer for fear of social rejection. Although classical studies have suggested that Asch-type conforming experiments can only elicit public compliance, interestingly, neuroscience studies have shown that private acceptance can also be triggered. Conformity affects the implicit memory (Sect. 1.1.3.1), even the automatic processing.

2.2.4 Power of Social Situations

The conforming behavior study began with classical experiments (Deutsch & Gerard, 1955), followed by majority vs. minority studies in the 1970s, a discussion based on self-categorization theory (Sect. 2.3.2) in the 1980s, and has evolved to socially shared cognition since the 1990s (Sect. 2.4).

Even today, social psychological research is generally widely known as classical research. The reason is that classical research is not only easy to understand, but many people intuitively feel that the psychology of the group is involved in human deficiencies that cause bullying, war, etc. One of the most influential studies is the Stanford prison experiment.

Lucifer Effect

The Stanford prison experiment is a study in which university students were assigned to be either "guards" or "prisoners," to observe changes in behavior in a simulated prison situation. In recent years, Zimbardo has rewritten his report for the 1971 prison experiment, focusing on the Lucifer effect, and reported that personalities could vary in social situations (Zimbardo, 2007).

Before the experiment, Zimbardo performed authoritarianism, macabreism, and other personality tests on subjects and found that most of them did not relate to the behavior during the experiment. This was especially true for the guards who showed a dramatic change in personality, and here, there was no correlation between each score and their behavior.

There are many criticisms about this experiment. In particular, we should not overlook the effects of Zimbardo himself instructing guards as the prison director. Some of the students who participated in the experiment had pre-learned the techniques for guards to control. Therefore, some role actions of the guards were artificial. The prison experiment is an effect of the social situation created by Zimbardo's leadership.

Zimbardo thought that systems created situations. The system he means is a program sharing the ideology that determines good and evil. The guards give orders to the prisoners as part of role acting, yet if the prisoners resist, the guards will have to respond and escalate the forced actions. Even guards who are not willing to join them are bystanders.

Prisoners' resistance also does not have an effect, because they follow the context that the situation gave. The analysis of prisoners' conversations in prisons showed that 90% of prisoners' conversations were as prisoners. In addition, 85% of the ratings for fellow prisoners were negative, implying that the guard's perspective had divided and conquered prisoners via the internalization of the prisoners. There may be some evidence of bullying in organizations with strong behavioral restrictions, such as the military. The shared context removes the boundaries between the original self and the role, that is, the power of the situation created by the system.

2.2.5 Influence from the Minority

How can minorities resist the power of social situations? Moscovici et al. began to study the influence of minorities, arguing that if two or more minorities make flexible and consistent claims, they can overcome the pressure of the majority and have an innovative impact (Moscovici & Doise, 1994). The influence of the majority corresponds to the normative influence, whereas the power of the minority can exert the informational influence. It is unlikely that the impact of the minority will alter the public compliance behavior of the majority, but will affect private acceptance (Sect. 2.2.3.1). For example, in a cognitive task where participants answer the color category name (the correct answer is "blue"), if there are minorities who consistently mistakenly answer "green," the color categorization of the majority was slightly moved (Moscovici et al., 1969). However, it has been pointed out that this experiment is not reproducible.

The majority/minority experiment paradigm has two problems with its experimental procedures. One is that the experimental framework changes depending on the level of the group that places the minority. Doise (1986) claimed that Asch's experiment did not demonstrate the process of the influence of the majority, merely that of the minority. To put it simply, the experimental confederates prepared by Asch are the minorities who mistakenly judge the length. The majority that is interpreted as a minority by expanding the framework is called the local majority.

Asch's experiments showed that even if minorities are far from true, they can win if they occupy a majority position locally. The cult religion is a typical example. However, the influence of the local majority is weaker than that of the global majority (Sect. 2.4.1.1).

Another problem is that quantitative and qualitative factors cannot be separated in a research framework in which the majority and the minority conflict. The proportion of people in a group and the divergence of opinions are quantitative factors, while the labeling of majority/minority is a qualitative factor; thus, the latter does not necessarily correlate with the proportion of people. The silent majority may be labeled as a minority. Therefore, qualitative factors must be considered separately as categorization issues.

Give It a Try: NASA Tasks

NASA Tasks

To gain a deep understanding of group psychology, let's experience the group decision-making process. When trying to decide something in a group, it is rare to make linguistically rigorous decisions—such as a joint statement of a summit—and in many cases, we choose one of several options, to reach the decision. The case of decision in a group is called group decision-making. Many studies have reported trends in group decision-making.

One of the most famous tasks involved in group decision-making is NASA's task of choosing luggage to survive on the moon. Similar tasks are available for free online.

First, prepare some options; each participant will answer individually, and then discuss in groups of three to five people. It is a good idea to divide the requirements for completing a group decision into a unanimous consensus group and a majority decision group and compare them. After the group discussion, compare the average error within the groups, the error in group decisions, and the performance of the best member with the smallest error. In general, group decisions are closer to solutions than the average of individual decisions.

No one has ever been to space, yet while the group discusses, members feel like they're right about an opinion close to the solutions. This is because the knowledge structure determining the solutions is shared to some extent (Sect. 4.2.3). The unanimous consensus condition that sufficiently examines information is an easier approach to the solution, but even if a majority rule is applied, there is a high probability that a conclusion using the shared part of knowledge will be approximately obtained.

In other words, conformity pushes groups in the right direction unless the shared knowledge is wrong. This is one of the effects of collective intelligence.

2.3 Social Identity

Social identity (Tajfel & Turner, 1979) is a self-concept defined by the group to which it belongs. Group members need not be acquainted with each other, and all categories involved in one's self-concept are considered to be groups. Any characteristic that is important to oneself can also belong to the group—e.g., generation, gender, hometown, home school, and a favorite baseball team.

A group to which oneself belongs is called an in-group, while a group to which one does not belong is called an out-group. Here, categories run subconsciously as automatic cognitive processes (Sect. 1.1.4.3).

We acquire self-concept by dividing ourselves from others according to the developmental stages. Even if we grow up without being aware of gender, we come to know the existence of gender and gender categories. Also, if we grow up without knowledge of nationality and race, once we know that there are various countries in the world, the knowledge of being Japanese, for example, becomes an important self-concept. In this view, discovering oneself is equal to discovering others. In other words, encountering others increases knowledge about oneself and accumulates self-concepts as in multiple layers. The acquisition of the viewpoint of the self seen by others creates social identity.

2.3.1 Requirements for Group Formation

A theory has brought a new aspect to collective research. It showed that merely giving a fictitious name to a group would bring in-group favoritism. That is the minimal group experiment by Tajfel et al. (Billig & Tajfel, 1973; Tajfel & Turner, 1979). In-group favoritism means considering the in-group members to which they belong so that they can benefit each other.

Participants in this experiment were initially assigned to two groups by an easy task. Participants performed the decision-making task of distributing rewards to others without knowing who belonged to which group. As a result, in-group favoritism was observed that rewarded the in-group better than the out-group. Participants' behavior changed just because they were given an arbitrary group name without knowing the members.

In social identity theory, the requirement of group formation was regarded as an emotional factor that promotes self-esteem. In contrast, self-category theory emphasized cognitive factors (Turner et al., 1987).

2.3.2 Self-Categorization Theory

The categories in which an individual can belong to multiple categories include race, gender, and nationality. Which category to choose depends on the ease of recall of the category based on experience—accessibility (Sect. 1.1.3.4) (Bruner, 1957)—and fitness (Oakes et al., 1991). Therefore, one's cognition and behavior change depending on the prominent category at that time. For instance, even if someone is not conscious of being Japanese who is in Japan, it is easy to be aware of this if he or she goes abroad. Depending on the experience of each individual, some people are more conscious of race, while others are more conscious of gender, giving an individual difference in category cognition.

Category cognition has the effect of promoting the similarity of the in-group and highlighting the differences with the out-group.

Consequently, the member who maximizes the ratio of {difference among groups/difference within in-group becomes the prototype (Sect. 1.1.4.2), showing the characteristics of the group. The prototype influence is called referent informational influence. Turner proposed this as a theory integrating normative and informational influence (Turner et al., 1987).

For example, a scholar who visits an unfamiliar foreign academic conference is more likely to dress casually if he or she sees local scholars dressing casually. Conversely, if they look cool, he or she may behave similarly. This is conformity to the prototype. Prototypes for the category chosen in the context are the criteria for appropriate behavior.

2.3.3 Social Comparison Theory

Why does one try to form a self-concept by comparing the in-group and out-group? This is thought to clarify the relationship between the self and the surroundings and is called ambiguity reduction. This idea is derived from social comparison theory (Festinger, 1954).

The main points of the social comparison theory are as follows:

1. Assume a social-comparative drive to reduce the ambiguity of self-evaluation.
2. If a physical reality does not exist, perform self-evaluation based on social reality by comparing it with others.
3. Try to select similar people for comparison.

This can be seen in the following example: Tallness can be compared in reality, but there is no physical standard for proper clothing. So we will compare with others similar to ourselves, the same gender from the same generation. If everyone's clothing is entirely different, the standard scale will not be achieved, and self-assessment will become unstable; thereby, groups exert power to diminish differences within the group. This is the pressure on conformity. In-group excludes individuals with too different characteristics.

2.3.4 Optimal Distinctiveness Theory

A new trend begins when novelty is lost by many people having the same thing. Trends are driven by two desires: needs for conformity, a desire to be the same as the latest group, and needs for uniqueness, a desire to have something different from others.

The balance between these two opposing needs leads to cyclical change in trends. Previously, the cyclical change in the length of skirts has been observed. But now, it is not noticeable since the categories of clothing have been subdivided. Cyclical changes become prominent if the item is associated with social identity.

Optimal distinctiveness theory (Brewer & Gardner, 1996) is a theory that considers that social identity is formed at an equilibrium point between two opposing drivers, needs for conformity and needs for uniqueness. If either is too much or too little, it will attempt to restore equilibrium. In other words, we want to retrieve originality if we are labeled in a large group, yet conversely, if we are in a too-small group, we want to belong to a larger group. For individuals who feel that they are the majority in their own country, subdivided categories such as occupations are more critical; in contrast, for those who think that they are the minority, broader categories are becoming more important, e.g., nationality and gender.

2.3.5 Effect of Categorization

The self-categorization theory can reinterpret many findings. The effects of minority (David & Turner, 1999) and groupthink phenomena (Turner et al., 1992) have been shown to change the results by categorization operations. Abrams, Wetherell, Cochrane, Hogg, and Turner (1990) found that in order for a majority to exert social influence, it must be recognized by people as an in-group. Even a majority opinion will be rejected if people recognize it as an out-group opinion. A phenomenon in which people's attitudes often contradict behavior can also be explained in the salience of category (Hogg & Abrams, 1988).

Stereotype

A stereotype is a cognitive bias; whereby all members of a particular group look similar, and this causes a cognitive trait that accompanies categorization.

As everyone has experienced, it is easy to distinguish subtle differences in faces between individuals of the same race or age group, but it is difficult to do so between other races or people of different ages. This is called an out-group homogeneity effect.

Illusory Correlation

The tendency to impart a negative property to a minority population is called illusory correlation. When members of the two groups took various actions following instructions, unusual behaviors were more likely to be remembered in association with prominent minority categories. This is due to the illusory correlation. That is, here, a stereotype is formed predicting that "minority is more likely to behave unusually." Cognitive processes causing illusory correlation can also be described using connectionist models (Van Rooy et al., 2003).

When stereotypes are associated with emotions, they become attitudes (prejudice), and when they appear as actions, they become discriminatory. People tend to favor in-groups while discriminating out-groups.

Psychologists learn the assessment criteria for various personality types and mental illnesses. However, they are insufficient to understand complex psychological events. Those who study psychology should be aware of the risk of labeling themselves or others in categories. Even professionals cannot escape the bias running subconsciously. There is a risk that the flexible human mind is fixed by confirmatory communication.

2.4 Social Cognition

What does "group known information" mean? Not all members need to have information to be processed at the group level. However, it has been found that at least two people need to share information to get the attention of a group (Hinsz et al., 1997). In other words, social influence can only be exerted if two or more people have commonly shared knowledge (Sect. 2.2.5).

However, merely increasing the number of people does not increase the amount of knowledge of the group. Nickerson (1997) mathematically showed that, when randomly selected pairs have nonoverlapping knowledge with a certain probability, the amount of nonoverlapping knowledge hardly increases even if the number of people increases. What increases here is not the concept itself, but the link between the concepts. The odds of sharing a relationships link are even lower than the odds of sharing concepts.

Then, in fact, to what extent do we share knowledge structures? Horowitz and Turan (2008) examined individual differences and commonality of associative semantic memory within a group. Examining the degree of overlap in the list of features related to the concepts in order of importance revealed that the correlation between individuals was about 0.30. This overlap rate is large enough that the astronomical number of associative links will match. Still, how do we communicate when about 70% interpret differently from others?

2.4.1 Shared Knowledge Effect

The more information that can be gathered from the group members, the better the group can reach conclusions—but that is difficult. The group tends to focus on the information shared from the beginning, while it tends to be less aware of the importance of the information that has not been shared. This tendency is called the shared knowledge effect.

To confirm the effect of shared knowledge, use an experimental excise called a hidden profile, i.e., a puzzle task solved by combining information (Stasser & Stewart, 1992).

In this experiment, the subjects participate in a simulation meeting for recruitment. Subjects will be provided with a file of candidate profiles, which must be read and the most appropriate person selected. The file contains common information and information that varies from person to person. When subjects combine non-shared information into a selection criterion, it is possible to find another candidate that is more appropriate than a candidate based on shared information alone. That is, the decision differs depending on whether to use a disclosed profile (shared information) or a hidden profile (non-shared information) as a reference. The experiment showed that groups are less likely to notice hidden profiles.

Stasser and Titus's (1985)information sampling theory explains why the shared knowledge effect occurs.

When calculated from the odds of referring to information multiplied by the number of members, the more members sharing the same information and the longer the discussion, the easier it is for the group to talk about the shared information, it has been reported that the shorter the discussion time, the greater the shared knowledge effect (Larson et al., 1994). Besides, the same sharing knowledge effect can be achieved even if the group takes up the information at the same frequency. Therefore, other hypotheses are considered, e.g., the hypothesis that shared knowledge is perceived to be highly relevant (Winquist & Larson, 1998) or that members with shared knowledge are more likely to be accepted by others (Sargis & Larson, 2002).

Cognitive Centrality

Cognitive centrality is one of the social influences caused by sharing information. For example, if people learn by giving them two knowledge structures, an information paper recording evidence as a story and an information paper containing testimony for each witness, the more people with the same knowledge structure, the greater the impact. Kameda, Ohtsubo, and Takezawa (1997) demonstrated that cognitive majority (high knowledge sharing) and preference majority (many people make the same decision) are not the same. Members with high cognitive centrality having a lot of shared information were less likely to conform to the majority, even if they were a minority in the preference (Fig. 2.4). Therefore, the impact of the local majority (Sect. 2.2.5) is expected to be small compared to the normal majority.

Majority Bias

The difference in influence between the majority and the minority is called minority-majority asymmetry. This asymmetry is caused by the influence derived from the force of number or the influence derived from the amount of shared information. The former corresponds to the normative influence and the latter to the concept of informational influence (Sect. 2.2.3). In this book, the cognitive bias that gives weight to the information from the majority rather than the minority is simply referred to as the majority bias. The bias that gives weight to shared information is called the shared knowledge effect (Sect. 2.4.1).

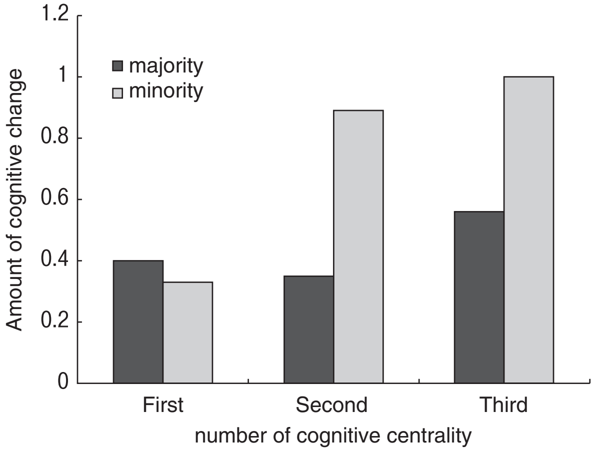


Fig. 2.4 Effect of cognitive centrality (Kameda et al., 1977)

Give it a Try: Shared Knowledge Effect

Experience the challenge of finding the right answer by combining information. You can use puzzles as well. The author (Arima, 2010) used a puzzle-type task in the mock jury trial created by Kohara (2013).

Let's include members who have a lot of shared information and members who have a lot of non-shared information in the discussion group and compare their remarks by text analysis (Sect. 5.4.5).

2.4.2 Cognitive Tuning

What would be the best place to meet up with a visiting foreigner? In such cases, we have to anticipate their knowledge and the tools available and choose a place they can find.

Although this sounds like a difficult problem, it has been shown experimentally that we can accurately predict other people's knowledge (Fussell & Krauss, 1992). We don't just predict. We try to exchange views and knowledge structures through communication.

When people are given stereotypes (prejudice) and given matching/unmatched information for conversation, confirmative communication (Sect. 1.1.5.1) occurs, whereby they confirm only the matching information (Ruscher et al., 2003). Besides, when one talks to a person having a negative attitude toward a third party, he or she tends to change in a direction having a negative attitude toward that person (Higgins, 1992). The latter effect is called cognitive tuning.

Attitude studies have shown the sleeper effect (Hovland & Weiss, 1951), of which effects emerge 1 month after the information is obtained.

The sleeper effect is the effect that even if one never believed the information, after forgetting the information source, only the content is associated with the existing memory structure, and the latent memory is partially affected.

A similar effect was seen with cognitive tuning, with a more significant change in attitude 2 weeks later than immediately after the experiment (Echterhoff et al., 2005). However, just trying to communicate does not have an effect, and actually telling others changes one's attitude.

In communication with others, even though the shared part of the knowledge structure is small, we can communicate by creating a model simulating the other person's knowledge structure in one's mind and modifying the model and feedback. The cognitive tuning effect indicates that traces of the modification work remain in our knowledge structures. We conduct conversations while exploring contexts that can be shared with the conversation partner and select the contents and tone of the statement. Even though it's a temporal conversation, it unconsciously affects our knowledge structures.

2.5 Attitude Change by Group Discussion

2.5.1 Risky Shift Experiments

The risky shift experiments have revealed that humans tend to make risky decisions when they form a group. Stoner (1968) showed that when people considered information in a group, they make higher-risk decisions than individual group members by themselves. Wallach, Kogan, and Bem (1962) showed that group decisions are about 10–20% riskier than individual decisions. These phenomena had shocked the United States, who put trust in group decisions in politics and trials; hence it had been actively studied. As an explanatory theory for this, a leadership theory was proposed in which individuals who are not afraid of risk are preferred as leaders.

However, through research on the risky shift phenomenon, it has been found that, depending on the topic of the debate, a cautious shift that shifts toward a more safer direction may occur (e.g., McCauley and Kramer, 1972). When examining each item of the choice in dilemma questionnaires used in the risky shift experiments, the cautious shift was observed in horse racing betting, marriage partner selection, etc. This shift is more likely to occur in any behavior that the general public sees value in a cautious choice.

2.5.2 Group Polarization Phenomenon

Moscovici and Zavalloni et al. (1969) showed that, regardless of topic, discussions in groups exaggerate individual attitudes. The questions in this experiment consisted of 12 items on political attitudes. Participants first responded individually to the questionnaires, then participated in a four-member discussion group, and debated until reaching unanimous agreement on each item. Participants were then asked to answer the same questionnaires individually, and the difference before and after the discussion (shift: attitude change) was calculated.

Even with topics that are not related to risk, group discussions can exaggerate initial attitudes. Moscovici has named this impact of group experience on overall attitudes as group polarization. Although social psychologists have experimented on this group polarization based on various hypotheses, despite the phenomenon being highly reproducible, the definitive explanation theory has not been unified yet. There are two influential explanation theories for this phenomenon: the hypothesis based on social comparison theory that attitudes change in a favorable direction through comparison with others and the informational influence theory that attitudes change in the direction of more information pooled in a group. Isenberg (1986) performed a meta-analysis of experiments based on these two hypotheses and found that the hypothesis of the informational effect was more explanatory. Experiments for decision-making theory (Stasson & Davis, 1989), which controlled the number of arguments and the number of positions, also found a stronger influence with the former hypothesis.

In the experimental procedure for the group polarization phenomenon, the subject's attitude was measured before and after the group discussion. A follow-up study revealed how long those attitudinal changes lasted (Liu & Latane, 1998). It was found that the polarized attitude returned to the initial attitude unless the attitude was repeatedly measured. It means that unless messages are sent constantly, such as via the media or as SNS, a polarized interaction will not last.

Polarization Brought by the Majority Rule

The majority rule (Sect. 4.4.1) can also be one of the factors causing the group polarization phenomenon at the social level (Davis et al., 1992; Kerr et al., 1975). Discussion groups selected from societies leaning slightly in the agreement are more likely to lean in agreement before the discussion. If people apply the majority rule to the group decision-making, even if the vote is "favorable" (six votes) vs. "unfavorable" (four votes), it will be represented as 1 vs. 0. Even if the difference in the number of votes of the two major parties is narrow, this decision procedure causes a large difference in the number of members.

However, according to the self-categorization theory, the direction in which the attitude changes depends on the direction of the group to which the attitude belongs, that is, the category manipulation (Turner et al., 1989; Hogg et al., 1990). Therefore, it cannot be explained only by the majority rule.

Influence of Shared Knowledge

Even at the individual level, people tend to become more extreme when asked again about their attitude (Sect. 1.4.7.3). The characteristic of the group polarization phenomenon is that the direction of polarization follows the average tendency of the population, not the individual's initial attitude.

Lamm and Myers et al. (1978) suggested that the mean of the population and not that of each subgroup determines the shift in direction of group polarization.

In actual cases, when political issues were discussed in a liberal-dominated era, the liberal group was polarized, while the conservative group—the local majority—was depolarized in the opposite direction (Myers & Bach, 1974). Here, the direction in which the average value of the population is initially inclined is called the initial average value trend. In the 1970s, the population was liberal, but nowadays, the liberal population may be the local majority.

Researchers cannot know the initial average trend in advance. Just as researchers discovered cautious shifts later, only by knowing the pre-discussion mean values can they know the direction of the shift. The same goes for experiment participants. Interestingly, however, the experiment shows that the participants behave as if they knew where the overall average was located.

The author considers the group polarization phenomenon to occur when people are trying to share contexts (Arima, 2012a, 2012b). People first attempt to share contexts that makes sense to each other, rather than discussing without knowing the contexts. Here, it is highly probable that the information people share in common is abundant in the population, and hence it might lead to group polarization.

Influence of Mean Tendency of Society

In Auther's experiment, when the mean value of a group was in the opposite direction to the initial mean value trend (e.g., the overall mean was in favor, while the mean value of the discussion members is opposite), the consensus probability of that group was low (Fig. 2.5). That is, the population affects a small group, even if small groups discuss individually.

The reason why the impact of the population appears may be that the information recalled during the discussion extends to implicit memory (Sect. 1.1.3.1). Before the discussion, even knowledge not in the members' minds is recalled by trigger information from others. As a result, the direction of the information that was more shared in the member's potential memory—the initial mean value trend of the population—affects the group direction. Here, if it conflicts with the direction of the mean value of each discussion group, it will be difficult to agree.

The degree of polarization in disagreement groups weakens (Stephenson & Brotherton, 1975), or it moves in the opposite direction (Arima, 2019 preprint). However, the overall variance remains constant before and after the discussion (Fig. 2.6) (Arima, 2012a, 2012b). It seems as if the "invisible hand" is working in public opinion change.

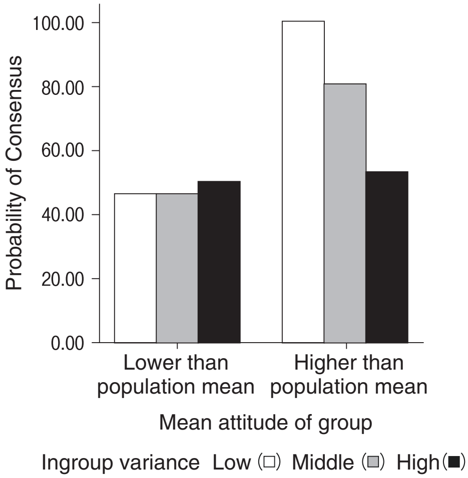


Fig. 2.5 Consensus probability within the group (Arima, 2012)
In the group where the average value of the small groups is consistent with the overall shift direction (right), the smaller the differences of opinion among the discussion members, the easier they are to agree. However, on the other hand, the group that is in the opposite direction to the overall shift of direction (left) has a low consensus probability regardless of variance in opinions inside.

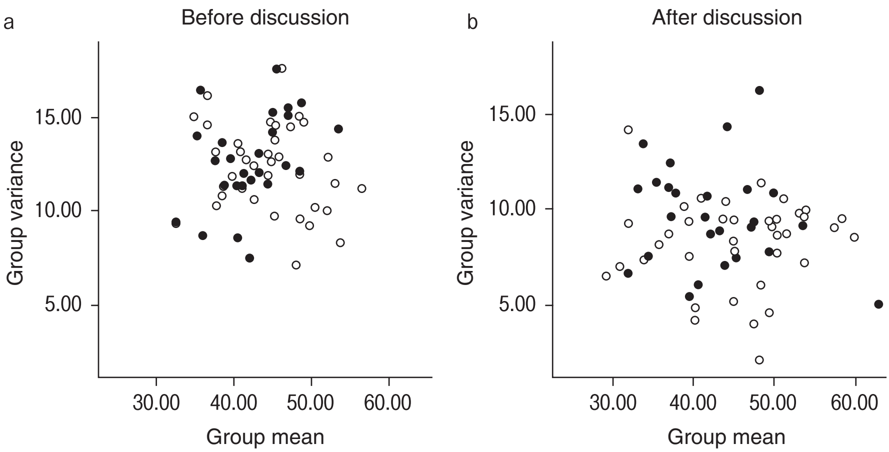


Fig. 2.6 Change in average variance before and after discussion (Arima. 2012)
The horizontal axis represents the average value of the discussion group, and the vertical axis represents the variance within the discussion group. A comparison between before and after the discussion revealed that regardless of whether the group reached an agreement (white circles) or not (black circles), the variance of opinions within the group (vertical axis) declined, but the variability of the mean between groups increased (expands along the horizontal axis). This shows that the overall opinion dispersal remains unchanged.

Reduced ambiguity trying to balance both differences and identity could be the driving force for this phenomenon.

Give it a Try: Group Polarization Phenomenon

The choice dilemma questionnaire (Wallach et al., 1962) instructs participants to advise those required to make some choices and then answer a questionnaire. For example, for a heart disease patient A, "How much of a chance of success would you need to recommend to have surgery?" Or for President B, "How much of a chance of success would you need to recommend investing in emerging countries?" For such questions, there are options from "I recommend it if there is a 10% chance of success" to "30%", "50%", "70%", and "90%", "no matter how high the probability is, I would never recommend". After answering 12 such questions, participants join a discussion group of about 4 to 6 people and discuss each issue until the decision is unanimous.

Case 1. Example of Items for Risky Shift Experiment.
A is thinking about marrying B.
A and B have a lot of fights and an on-again-off-again relationship.
You are A's friend group whom A consulted about marriage.
With what probability that A and B having a happy marriage, would you recommend A to marry B? Please answer with a chance of success as 0% to 100% (in 20% unit).

It has been thought that a marriage problem is likely to cause a cautious shift, but without the sharing of values in society, it will not shift. In Auther's recent experience, risky shifts can occur on marriage problem as well, because marriage may have become a risky behavior in Japan. Yet, such retrofit interpretation is a flaw in risky shift research. In the group polarization experiment, the hypothesis is confirmed by the mean score of each question before the discussion. Example 2 shows a representative form of the group polarization questionnaire. Generally, a plurality of such items is first provided. Then an axis indicating values are extracted by factor analysis, and then the average values of items are set as the initial average value tendency.

Create and compare the conditions that the group decides by majority vote and the conditions which they discuss until they reach unanimity. In the NASA task, the unanimous consensus condition has a positive effect on the group because members provided sufficient information and approach the correct answer. While in the group polarization phenomenon, the unanimous condition negatively affects the group such that the attitude of the group becomes extreme.

Case 2. Example of Items in a Group Polarization Experiment.
For the proposal, "Be cautious about accepting immigrants."
Answers are made in seven stages from "strongly disagree (1)" to "neutral (4)" to "strongly agree (7)".

In the group decision-making study, questionnaires are not implemented after discussion. On the other hand, in the group polarization study, individual answers are again asked after the discussion to measure the attitude change as private acceptance. In the latter case, the degree of group polarization is attenuated. In addition, when conducting it as a research, hierarchical analysis is required.

Belief polarization

Terrorism and polarization of public opinion come to mind as instances where the group process works negatively. Who is going to have extreme beliefs? Attitudes usually appear to be more extreme in minority groups, but this may be an illusory correlation (Sect. 2.3.5.2).

According to Brewer's optimal distinctiveness theory (Sect. 2.3.4), social identities become ambiguous if they belong to a large population, so people choose a group clarifying their identities. On the other hand, according to Festinger's social comparison theory (Festinger, 1954) (Sect. 2.3.3), the minority is vulnerable to division if there is a difference within the group because the minority is exposed to the threat of comparison with the majority. Therefore, it is predicted that the ambiguity of the self-concept, whether majority or minority, is likely to be extreme. The following studies provide instances.

Extremes of Political Beliefs

Extreme political beliefs, such as the US Tea Party movement, which were initially ruled out as a minority, gradually influenced Republicans. What conditions determine whether extreme members are excluded as outsiders or recognized as members of the same group?

Gaffney, Rast III, Hackett, and Hogg (2014) experimented with answering this question. They had the subject, a Republican supporter, read a Tea Party speech. The content of the speech was set to include intergroup conditions for the Democratic Party (out-group) and intragroup conditions for the Republican Party (in-group). In addition, ambiguity was manipulated by "conditions making them think about events that they were convinced of in life" and "conditions making them think of events that they lost their conviction for."

This experiment revealed that, with increasing ambiguity, people tended to support extreme opinions only in the message directed to out-groups. This indicates that those who are not convinced of their judgment support extreme opinions toward the outside group while excluding those toward the inside group.

Self-efficacy also affects the process of extreme behavior, such as terrorism (Tausch et al., 2011). People with high self-efficacy who believe that their actions can change society take normative protests like demonstrations. However, conversely, lower self-efficacy and higher emotional responses tend to lead to antinormative behaviors such as terrorism.

2.6 Summary

There are various losses in the process of working together as a group. On the other hand, even individuals with limited knowledge can operate complex systems using information obtained from the environment and others. What makes this possible is the ability to establish cognitive cognition with others, which is based on automatic processing that works subliminally, as seen in Chap. 1.

Automatic processing does not always work adaptively. The ability to compress vast amounts of information to reduce cognitive load is also a source of prejudice. Groups also communicate quickly and pay attention to shared information, yet because of their wisdom, they make various errors.

While differences in the knowledge structure within a group could decline their performance by making it difficult to share the mental model, the emergence of a new collaboration could improve it. However, it is difficult to reach the latter situation because of a trade-off between the memory capacity and the complexity of the shareable knowledge structure that the group can share.

Groups try to build a context for conversation around shared information. Here, they show a high degree of predictive ability to match the knowledge structure of others according to the situation, while the shared knowledge effect (Sect. 2.4.1) and cognitive tuning (Sect. 2.4.2) cause cognitive bias. This cognitive bias is amplified by being shared among people (Kerr, MacCoun, & Kramer, 1996). The shared knowledge structure determines the direction of extremes.

Since collective intelligence itself is a position represented by an average value, it rarely becomes extreme from the initial answer distribution. However, if the group is placed in an environment that repeatedly uses specific information, the average value will move. The group process can be said to be the engine driving public opinion change.

The next section describes the process by which conformity expands into a crowd.

Chapter 3
Collective Behavior

People walking on the boulevard seem to move individually, but they move according to the information embedded in the environment—architecture—the social information of surrounding movements, and their personal purposes. Even if the crowd flows intersect, few people fall or bump, and the crowd adjusts its behavior unconsciously and moves smoothly on. “Fluctuations” are always occurring, such as cars ignoring confirmation at intersections and pedestrians ignoring traffic lights, but in most cases, their coordination works well, and they can cross the intersection with ease. Therefore, if an accident occurs, people are shocked, pay attention, and investigate the cause. Why do people place trust in each other’s judgment? This chapter describes how collective intelligence develops in groups.

3.1 Flock Behavior

The crowd has no known role structure and no shared knowledge. However, some structures are present and maintained in groups.

For example, when riding an escalator, local rules such as standing on the right and standing on the left are established. People may first just follow the person standing on the right or left side with a certain probability, but they gradually begin to take learned actions, and the tendency is fixed. This is an unintentionally occurring collective intelligence to avoid confusion. But people can sometimes create problematic structures. A traffic jam is one instance. Even if the cars that are part of the traffic jam move one after another, the movement in the opposite direction is maintained as a lump of cars. Reading the “purpose” in this flock, the intelligence depends on the judgment of the person viewing it from the outside.

Swarm intelligence attracted early attention in biology such as insect studies using ants or studies of slime molds. Biology treats the term intelligence with caution and avoids the term collective intelligence and instead refers to this as

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collective behavior (Gordon, 2015). It is expected that some knowledge of biological communities could be applied to the collective intelligence of humans.

3.1.1 Flock Movement

Birds can act as a flock without a leader. Even if the head of a migratory bird that flies in a V shape falls off, a substitute bird automatically flies at the head. But how do birds find their way without a leader?

Figure 3.1 is an instance of a program called void that simulates the movement of a flock of birds. You can fly around obstacles using a simple program. The simulation does not perfectly reproduce the internal rules of the animals, but it helps to understand the actual movement of the animals (See Glossary G-7-3-3). These findings have also been applied to movement in computer graphics (Thalmann & Musse, 2007).

Void's basic algorithm consists of two components: "repulsion to keep a certain distance between nearby individuals and obstacles" and "incentive to follow the nearby individuals or the center of groups."

Each bird has a limited perception range, and each individual causes an information cascade (Sect. 3.4.5) by moving in quick succession, which enables swift flock movement. The addition of angular and network information to the perceptible range of variables brings the simulation to life. For instance, Harpaz and Schneidman (2014) measured the movement of a zebrafish school and examined which of the options of the distance model, the topology model, and the vector model or a

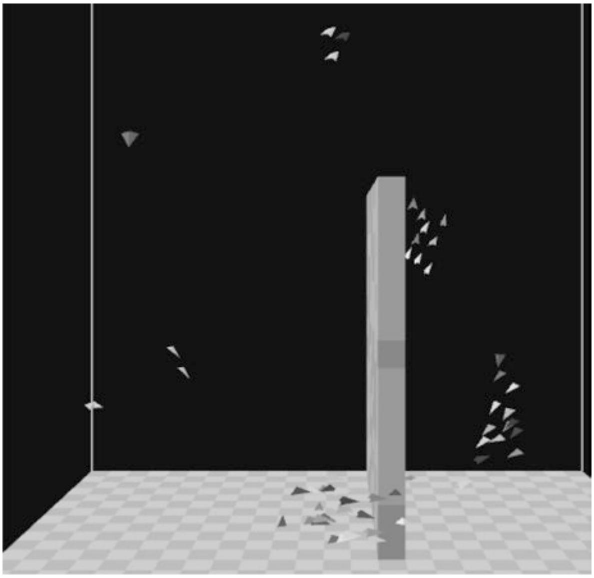


Fig. 3.1 Simulation by NetLogo
You can program a flock of birds that fly around avoiding obstacles (Wilensky, 1998)

combination of the two fits best. As a result, they reported that the vector model was the best reproduction of the actual fish school movement.

3.1.2 Environmental and Social Information

There are a variety of definitions of intelligence, but in this chapter, we consider it to be the information processing necessary to adapt to changing environments (e.g., actions such as avoiding predators and finding food). The advantage of flocks is obtained when watching predators or searching in a situation where the feeding ground changes randomly. It is obviously not "intelligent" that the flocks go around the same place forever and just waste energy.

If the group behavior has a higher survival rate over moving individually, it can be said that collective intelligence has appeared in the group. Collective intelligence requires both information obtained from the environment and information obtained from surrounding individuals (motion, voice, gaze direction, etc.). The former is called environmental information, and the latter is called social information.

Setting the perceptual range of social information and adjusting the degree of conformity changes collective behavior. Berdahl, Torney, Ioannou, Faria, and Couzin (2013) observed a school of fish that favors dark places and found that the school of fish in bright places moves faster, creating a school-wide turning movement. In other words, environmental information can affect the responsiveness to social information. The larger the size of the group, the more the environment can be sensed, and the more accurate the movement of the group. This brings collective intelligence as a group.

3.1.3 Group Conformity

Whether individuals will survive following a group depends on the severity of the environment. Pratt (2014) found that insects that prefer a darker nest out of three nests perform better in crowd movements than in average individual movements if there is a subtle difference in darkness. However, when the difference was clear, the individual average performed better. This result indicates that if each individual can obtain sufficient information from the environment, it is better to decide as the individual rather than following the group.

If one could obtain information not only from nearby individuals but also from the whole group, one can grasp a wider range of situations. In other words, under the condition of full cooperation (where all information can be shared), the probability of survival increases (Karpas & Schneidman, 2014). If one individual (leader) has a strong influence, it is easy to share the information throughout the group. However, if members gather too much, a wide area cannot be searched. Then, under what circumstances is the presence of a leader adaptive?

Krause (2014) has examined fish "leadership." Krause simulated two routes for model fish, one with food and one with predators, and observed group determination without a leader. In this situation, the larger the group size, the more accurate the group judgment, but it requires prior feedback learning. Besides, Krause experimented by making the fish follow a robot fish reader. The experiment revealed that fish flocks follow the robot fish leader when the food location is unknown. That is, in cases where it is difficult to get information from the environment, the group needs a leader. However, if an individual happens to be at the front, and the group follows him or her, they may move to dangerous places with many predators. Group intelligence requires more than randomness, and the process is suggested by swarm intelligence.

3.2 Group Intelligence

Ants and bees can create complex structures without leaders, despite the limited intelligence and perceptual range of each individual. What makes this possible?

3.2.1 Swarm Intelligence

The most prominent example of swarm intelligence is that of ants. They can create a complex social division of labor, even though the information processing capacity of each individual is small. The key here is the ability to build structures and store information in the environment.

3.2.2 Example of Swarm Intelligence

The food of ants is dispersed in the environment. Here, the ants have to take foods to the nest before competitors find it. The optimal solution to this challenging task can be reproduced by simulation (Fig. 3.2). Ants drop their pheromones on their way back to their nests. The increasing number of ants that follow the pheromone causes the pheromone to accumulate (positive feedback (Sect. 3.4.3)), which eventually becomes a path. As the pheromone evaporates over a period of time (negative feedback)as they exhaust their food, the road disappears.

The advantage of this solution is that slight fluctuations in the pheromone concentration cause positive feedback to start first, and then negative feedback to start with a time delay. As a result, it is possible to determine a specific location from similar feeding grounds, and individuals can efficiently collect fresh food without wasteful dispersion. The linearly increasing/decreasing information of the pheromone concentration translates into a nonlinear decision of the choice of feeding

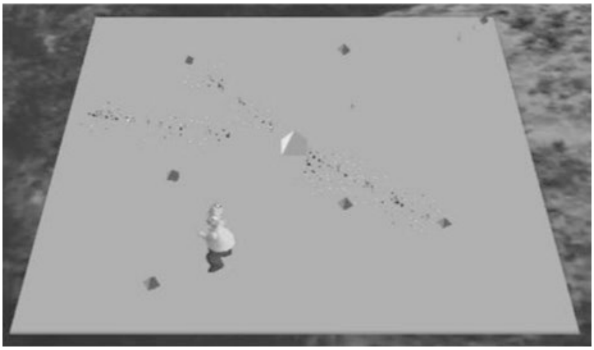


Fig. 3.2 Simulation of food-collecting behavior of ants by StarLogo

grounds. Linear means adding/subtracting gradually, and nonlinear means taking two values, yes/no. Ants efficiently solve the problem using the above way, which is challenging to represent with mathematical formulas.

Give it a Try: "StarLogo"

The best way to understand swarm intelligence, such as collecting ant food, is to experience a simple program and its output. MIT provides StarLogo, a multi-agent software for kids.

NetLogo (Sect. 1.2.1) has multiple functions, but StarLogo is suitable for students who are new to programming and want to learn multi-agent simulation (Klopfer, et,al, 2009). You can get free educational materials here and draw simple graphs.

3.2.3 Combined Decisions

Honey bees are also famous for creating beautiful nests. Honeybees collectively decide where to move when a herd becomes so large that it must move its nest (Miller, 2010). Let's see the procedure. First, a reconnaissance bee finds a candidate to move to, returns to the nest, dances, and informs the companions of the location. The better the place the bees find, the longer it will dance.

Although the judgment differs depending on the individual, as the search is repeated, increasing numbers of honey bees dancing show the same place. In social insect swarm decision-making, the reaction switches from linear to nonlinear through three steps (Table 3.1) (Miller, 2010).

Sympathizers gradually gather the information obtained from the search, and when that ratio exceeds a certain level, the decision-making is urged. These processes enable group decisions to be made based on the fewest differences. This is called collective decision-making.

Table 3.1 Linear-nonlinear transformation process

1. Distributed search phase.	Search and collect information
2. Aggregation phase.	Aggregate information
3. Decision phase.	Threshold reaction

Collective decision-making is observed in the behavior of a herd of primates: a voice that responds to a cry that someone is alerting becomes louder, and when the threshold is exceeded, the herd changes to a moving behavior. Is such conforming found in modern humans?

3.2.4 Human Crowd Behavior

In the past (Tarde, 1901; Le Bon, 1905), psychologists have regarded crowds as if they generate different intentions due to emotional and behavioral contagions. On the other hand, modern social psychology states that a unified consciousness in the collective situation cannot be assumed (Kameda et al., 1997; Kugihara, 2011).

Anonymity (inability to identify individuals) was thought to be the cause of aggressiveness of the crowd. The deindividuation theory has shown that increasing anonymity in collective situations reduces the suppression of social norms (Zimbardo, 1969). However, anonymity does not necessarily promote aggression. Emotional and environmental cues can also facilitate helping behavior.

Movement of Human Crowd

The movement of human crowds is also studied by observation, experiments, simulations, etc. A study in which some people were given directions before others revealed that crowd could move together when the number of information holders is 5% or less, for example, providing directions to only 10 of the 200 people in one place and instructing the rest of the people not to leave the crowd. When some people start moving, people are quickly guided in the direction indicated. Even though 2% of people move at the same time, it caused a cascade (Boos et al., 2014). People with higher network densities (more people nearby) have more influence over others (Leonard, 2014).

It was assumed by such a crowd flow study that people do not recognize the norms of the situation. The unconscious conformity to others and emotions within the perceivable range gives rise to crowd behavior. The phenomenon called contagion is one such unconscious conformity.

3.3 Conformity and Contagion

As mentioned in Chap. 2, at the time when classical studies of conformity were being conducted, the concept of automatic processing was not yet general. Hence, the researchers did not presume that conformity or contagion could occur unconsciously. The unconscious conformity is called mimicry, or emotional contagion. The human crowd brought together by emotional contagion may remind us of Le Bon's view of humans.

3.3.1 Emotional Contagion

Crowds tend to have the same emotional reactions. In conversations in which one wouldn't laugh alone, it may become easier to laugh together if there are frequent laughs around them.

That's why laughter is set up in TV shows. If the screams of fear rise from the surroundings, peoples will be appalled, even if they don't know why. Why are emotions transmitted? One of the explanations for this is emotional contagion (Neumann & Strack, 2000). Here, the mirror neurons (Sect. 1.5.2.2) that are activated by observing the actions of others and the nerve system that links perception and action in the premotor cortex when looking at the action target (Sect. 1.5.2.1) both become activated. These two neural networks initiate an automatic process that captures the behavior of others as their own experience, causing emotional contagion.

Process of Emotional Contagion

Hatfield, Rapson, and Le (2009) organized the mechanism of emotional contagion as follows (Table 3.2). Imitation of the first step is rapid and subtle. The posture is imitated as a slight movement within 21 ms. This rapidity is proof that it is an automatic process that has not reached conscious processing. Imitation can also be seen in the speed of speaking, the duration of speech, and the reaction time. In the second step, the mimicked tone of the muscle retrogrades the neural pathway. In the third step, emotional contagion is triggered.

Carter, Harris, and Porges (2009) considered mimicry to be an innate ability because emotional contagion is also found in social primates such as bonobos and

Table 3.2 Emotional contagion

First step	Automatic imitation of others' facial expressions, voices, postures, etc.
Second step	Self-feedback of changes in facial muscles, voice, posture, etc.
Third step	The spread of contagion that instantly catches the emotions of others and conveys them to the next person

chimpanzees. Besides, reaction to pain and fear is seen from the earliest stage of evolution. Emotional contagion uses the same neural base as the perception of distress, so it is easier to automatically activate distress among emotions. Ickes (2009) found that the physiological conformity with the target person was related to the accuracy with which negative emotions were estimated. This is due to the neural circuits we acquired during the evolution from reptiles to mammals because it was an adaptive response to quickly prepare in response to the pain of other individuals.

3.3.2 Behavioral Contagion

Behavioral contagion is called mimicry, and the appearance of mimicry synchronizing to others is also called behavior synchrony or chameleon effect (Dalton et al., 2010).

Unconscious mimicry cannot be recognized by the person who imitates or who is imitated. Imitation is the default; thus if one controls their actions to not imitate, he or she will give a negative impression to others. Maurer and Tindall (1983) found that a counsellor's behavior of synchronizing arm and leg positions with the client significantly elevated the client's evaluation of empathy. This finding indicates that the non-mimicked control group gives a poor impression. In the brains of participants whose facial expressions were out of sync with their emotions, activation of the brain regions that indicated that unexpected events that had occurred was observed. Recently, synchronization of EEG between interacting humans has been reported. Ohira (2017) considered this as a synchronization phenomenon in complex networks.

The reliability of the cognitive empathy score on the questionnaire is not consistent. While there is a report that activation of the amygdala did not correlate (Pfeifer & Dapretto, 2009), there is also a report that cognitive empathy scores were associated with the synchrony of pupil dilation (Kang & Wheatley, 2017). There is a limit to grasping the subconscious process with a questionnaire, and an experiment is necessary.

Social Factors Affecting Behavioral Contagion

The degree to which imitation occurs depends on the companion. Gueguen and Martin (2009) compared the frequency of imitating facial touching between the conditions in which the first name of a person in the video happened to be the same as participant and the conditions in which the name was different. As a result, they reported a significant increase in imitation under the same first name conditions.

Using a virtual space, Shteynberg, Hirsh, Galinsky, and Knight (2014) have additionally examined the results of a study (Bayliss et al., 2007), in which the evaluation of person B, who is looking at person A, affects the facial expressions of participants: pleasant or unpleasant (Sect. 2.4.2). This virtual experiment revealed that as the similarity between A and the subject's own avatar increases, the facial expression of A influences the subject's evaluation of B.

The cyber ball task on computers (Sect. 1.5.4.2) also revealed that the experience of social exclusion increases the imitation of facial muscles in subjects (Kawamoto et al., 2014). These findings indicate that fears of social exclusion also influence behavioral contagion.

The responsiveness of behavioral contagion, which is one of the automatic processing, can change depending on social situations.

Emergent Norm Approach

The emergent norm approach is the idea that "collective behavior follows the norms that emerge in a situation" (Turner & Killian, 1972; Tanaka & Tsuchiya, 2003).

People's recognition of certain norms based on situations is reflected in our daily activities, such as waiting in line. In other words, crowd behavior is an extension of daily behavior. The idea of the emergent norm approach is that the crowd immediately forms the norm by surrounding cues. In situations where attention is shared within the crowd, such as in a concert audience, the situation is quickly defined, and the actions of other members guide them. For one instance, symbols such as applause are selected, and the crowd shares one interpretation.

The social identity theory (Sect. 2.3) also states that the crowd can be aggressive or supportive, depending on the identity created in the scene. However, it is not clear how certain clues are chosen or why certain norms and identities are shared. In a situation where "common sense" (Sect. 1.6) on how to behave is shared in advance (e.g., applause for an encore in a concert hall), the process of crowd synchronization can be expressed by a network model using sound feedback as a clue. The speed at which the collective action outbreaks to the whole depends on the network structure. In the case of applause, it is close to the state where the network link is wholly added over a wide area. Next, let me explain the basic concept of network science.

Give it a Try

In a hall such as a theatre, the time required to spread laughter and applause hardly changes even if the size of the hall is different. Like the encore in the concert hall, let's try to match rhythmic clapping with scattered clapping. Don't set the start signal or tempo, but just follow when someone starts clapping. The person who started the clap measures the time it took for everyone to sync. How much will it change depending on the number of people and the size of the classroom? The clapping rhythm can spread the behavior (social information) of others widely so that we can easily synchronize it through auditory feedback.

3.4 Network Science

Networks exist in many places. The power outage caused by the 2018 Hokkaido Eastern Iburi earthquake is an example of a network phenomenon in which a power failure at one location instantly spreads to large-scale failure. Network science deals with not only technological networks but also natural networks (e.g., food chain, the nervous system, intracellular metabolism), semantic networks (e.g., links between cited documents and words), and interpersonal networks.

In network theory, the frequency of signals travelling back and forth on a link gives the strength of the link. Signal strength has the effect of changing the network structure. For example, some ants build a bridge on a puddle. If the number of ants walking exceeds a certain frequency, the ants below stop moving to build a bridge, and when the frequency falls, they start moving again.

Even in social psychology, sociometric research of friendships has been conducted for a long time, but the sample size was small. A small world study by Watts et al. (Watts, 1999) has solved the issue. Watts initially researched the biological community of the light emission synchronization phenomenon of fireflies. It can be said that complex network science originated in biology. Watts' small-world research promoted research on complex systems networks that handle huge sizes.

3.4.1 Small-World Experiment

Social psychologist Milgram experimented with how many friend networks needed to send a letter by postal mail from Omaha to Boston (Fig. 3.3) (Milgram, 1967). Participants were asked to look for acquaintances who could reach the target person. Participants were only allowed to send letters to those they can call by their first names. It seems that about 100 people are needed to succeed, but in the experiment, participants could reach the target in about six steps. After this, this experiment was called the small-world experiment.

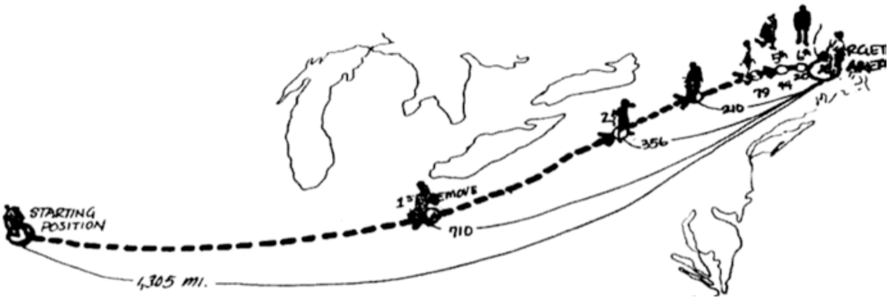


Fig. 3.3 Small world experiment by Milgram (Milgram, 1967)
An example of an efficient decentralized search (See Glossary G-2-2)

Duncan J. Watts mathematically defined the small world. A small world is created by rewiring links from a networks that are connected only in the neighborhoods (the left end in Fig. 3.4) to distant places with a certain probability. Figure 3.5 takes the ratio of rewiring from all link numbers on the horizontal axis, and takes both the path length (See Glossary G-2-1) indicated by black dots and the clustering coefficient (See Glossary G-2-2) indicated by white dots on the vertical axis. The path length decreases rapidly due to rewiring, but the clustering coefficient does not decrease immediately (Fig. 3.5). In other words, this difference in the rate of decline narrows the world, leaving the familiar relationship links. See Fig. 3.4. The graph in the center represents the small world. Rewiring as shown in the graph on the right creates a world where the clustering coefficient is low, that is, familiar human relationships are destroyed. Approximately 1% of rewiring links make up a small world where we can connect to the world via six to seven people. This abrupt change is the phase transition (See Glossary G-7-1) (Watts, 1999).

The small-world phenomenon is also called six degrees of separation based on Milgram's experimental results. In the Milgram experiment, the probability that a

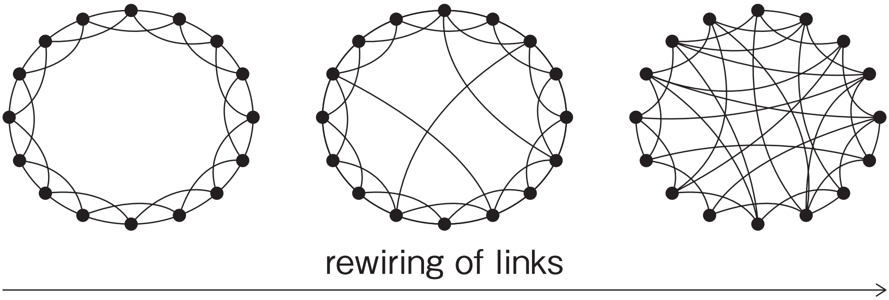
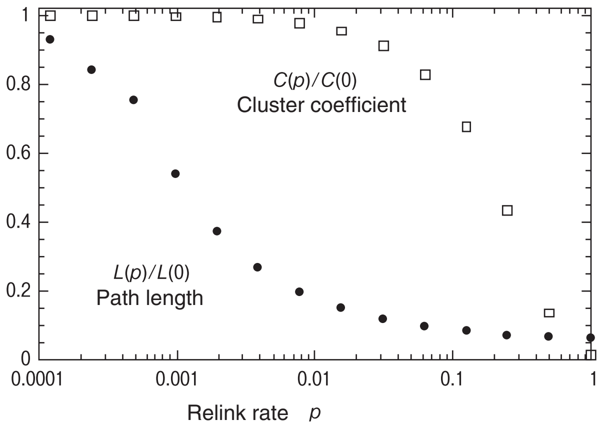


Fig. 3.4 Small world
The central figure shows the "Small world" that is with the links in the left figure replaced. The points (black dots) that connect the links are called nodes (See Glossary G-2-1)

Fig. 3.5 Small world region



letter arrived was about 35%, and the median of those cases was the six degrees of separation. Similar numbers are found in various networks. For example, Microsoft's IM (instant message) network has an average distance of 6.6. The co-author network of papers, the Erdesh number, is 4 to 5, and the co-star network of movies, the Bacon number, is at almost 8.

The real world is composed of a small world. Furthermore, it is a fractal (See Glossaru G-7-1) structure in which similar network structures spread at each level, such as global scale, national unit, and region.

Give it a Try

Let's experience firefly light emission synchronization on the Nicky Case site (https://ncase.me/fireflies/).

At first, it will be slightly affected when a nearby firefly flashes, but eventually, the whole flashes at the same time. In this way, since "interaction" in the real world network is often not visible, this simulation is modelled assuming a link with individuals within the perceptual range. Even if you can see only a narrow range, you can visually experience that the synchronization phenomenon (See Glossary G-7-1) appears within the whole by just reacting automatically. The phenomenon in which a slight influence from individuals on the network spreads to the whole synchronization is called entrainment. Only male fireflies flash. The response rate of females exceeds 80% when the males are entirely synchronized but decreases to 3% without synchronization (Moiseff & Copeland, 2016). That is, the synchronization phenomenon of males becomes a strong signal to females. The synchronization of networked nodes produces information. Repetition with a constant rhythm is called oscillation, and the element that synchronizes the oscillation is called a coupled oscillator.

Role of Weak Ties

A survey revealed that important information such as job changes and matchmaking comes from people who do not usually interact (weak bonds), rather than friends and colleagues we usually involve. We refer to this as the strength of weak ties (Granovetter, 1973).

The following explains why weak ties bring helpful information. In a dense cluster, people are more likely to share information, so if there are profitable options, they are apt to compete. New information that is unfamiliar within the group of which we belong comes from different clusters. It's not just information; it involves new viruses or fake news. Linkages bring both good and bad things.

3.4.2 Balance Theory

One method of human network surveys is asking participants to list the people with whom they have had important conversations in the past week. However, interpersonal relationships are not always positive.

Heider's balance theory can be applied to interpersonal relationships including negative relationships (Saito, 1987b). Heider's balance theory (Fig. 3.7) predicts that an imbalanced tripartite relationship stabilizes in a balanced state. When the relationship between links is positive, it is expressed by +, and when it is negative, it is expressed by -. Multiplying these signs, the + is the balanced state, and the - is the imbalanced state. Suppose P (person) and O (other person) are in conflict. X, who has a good relationship with both, will experience an unstable tripartite relationship until X breaks up with either P or O, or until P and O get along well.

Extending the balance theory to large networks, we can predict structural equilibrium—a state in which relationships are stable. The network (See Glossary G-2-1) is analyzed as a matrix of x nodes. The network is not stable until all are in a balanced relationship, and the force for change keeps work.

The equilibrium theorem (See Glossary G-2-3-1) proved that there are two mathematically stable networks: networks comprised only of friends (+) or networks divided into enemies and allies. Conflicts within the community are prone to lead to bipolarization dividing the core and its surroundings (Kadushin, 2012).

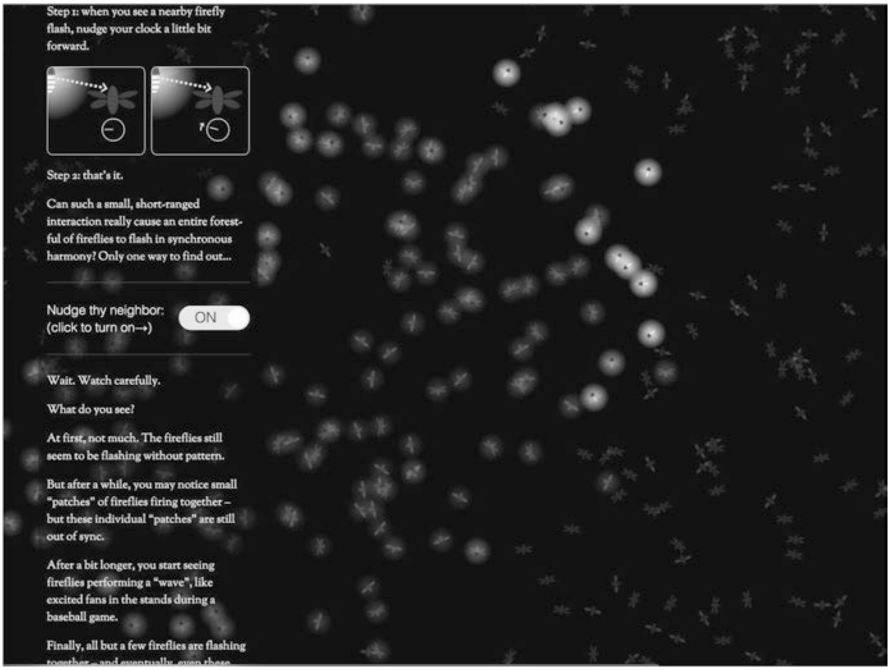


Fig. 3.6 Firefly light emission synchronization

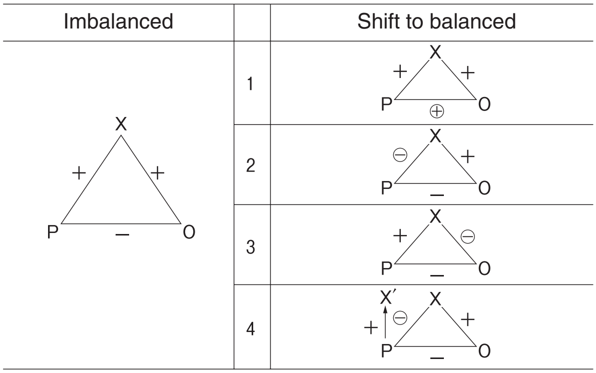


Fig. 3.7 Transition from imbalanced state to a balanced state in a triad relationship (Saito, 1987b)

Triadic Closure

Two people with a common friend are likely to become friends eventually. This is called a transitive relation, and a tripartite relation with positive relationships is called a triadic closure.

The reason why the tripartite closure operates can be explained by the many communication opportunities and the balance theory. A network with few triadic closures is said to have many structural holes.

Stronger links are more likely to cause triadic closure (Fig. 3.8). The strength of the link is the amount of information flow measured by the exchange time and the number of times within a fixed time. For example, the more messages are sent online, and the longer the time spend chatting online, the stronger the link.

The probability that two randomly selected friends from each node are connected is called the clustering coefficient. Networks with many tripartite closures (high average cluster coefficients) have high mutual reliability, but new information is difficult to gain (Sect. 3.4.5.2). Networks with many structural holes have the advantage of being provided with diverse information by weak ties (Sect. 3.4.1.1).

The strength of the triadic closure depends on the network. Christakis and Fowler (2009) found that while the friend networks have a high clustering coefficient (52% on average in the United States), the sex partner networks have a low clustering coefficient, forming a tree-like network. This is probably because they avoid cheating with their partner's friend. The reflection of implicit rules as the structure of networks is an interesting aspect of network science.

Social Capital

Social capital is the benefits that human networks bring, such as academic clique and personal connections, and there are two types: internal bonding social capital and bridging social capital. The number of links in the network/the number of links

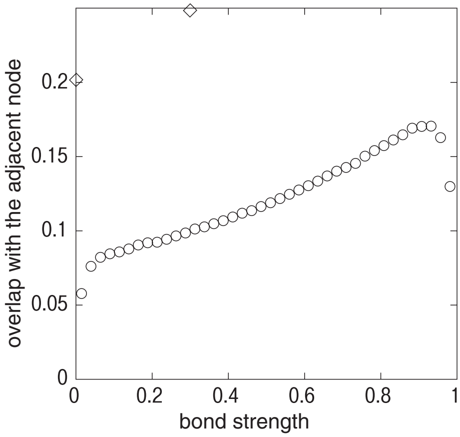


Fig. 3.8 Bond strength and triadic closure (Easley & Kleinberg, 2010)
This graph shows that the bond strength (frequencies of communication) and the overlap with the adjacent node have a positive correlation. That is, more communication tends to cause triadic closure

between all nodes is called the density. The higher the density, the larger the internal bonding capital. Increasing internal bonding social capital and visualizing relationships will build trustworthy and secure relationships.

The bridge (path connecting ⑦ and ⑧ in Fig. 3.9) does not have internal bonding social capital. However, the disconnection between ⑦ and ⑧ loses the linkage between the two clusters, which brings advantages to ⑦ and ⑧. We refer to this as bridging social capital. A node that must pass through to send information is called as a highly centralized node.

Since Japanese companies place more importance on internal bonding capital than bridging social capital, they prefer membership-type personnel. However, this tendency has a negative side because the internal bonding social capital and bridging social capital tend to fall into a trade-off relationship.

3.4.3 Positive Feedback

The restaurant with full reservations seems good, so customers just keep pouring into there.

Even information sites such as popular rankings can easily create a wider gap between rankings. Also, if the recommendation system of an online shop is designed to draw attention to a less popular item, it eventually leads to a widening gap.

Network theory and complex system theory provide the understanding of the society brought about by such positive feedback that "the rich grows richer." The airport network on the right of Fig. 3.10 is an example. Consider the example of creating a new airport. Linking with the airports, which already have many routes, makes it possible to transport throughout the country. Therefore, more requests for

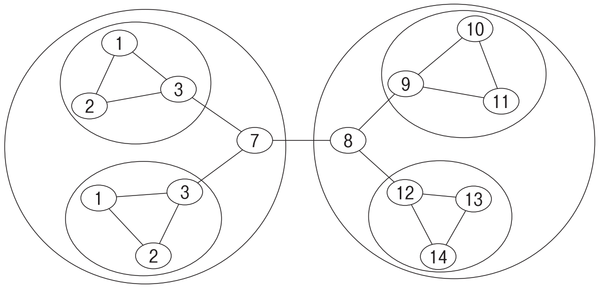


Fig. 3.9 Example of bridge

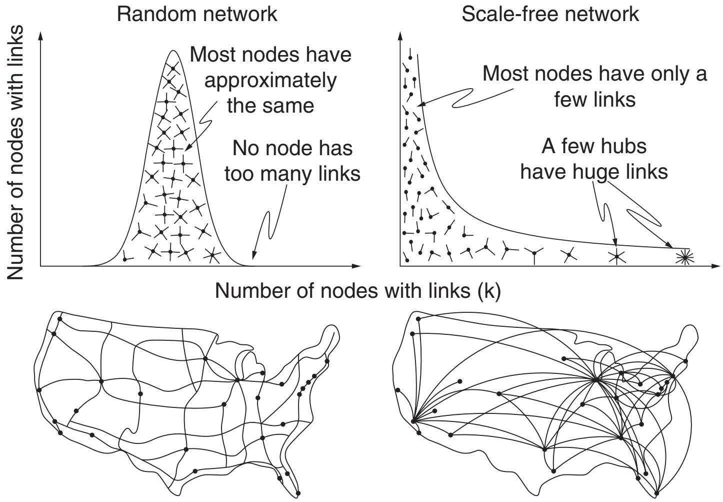


Fig. 3.10 Example of US transportation network (modified from Barabashi, 2002)
The graph above shows the frequency of links at each location. The airport network is close to a scale-free network where there are few hub airports with many links, while the highway network links are close to the Poisson distribution, which is distributed around the average number of links. In airport networks, the efficiency of trying to shorten path lengths makes them scale-free

new links come to the hub airport. Addition of new nodes based on the rule that "the more existing links, the more links will be acquired" creates the scale-free network with hubs (Barabasi, 2016).

Give it a Try

Visit the Flightradar24 site to see the fleet of planes flying around the world (Fig.3.11). Planes connect networks between airports. We can see that the distributed processing at each airport controls the flight in detail. In a scale-free network, nodes are not very isolated, even when links are removed. This brings the robustness of the fluctuation-resistant system mentioned in the "Introduction."

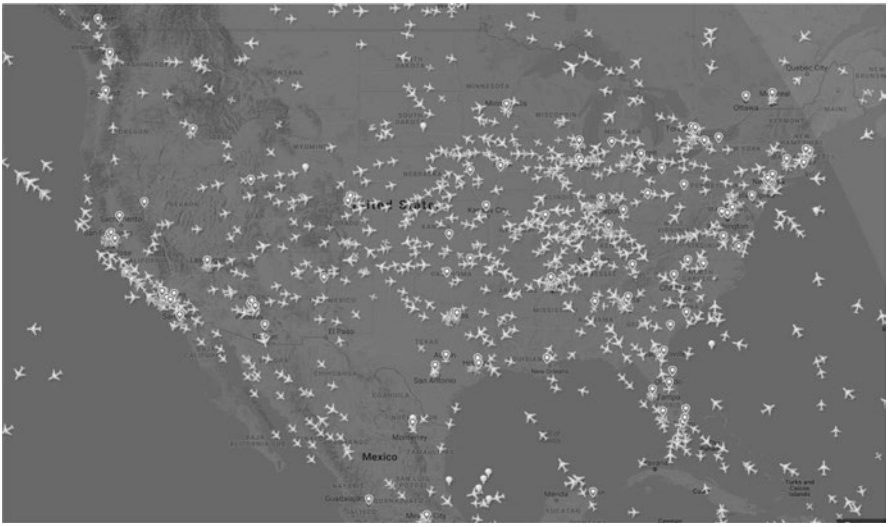


Fig. 3.11 A flock of airplanes moving on a scale-free network

3.4.4 Power Distribution and Scale-Free Network

In a random graph with links randomly attached, the degree distribution of the number of links shows a poisson distribution (Fig. 3.10, upper left). On the other hand, in scale-free networks, a minority with very many links and a majority with few links will appear. Figure 3.10, the graph on the upper right, shows a typical example. This is referred to as a power-law distribution, or long tail (the line drawn by the graph resembles the long tail of a dinosaur) (Fig. 3.12).

The conversion of both axes in this figure into a logarithm turns the graph into a straight line with a negative slope. Here, the minus value is called the power exponent.

The term scale-free comes from statistical physics and the study of the theory of phase transitions. Scale-free means that no scale can be created because it does not intersect the axis. The power-law distribution emerges through the preferred choice of growing networks.

The power-law distribution is found in various phenomena from nature to society, such as the probability of an earthquake and stock price fluctuations. Barabasi (2016) found that large networks cannot be scale-free networks when the power exponent is two or less. In fact, the power exponent in many real scale-free networks is between two and three. Figure 3.13 shows that the number of real web links follow the power-law with a slope of −2.1. The disparity that appears here is not due to the difference in link aggregation capabilities of each website.

Barabasi (2016) found that the degree-of-growth rate (fitness) in each node is almost the same, and only mechanical priority selection creates the scale-free network.

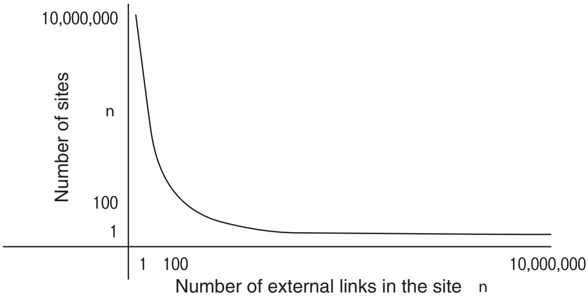


Fig. 3.12 Longtail observed in the number of website links

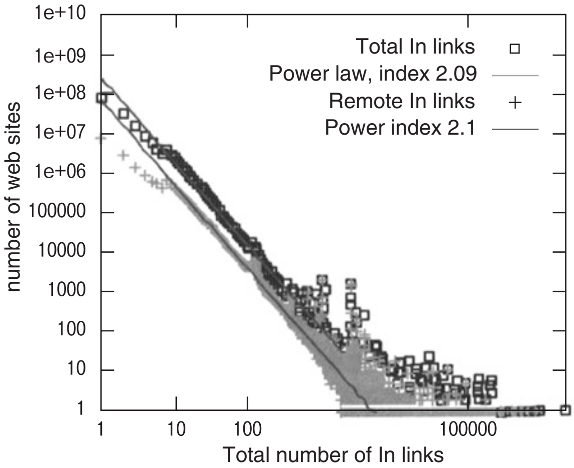


Fig. 3.13 Distribution of the number of "In link" on web pages
(Easley & Kleinberg, 2010)
Converting Fig. 3.11 to Log-log plot draws almost linear

Scale-free also explains the reason why people tend to choose "coordination" in the dilemma game (Sect. 1.2) (Watts, 1999). Under the condition that they could compete with opponents on a scale-free network with each other, they apt to select "cooperation." As we adapt the change in the weight of communication from face-to-face to the Internet, we optimize the network to fit the environment. Changes in the network structure alter the optimal strategy.

3.4.5 Information Cascade

Network theory makes an essential contribution in the field of epidemiology, especially in the analysis of disease outbreak networks (Fig. 3.14). The assumption that what breaks out on the network is information, rather than viruses, enables a model

Fig. 3.14 Network of H1N1 virus epidemic in 2009 (Barabasi, 2016)
Data for the textbook "Network Science" written by Barabasi (2016) is available at http:/network-science book.com. Chapter 1 of the site offers a video of how this epidemic spread

for information spread. Considering that not only information but also behavior such as "whether to buy a certain product" or "join in a riot" can be infected, it can be a model of crowd psychology. All of them are collectively referred to as an information network here. A major issue in information networks is a cascade. Cascade is a word that represents a waterfall that conveys information to one after the other on a network.

Information cascades are more likely to occur when people infer from the behavior of others and make decisions one after another. The ease of contagion is called the threshold (Sect. 2.2.3.2). The extent to which the cascade spreads depends on the threshold distribution of individual infection (conformity).

Process of Information Cascade

Let's show the simplest cascade example. There is a vase containing red and blue marbles. From that vase, multiple people pick up marbles one by one, in order. Your turn is third. Then, guess whether the pot contains a lot of red or blue marbles. The information cascade begins from the third person (you) regardless of the color of the marble you pick up. If the first two persons reported different colors, you would say the color you picked up. But what if you picked up blue after the first two persons say red and red? If you say red, there is a two-thirds chance of getting the correct answer. So you answer red, even if you actually pick up a blue marble. The fourth person doesn't know if you really picked up red, thus said red, or if you looked at the previous two and said red. That's a 50% chance, so the fourth person is more likely to get the correct answer if they also say red. After that, similarly, although there are more red in reality, blue is selected by the information cascade. The occurrence of greater than two people differing from the state of the same vote starts the cascade.

Structure to Prevent Cascade

The cascades arise from a few differences in population. It is not difficult for the same person to push the opinion of a group in a specific direction by using multiple IDs on the Internet. How can this be prevented?

A time lag of choices creates a cascade, and dense network connections spread the contagion. When the choices were made at the same time, as demonstrated by Asch's entertainment experiment (Sect. 2.2.3.3), about three to one, that is, if 75% of linked acquaintance take the same action, people will conform with a high probability. However, it is difficult to spread beyond the bridges (Sect. 3.4.2.2) that connects to other clusters. Therefore, the bridge prevents the cascade. When the threshold of the bridge is high, information cannot get over the clusters.

Applying this problem to the concept of a message spread, we can find that it is difficult to convey a message whose meaning is difficult to understand due to the difference in context between clusters.

Then, what should we do to spread the new idea?

Simple and Complex Contagions

A simple contagion is one that infects with a certain probability, such as the epidemic shown in Fig. 3.14. On the other hand, the infection of the meme (See Glossary G-1-8) that contains cultural information has a pattern called a complex contagion different from that of the pathogen. The complex contagion is one that requires a strengthening process with repeated contacts, rather than a single contact. Barabasi et al. (2016) analyzed Twitter and found there are hashtags that spread with one contact and hashtags that require multiple contacts, and the latter do not spread from inside the community to the outside. This shows that memes, whose context is incomprehensible, are difficult to spread.

Give it a Try

Visit NickyCase's site and do some activities. https://ncase.me/ You will find that a new idea is hard to spread to clusters with close links (Fig. 3.15).

Network Effect

The network effect is a positive feedback effect in which an increase in the number of users increases the utility value. For example, an increasing number of iPhone users will increase the number of app developers, improve convenience, and in turn attract more and more users. However, many products disappear before a certain number of adopters gather. The distribution of thresholds can predict the difference.

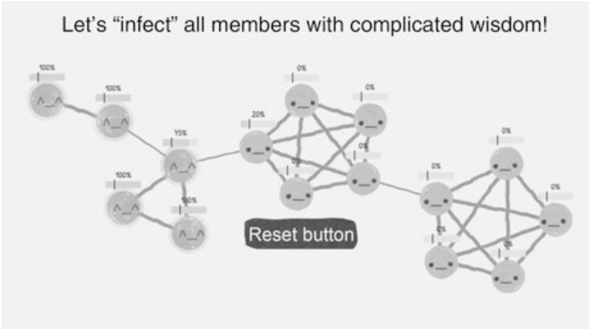


Fig. 3.15 Complex wisdom is hard to spread

Granovetter (1978) explained collective behavior by modelling the conformity "how much an increase in the proportion of others who perform a specific behavior, let us follow them."

Assuming the threshold distribution is a normal distribution—most people think, "if half of the people participate in the action, I will too," and a few people are at both ends. This cumulative distribution function draws an S shape, as shown in Fig. 3.16.

As a result of comparing the expected value with the actual number of people, if people think that they will not make the purchase if it is less than expected and buy if there is more than expected, the value will be balanced at the intersection of the expected value and the actual number of people.

As shown in the graph in Fig. 3.16, if there are two equilibrium points between the gradually increasing consumer and the threshold, they are divided into two poles by the initial value. Dissemination can be expected by setting prices above the initial equilibrium point. Many systems, such as apps, are initially distributed free and billed after the network effect is obtained.

Schelling's Segregation Model

Assume eight neighbors surround your north, south, east, and west. Suppose that many people don't move if half of the neighbors are the same race, but if they are the minority, many people choose to move (Fig. 3.17).

Such problems can be expressed in a network that assumes links between adjacent cells. The simulation revealed that several relocations of people create separate living quarters. Schelling (1971) showed that even if the majority of people does not mind race, the residential area was divided in the long run using a segregation model. Since rigorous mathematical analysis is complicated, its study is limited to simulations, but the benefits are significant. The category of belonging in groups divides society even if the individual does not have that intention.

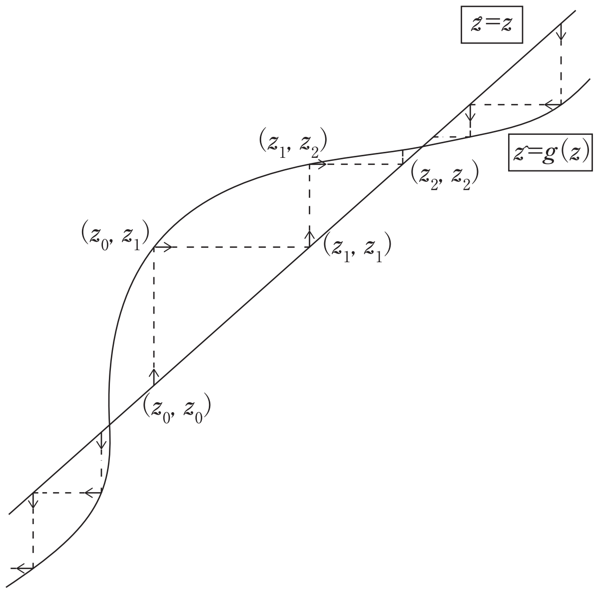


Fig. 3.16 Model of the diffusion process
When the number of participants increases up to Z0, the price increases up to Z2 because there are recruiters who exceed the threshold

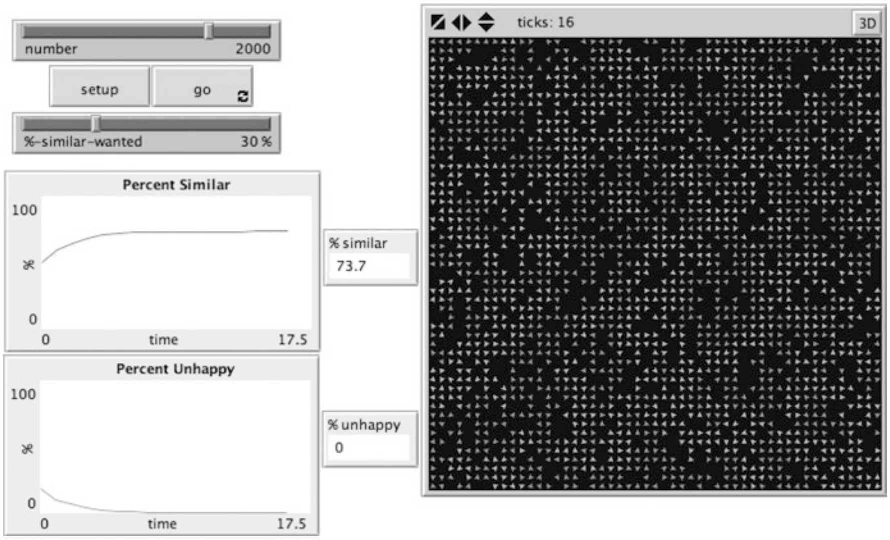


Fig. 3.17 Simulation of Schelling's segregation model by NetLogo Segration
Residential areas will be segregated in the long run, even if the residents do not care 70% of their neighbour are difference race (Wilensky, 1997)

3.4.6 *Real-World Networks*

Dunbar's Number

Vital data often quoted in evolutionary psychology is Dunbar's number (Dunbar, 2011). Dunbar's number is a numerical value calculated from the results of a study that reveals the correlation between the weight of the brain and the number of ape herds. Approximately 150 people are the number of herds that match the weight of the human brain. The idea suggests that the maximum number of people the brain can recognize in relationships is about 150.

Dunbar (Matsuura, 1996) proposed the "social brain" hypothesis based on this result. The social brain hypothesis states that the large brain size of humans was necessary for communication within the group and memorizing others. Dunbar considered that the grooming relationship found in apes corresponds to human rumors. Moreover, languages emerged to maintain interpersonal networks and even a reputation system that guarantees indirect reciprocity.

Let's guess how many people modern know and communicate with each other The average number of people who have been contacted in the past two years is about 290, and the mode is around 150 to 200 (Fig. 3.18) (Killworth, 2006). The relationships that individuals can handle are still within the range of Dunbar. Even within SNS, the number of people who interact with each other is smaller than the number of followers (Fig. 3.19). Living in the cluster, we are connected to the whole world through the small world.

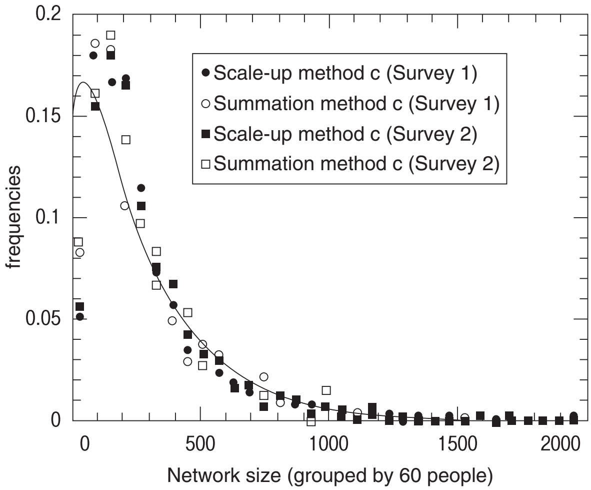


Fig. 3.18 Distribution of numbers of acquaintances (modified from Kilworth, 2006; Kadushin, 2012)
The long-tail distribution can be observed regardless of the difference in the survey target or modelling method

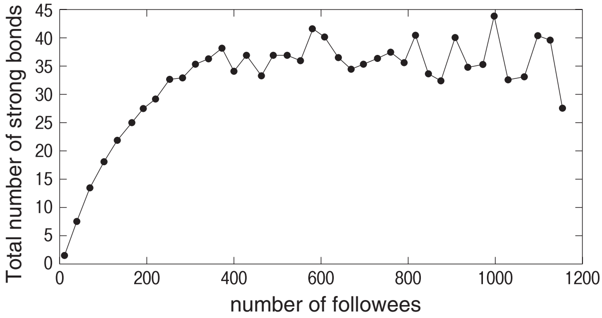


Fig. 3.19 Strength of bond on Twitter (Easley & Kleinberg, 2010)
Even if there are 1000 followees, only about 50 people will post with @ mark. The number of such followees does not increase from more than 400

"Reputation" in the face-to-face community only works for groups within Dunbar's number. Therefore, groups that exceed the number of Dunbar need a system of punishing traitors to maintain trust. Here, the group must pay costs (Sect. 5.3.4) to keep the surveillance and penalty system. Harari (2015), who is well-known for publishing *Sapiens: A Brief History of Humankind*, has considered that the tribe of humankind who exceeded Dunbar's number needed fictions (shared values: money, class, etc.) as the costs.

Effect of Belonging Group

The networks cannot be described with a graph that is predicted only by triadic closure. Links are more easily formed if there are similar categories, such as race and gender. We call this homophily—the effect of social identity in social psychology. High homophily is more likely to form links, and the formed links give feedback that social influences make them more similar.

Homophily

Homophily refers to the tendency of people with similar social backgrounds to link to one another easily. In human networks, we find degree correlations that tend to connect people with a similar number of links. Homophily is one of the possible causes of these trends (Barabasi, 2016).

Easley and Kleinberg (2010) investigated the potential for friendship formation between Wikipedia editors. In this study, a reply to a user-created page was considered a conversation. More conversations increase the probability that they will edit the same page. Is Wikipedia's homophily (the tendency for people who edit the same page to be friends) to be the "choose-the-same-article" choice or the social impact of conversation?

The verification of the similarity of the edited pages before and after the first conversation revealed that homophily preceded — communication between editors increased after the similar page was selected, and then, their edited pages became more similar.

"Homophily" and "exclusiveness" are two sides of the same coin. Exclusiveness is associated with the need for closure of wanting to be in a closed network. The need for closure is measured by the need for closeness scale (NFC), and the item contents are similar to ambiguity tolerance. Flynn, Reagans, and Guillory (2010) investigated a class of new students and found that the higher the need for closure, the more exclusiveness the tendency of interracial relationships.

Bipartite Networks

Actually, our interpersonal networks do not have powerful hubs such as a tipping point (Gladwell, 2000) that spread the behavioral contagion explosively. Barett, Eubank, and Smith et al. (2005) found that social networks have many shortcuts that don't go through the hubs. Rather, everyone is actually a small hub. We can explain this social network structure using the shape of a cone that spreads at each stage.

To understand such a staircasing network, the idea of the belonging group helps. Usually, network analysis tries to extract groups from interpersonal networks. However, conversely, we assume bipartite networks where the interindividual network spreads based on groups (Watts, 2004) (Fig. 3.20). Simulations of a bipartite network had revealed that clusters appear in a small world even when individuals randomly selected groups. This result is consistent with the actual distribution. In other words, everyone acts as a hub that connects different groups.

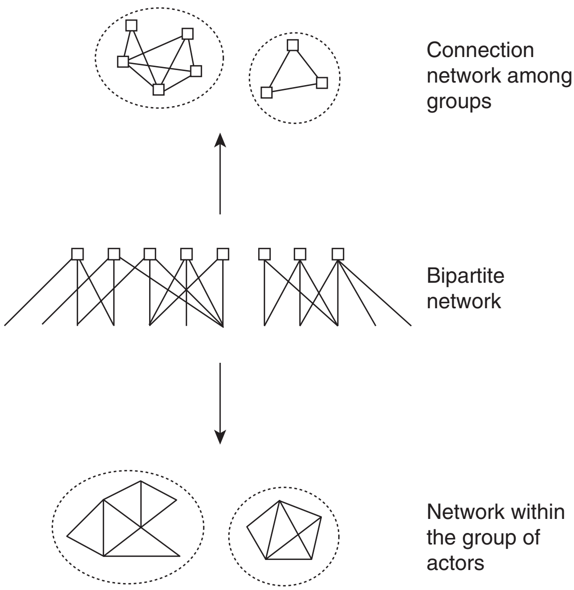


Fig. 3.20 Bipartite Network (Watts, 2004)
Social networks can also extend the triadic closure by connecting the networks that each person belongs. People who have a common base (membership group) are likely to be friends (base closure), and friends are easy to join the same base (member closure)

Contagion of Habitual Behavior

Homophily, who wants to connect with people who are alike, is also presented with the hypothesis that "when people connected with each other, they start to resemble," rather than "peoples who are originally alike are connected." It is a study by Christakis and Fowler (2009) (Sect. 3.4.2) (Fig. 3.21).

Christakis demonstrated that changes in behavioral habits (such as food and smoking) of others on the same network could extend to friends of friends. For example, people who are as fat as one another are more likely to be friends. Rather than one chooses someone with a similar body line as a friend, being fat was contagious. The rationale is that it affects third-order relationships that one does not know directly. This is because the social norms of what to eat and how much to allow will be affected by exposure to other's behavior.

Regarding smoking habits, no clusters were found among smokers in 1971, but clusters gradually appeared in 2000 when they were banished to the outside. The division of the network forms a new social identity. These results show that the network structure gives rise to categories without prior sharing of social categories of belonging groups. Latane, Nowak, and Liu (1994) predicted the polarization and division of public opinion by simulations based on social impact theory. Using a model in which the influence attenuates in correlation to the inverse square of the distance creates a minority cluster. Clustering creates a new correlation between attributes. For example, regardless of income and political attitude, living in an income-dependent residential area forms a similar political attitude.

Loneliness Is Contagious

Most of the large-scale community network research is conducted using Framingham research data. The Framingham study is conducted by the US Public Health Service for citizens of Framingham, Massachusetts, for the purpose of health management.

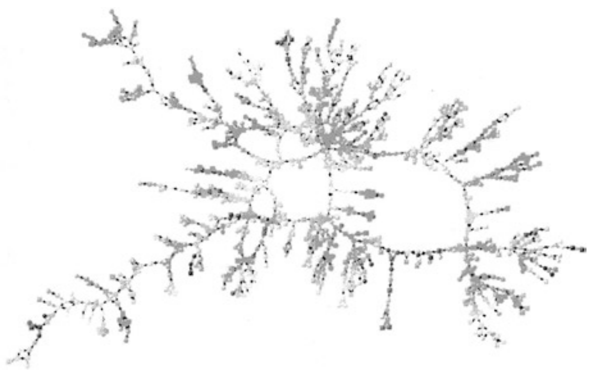


Fig. 3.21 Part of the final survey network (Cacioppo et al., 2009)

This survey had been conducted every 4 years from 1971 to the 2000s, targeting residents. Cacioppo, Fowler, and Christakis (2009) have examined the contagion of loneliness (Sect. 3.3.1) using 120,967 patient's data in this survey.

The loneliness index was set to the number of times a person felt lonely in a week. Factors that induce loneliness were searched by regression analysis from the fifth to the seventh and the seventh to the eighth survey results. The factors inputted to the analysis are the number of friends in the previous survey and this survey, demographic factors, the loneliness of the last survey, and the loneliness of friends.

As a result of the analysis, the loneliness decreased by 0.04 as the number of friends increased, but the loneliness increased by 1.5 to 2 times when some friends felt lonely (Fig. 3.22). The closer the friends, the stronger the influence. Separate living spouses and siblings will not be affected. In other words, it can be said that the amount of contact with friends of choice is more important rather than the blood relationship.

Regarding happiness, Christakis and Fowler (2009) found that a person with one degree of separation makes 15% of others happy, 10% at two degrees, and 6% at three degrees. It does not affect relationships more than four-degree separations. And the impact lasts for about a year. The authors believe that the influence transmitted on the network is up to the three degrees of separation and propose the rule of "three degrees of influence." Interestingly, the network also influences the onset of low back pain, which can be one of the culture-bound syndromes. Mental illness whose incidence varies with the times is also a culture-bound syndrome, and the influence of the network is predicted.

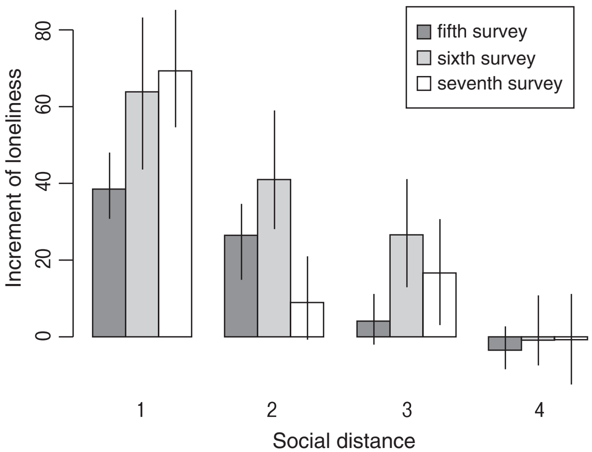


Fig. 3.22 Influence of loneliness on social network (Cacioppo et al., 2009)
The loneliness of one affects up to a social distance of 3 (friend of a friend's friend). This third degree of influence is also seen in smoking, obesity, and a feeling of well-being. fifth survey sixth survey seventh survey

Behavioral Contagion

Pentland (2014) (Sect. 5.2.2) found that observing model behaviors can change eating habits and cause weight changes (Sect. 1.4.5).

We can see the same tendency in the purchase behavior of apps and songs that people should be consciously selecting. The influence of social factors here was about 12%, while contact with other people affected is four times as much. However, these influences were limited to the free trial and did not affect actions such as purchase and renewal contracts.

How about voting? When voting days approached, people were changing the groups in which they spent time. The decisive factor in group selection was not the political topic, but the level of comfort in ordinary conversation. After joining a group, voting behavior is affected without direct discussion (Pentland, 2014). In other words, interpersonal relations influence group beliefs rather than political beliefs, but after belonging to a group, influences including unconsciousness affect people's political attitudes.

Intervention Case for Bullying Problem Considering Network

Social exclusion, that is, bullying and power harassment, is often a problem in human groups. Such group norms are often thought of as fixed, but they change in some circumstances. New students entering a school will adapt to the school's culture and form their own norms.

Paluck and Shepherd (2012) have examined the influence of interpersonal networks on bullying through a 1-year field experiment. They provided an opportunity to select students and talk about their bullying experience as a condition of intervention. The frequency of intervention varies from student to student. They then analyzed the difference in influence between "a well-known leader (a student named as a popular person) across subgroups" and a "clique leader with a high frequency of contact."

At the beginning of the survey, students had an attitude that "it is better to ignore bullying," but an increase in links with leaders went up the number of awareness of bullying and strengthened the belief "bullying is not normal."

Students linked to a well-known leader did not take action to stop the bullying of others, even if they purchased a band that signified anti-bullying. The students connected to the clique leader actually took action. They knew that their peers were against bullying, and they had more actions to protect bullied students. These results show that to promote behavioral change in a group, it is necessary to change the common sense of "what is normal" starting from the belonging groups rather than persuading the whole or individuals.

Political Activities

Will political activities spread over the network? From the 1980s to the 1990s, the polarization of democracy vs republic, as seen in the Joint bill proposal, proceeded rapidly but remained flat after that. However, in 2004, the network that appeared in the link between blogs was divided into liberal and conservative (Fig. 3.23). In 2008, the polarization of reading books appeared on Amazon's book purchase data (Fig. 3.24) (Kadushin, 2012). These indicate that the polarization of information networks was in progress before the 2010s when the extreme political beliefs became apparent in the United States.

Groups with dense reciprocal links are less susceptible to different opinions from outside the cluster. Christakis stated that densities below 0.5 increase the infect susceptibility to external opinions. Conservatives are more likely than liberals to eliminate an opposition. One of the possible reasons for the decline of liberalism is that conservative orientation—emphasizing credit by internal bonding capital (Sect. 3.4.2.2)—had a higher contagion threshold than a liberal orientation which prefers to connect to various clusters.

3.5 Summary

Collective intelligence is difficult to define. For example, the declining birthrate in developed countries may be maladaptive for the country, but it may be adaptive for the long-term survival of humankind. Intelligence, in a sense, is something that is judged by external perspectives at the specified timepoints. The generation of

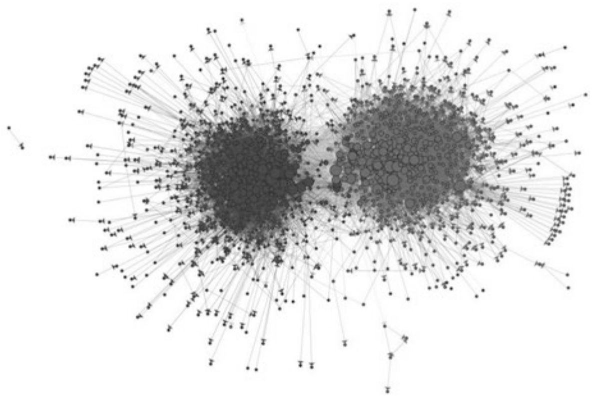


Fig. 3.23 Link relationships between political blogs
(Michigan University, School of Information Coursera "Social Network Analysis" Lada Adamic 2012)
Republican and Democratic blogs build different clusters and have few links between them

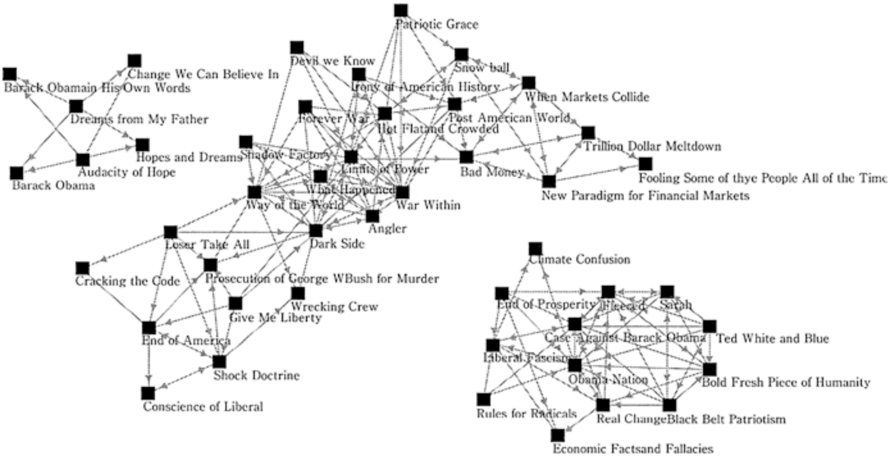


Fig. 3.24 Network obtained from book purchasing tendency (Kadushin 2012)
Amazon purchasing data for 2008. If a person who bought one book also bought another, a link is added. Obama candidate-related books are shown on the left, the Democratic Party-related books are shown in the center, and the Republican Party-related books are shown on the right, and there is no overlap between the clusters

"intelligence" at the collective level is different than at the individual level. Within this limitation, this book refers to the ability to adapt to a constantly changing environment as "intelligence."

Efficiently distributed processing requires dynamic structural shifts. In the case of insects, they need two phases—a distributed search phase and a collective decision-making phase. The linear-nonlinear transformation, which linearly accumulates information in the distributed search phase and then shifts to make decisions in the collective decision phase, creates insect intelligence. In humans, the control process collecting information is linear at first, and then the automatic process facilitating adaptation to the majority shifts from nonlinear to linear. Individual decision-making is "pushed" by subliminal emotions (Sect. 1.1.6.1). Group decision-making may have an aspect of emotional contagion that pushes the group in a certain direction. Such an unconscious process may have worked adaptively in groups within Damper's number (Sect. 5.2.2.3), as claimed by Pentland (2014).

Behavioral contagion can occur without a face-to-face conversation. Norms do not need words. The norms such as "what to wear to go out" and "whether it's okay to be fat" are implicitly formed as common sense (Sect. 1.6) by observing the other's behaviors.

Social identity that influences network structure increases similarity within groups and disparts into different groups. A high link density within a cluster makes it difficult to infect external information. On the other hand, if the information is leaked outside the cluster, it will be widely spread via the small world. In the next chapter, we examine how smart the group, which is the starting point of entrainment synchronization phenomena, can become.

Chapter 4
Group Collective Intelligence

"In fact, most bird flocks don't have leaders at all." This is a quote from Resnick (1994) who developed the StarLogo language, which inspired the author's study of collective intelligence. Resnick introduced a void program that simulates a flock of birds, pointing out that the flock of birds does not have a leader. It may be premature to say that every flock of birds has no leader, but the words opened the eyes of the writer, who had studied leadership in the past. The leading bird only happens to occupy his or her position but has not orchestrated it. Humans have also adaptively organized society as a flock. This chapter describes the mechanism that produces collective intelligence at the small group level.

4.1 Why the Many Are Smarter than the Few?

Surowiecki (2004), known for the collective intelligence book *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*, has found that the collective intelligence brought about by a large number of independent judgments, such as those found in a web search, involves the following four factors: diversity, independence, decentralization, and aggregation.

4.1.1 Diversity

Diversity in answers brings collective intelligence. This effect can be explained by the jelly beans in the bottle problem.

Show a large bottle containing jelly beans to students in the classroom, and ask the students to guess the number of jelly beans inside. An increase in the number of

Y. Arima, *Psychology of Group and Collective Intelligence*,
https://doi.org/10.1007/978-3-030-84698-5_4

people guessing brings the estimated mean value closer to the correct answer. This is because, if the problem is such that the errors are distributed on both sides of the correct answer, the errors will be cancelled out as the number of people increases. Even if there is one who answers correctly, it is better to think that it is a coincidence rather than that individual's ability to estimate jelly beans is high.

4.1.2 Independence

Group discussions bring conformity even when there are various member configurations. Each time a person communicates with others, cognitive tuning (Sect. 2.4.2) is operated. Here, each individual has to make the independent judgment to create a collective intelligence. However, since we cannot escape the daily influence of others and the media, independent judgment in the strict sense would be impossible. Even without communication, we are unknowingly influenced by others (Sect. 1.4).

4.1.3 Decentralization

Decentralization means that knowledge and skills for solving problems are distributed to individuals or local groups. Those who are closer to the problem are more likely to have specific knowledge. By consolidating these while keeping them local, some independence can be maintained.

4.1.4 Aggregation

Aggregation is necessary to utilize locally distributed knowledge globally. If an individual becomes aware of the solution before the results of aggregation algorithms and collective intelligence are aggregated, decentralization and independence cannot be maintained. For example, in a Google search, the algorithm is constantly updated because people distort search results by knowing the algorithm.

When imagining a society meets these four requirements, a certain dystopia comes to mind. In that world, machine learning aggregates the data obtained from individuals, and governments and companies use the information without knowing the calculation process well nor sharing complete information with the people. This is not the conclusion Surowiecki intended but maybe our societies come to this situation near future. There is a contradiction in collective intelligence that "knowing the solution from collective intelligence by individuals breaks the prerequisites for collective intelligence."

4.2 Index of Collective Intelligence

Malone (2018) has defined collective intelligence as "the result of groups of individuals acting together in ways that seem intelligent." Applying this definition, if there is a phenomenon that seems to have solved the problem, it will eventually recognize intelligence.

For example, even if people weren't asked to rate their credibility in a web article, the rating, such as a number of web links, would reflect the credibility of the article's content when compared to the external criterion. Therefore, it will be available as an index of reliability created by collective intelligence. Machine learning (Sect. 6.2.2) can generate prediction formulas even from a pile of various types of data that you might not know you can use. Therefore, instead of the problem form, the new question is how to establish an external standard for checking the correct answer.

4.2.1 Various Indicators of Collective Intelligence

Various performance indicators are used in collective intelligence research. For instance, let me introduce the research presented by leading research institutes at the Collective Intelligence Conference held in the United States.

The collective intelligence research team at MIT, a mecca for collective intelligence research, has developed a method for measuring general intelligence factors of groups (Sect. 5.2.3.1) (Woolley et al., 2010). The team performed a factor analysis of group performance on a variety of tasks similar to intelligence testing. In this research, the general intelligence factor is an index of collective intelligence, and the winning rate of games played by teams is an external criterion.

The IARPA and DARPA, a US Department of Defense research institute, are trying to apply collective intelligence to future predictions. Matheny (2014) reported on experimental results that let participants predict politics, science and technology, health, and other events that could occur within a year. The experimental results revealed that the average performance (collective intelligence) of the team with 20–25 people exceeded the experts. In this instance, the realization rate after 1 year is the external criterion.

NASA reported that it had run a contest to improve the efficiency of solar panels on the space station and that the participants in the contest offered better solutions than those of NASA experts (Lakhani, 2014). In this study, the best member's performance is the collective intelligence index, and the power generation efficiency is the external criterion.

The abovementioned empirical research related to collective intelligence is carried out in various research contexts in response to requests from various organizations. Therefore, it is impossible to simply compare the performance of the crowd with that of the best members. This book classifies tasks into tasks with correct answers and tasks without correct answers and clarifies the index of collective intelligence that fits each task.

4.2.2 Classification of Experimental Tasks

Regarding the classification of experimental tasks,_Steiner's (1972) classification (Sect. 2.1.2.2) is applied in group process studies, while for collective intelligence, classification into intellectual tasks with correct answers and judgmental tasks without correct answers (Tindale et al. 2001)is important. This is because the tendency is that the group will apply the majority rule (Sect. 4.4.1) to judgmental tasks but apply the truth-win (select a correct answer) decision rule to intellectual tasks (Laughlin & Ellis, 1986). That is, in the latter case, the minority who holds the correct answer may beat the majority.

According to Tindale et al. (1990), in the intellectual task, notifying the other members of the selection increases the probability of choosing the correct answer even if there is no discussion. It is considered that this is because the task representation implies the correct answer. The task representation is defined as an overarching term for the procedure that leads to the goal, such as chessboard images, linguistic description rules, and strategic mental models. The higher the demonstrability of the correctness (Sect. 2.1.2.2), the higher the probability that people will follow the task representation.

Exceptionally, there are cases where the principle of the majority rule does not work for a judgmental task. For example, in a simulated jury, people tend to be tolerant and deviate from the majority rule (Sect. 4.4.1) (Chandrashekaran et al., 1996). This is because even if the individual is in the minority position within the group, the majority position in society strengthens their influence (Smith et al., 2000). That is, when the power of the local majority (Sect. 2.2.5) becomes weak, the majority rule cannot be applied. The difference between intellectual tasks and judgmental tasks lies in the commonality of task representations, and the degree of sharing varies with the times and society.

In this book, the tasks that share the task representations before the discussion are categorized as the tasks with a correct answer, and tasks that require the agreement of the premise and rules leading to the correct answer are categorized as tasks without a correct answer.

Tasks with correct answers can be further divided into two types: tasks that can be solved by algorithms that individuals can understand, classified as "intellectual tasks," and tasks that cannot be solved such as algorithms related to complex systems which are classified as "judgmental tasks."

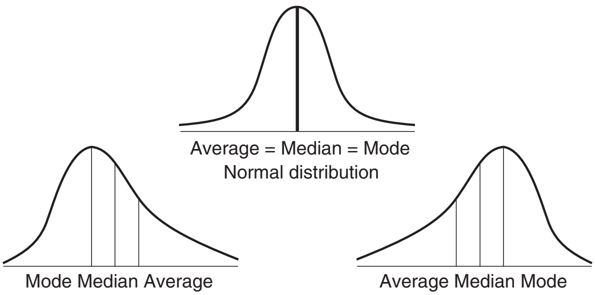


Fig. 4.1 Average, Median, Mode

4.2.3 Tasks with Correct Answers

Tasks with a correct answer is a task format in which one can determine the correct answer by using pre-shared knowledge, for example, the problem of estimating the number of traffic accidents in the last month, which has a correct answer, even though there is no algorithm. The number of traffic accidents that occurred in a month would be available after 1 month, so it is also the judgmental task. A mental model used by an individual to estimate a correct answer is called a prediction model. The model used for estimation differs for each individual.

The index of collective intelligence in tasks with a correct answer is the difference between the correct answer and the answers of the crowd. When the answer of the crowd (a population to which a group belongs is called a crowd) is normally distributed, the index of collective intelligence can be calculated by the square of the difference between the mean and the correct answer. When distorted from the normal distribution, the geometric mean or median can be used instead of the simple mean. The mean and median deviate as the normal distribution is distorted (Fig. 4.1).

4.2.4 Task without a Correct Answer

If the standard for determining the correct answer is not agreed in advance, it is a task without the correct answer. A typical example is a consensus-building task such as whether or not to introduce summertime. Topics that do not involve agreement on knowledge-sharing tasks, such as Wikipedia, often create a dispute over the correct answer.

The study sets some standard of correctness and measures performance based on it. Expert ratings are often used as this external criterion. For Wikipedia, the number of articles, evaluation by editors, and the degree of agreement with Britannica articles are indicators.

The consensus-based model and the metacognitive model are weighting methods often used for the performance of a task without the correct answer (Steyvers & Miller, 2015).

The consensus-based model is based on the assumption that the one closer to the mean or median of the sample is correct (temporary criterion), and the distance from it is calculated as an error. This method cannot be used for tasks that have common errors. In the metacognitive model, there is a method of weighting based on the idea that the more accurate the predictions of others' opinions are, the closer they are to the correct answer (Engel, Woolley, Jing, Chabris, & Malone, 2014). Prelec (2004) proposed a method in which the smaller the "false consensus" (Sect. 1.1.6.2), the greater the amount of information (See Glossary G-1-5) of that person. This can reduce majority bias.

4.2.5 Classification of Information

In biological community research, information is classified into environmental information and social information (Sect. 3.1.2). Environmental information is information that one perceives individually from the environment, and social information is what has obtained from behavioral observations of other individuals. In humans, social information is further divided into perceptual information obtained by observing the behavior of others and cognitive information transmitted by communication.

The error in cognitive information can be assumed to be a statistically independent error (Hong & Page, 2009), but there is a possibility of producing an information cascade (Sect. 3.4.5). Since cognitive information contains biases derived from the knowledge structure of both the person and others, the errors are correlated.

In this document, sharing information is called shared cognition. Sharing such as cognitive schema (Sect. 1.1.4.3) is referred to as a shared knowledge structure to distinguish it. Sharing cognitive bias stemmed from the latter.

4.3 'Page's Theory

4.3.1 The Diversity Prediction Theorem

Page (2007) proposed that the problem pointed out by Surowiecki was caused by the loss of three effects: majority rule effect, information aggregation effect, and error cancelling in the tasks with correct answers. The respective effects are as shown in Table 4.1.

Page expresses collective intelligence in the diversity prediction theorem. Diversity predictor is shown in Table 4.2. This theorem proves that collective

Table 4.1 Effects related to collective intelligence

1. Majority rule effect, Suppose an individual knows a solution by 50% chance. In this prerequisite, an increase in the number of people makes the answer more accurate (Sect. 4.4.1 majority rule)
2. Information aggregation effect Suppose the individual knows some of the solutions. In this prerequisite, if all members make predictions at the same time using the information held by each member, they will produce accurate predictions. However, if a cascade that changes the selection occurs after obtaining knowledge of the other's choice, the solution cannot be reached (sect. 3.4.5 information cascade)
3. Error cancelling Suppose an individual receives a solution containing noise, a continuous variable signal. With this prerequisite, independent errors can be cancelled.

Table 4.2 The diversity prediction theorem

C: The error in collective intelligence (average of the answers-correct answer) ^{2,} I: Individual error Σ (answer of each individual-correct answer) ^{2}, D: Diversity among individuals Σ (answer of each individual-average of answers) ^{2} C= I - D

intelligence (mean error) is always smarter than the individual's average ability (mean error). Besides, this theorem shows that both improvements in the average ability of individual and diversification contribute equally to collective intelligence. Contrary to intuition, if the average abilities of all members are unchanged, the answers should be diverse. This theorem also predicts that social influence, the so-called conformity, negatively affects collective intelligence by reducing diversity.

Quantity Judgment by the Group

In the collective intelligence experimental paradigm, the ability of an individual (the person who is closest to the correct answer is called an expert or the best member) is compared with the accuracy of the crowd average. Let me introduce an example of the procedure used by the author (Arima, 2016) in the experimental lecture and the result. This experiment aims to easily experience error cancelling, which is one of the effects of collective intelligence.

In this collective intelligence experiment, we will explore who can approach the correct answer from among the collective decision-making by a group of four, the class average value, and the best member.

Give it a Try: Collective Intelligence Experiment

Method: Use the task of estimating the number of random dot diagrams as a quantity judgmental task that is ambiguous but has a correct answer. Assuming that the maximum number of dots that can be accurately counted in 10 seconds is about 26, and we will create 10 dot diagrams from 26 to 226. The number of dots here manipulates the ambiguity of the tasks. For each dot diagram, we asked everyone to estimate the numbers, verify the individual confidence of one's estimation, and predict the lowest and highest number estimates of their class.

According to the diversity prediction theorem, the performance of collective intelligence equals individual error minus diversity (Table 4.2). We can confirm that the larger the diversity, the more accurate the collective intelligence.

4.4 Empirical Research on Collective Intelligence

Collective research roughly includes two research contexts. One is the study of group dynamics (Sect. 2.2), and the other is the study of decision-making using an economic model. The latter research has a high affinity with collective intelligence research. Collective decision studies have pointed out that majority rules provide "unexpected" smart decisions.

Majority voting is a method of deciding one of the multiple options by voting and selecting the option with the most frequent value that exceeds a specified threshold (such as one-half or two-thirds). The majority rule means a decision method that chooses the option with the most votes.

4.4.1 Majority Rule

We are often asked to choose "for or against" or "vote for whom." How does a group aggregate the diverse choices of each member?

Social decision schema theory (Davis, 1973) found that groups are most likely to apply majority-equal probability models as decision rules. The equal probability means that when there is a plurality of mode choices, one of them is randomly selected. Even if the majority vote is not explicitly made, groups tend to reach the same conclusion as the majority vote. Simply put groups tend to choose the option with the most votes at the beginning and choosing randomly among the options from the same vote.

The majority vote seems to lack deliberation, that is, it is not a well-thought-out decision, but the majority vote has a high probability of reaching the correct answer. Applying the unanimous rule for group decision-making is susceptible to distribution distortion (Ohtsubo et al., 2004), but applying the majority rule has the advantage that it is less susceptible to distribution distortion.

Figure 4.2 shows the probability of reaching the correct answer using the majority rule for tasks with correct answers. The average correct answer rate for each individual is shown by the dotted line (45%), broken line (55%), and solid line (65%) (Toyokawa, 2015). Insofar as the individuals are selected from the crowds

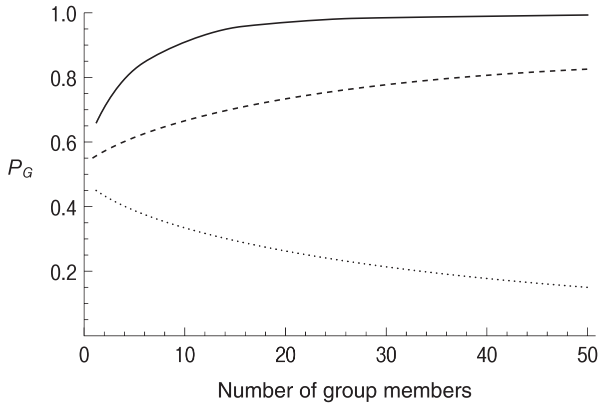


Fig. 4.2 Correct answer rate of majority rule

that consist of more individuals who have the correct answers, an increase in the number of participants would lead to a correct answer by the majority vote.

The majority rule has some defects, such as the paradox of the voting system (See Glossary G-3-2). But its usefulness, which allows the easy aggregation of decisions, is utilized in many situations.

Comparison of the Majority Vote and the Average of the Crowd

Hastie and Kameda (2005) have examined which decision rule stably brings crowd wisdom. Here we consider flocks of primitive people looking for a place to get food. The flocks must choose the best place that provides the maximum food among ten areas. The herds can obtain three types of sensory information at each point. Here, each agent is required to have the ability to select the best by weighting the three pieces of perceptual information (See Glossary G-7-2) in which errors occur randomly. The agent takes his or her decision back to the flock, and the flock determines the destination according to each decision rule. The difference in gain (opportunity cost) between the location selected by the flock and the actual best location indicates the performance of the flock.

The simulation showed that when the information is completely shared within the flock, the majority vote and the average crowd performance are almost equal, and conversely, the best members are better when there is a large difference in the ability within the group. The greater the variations in the information individuals get, the more the crowd average will beat the best members. Demonstration experiments with participants provided almost the same results as this simulation.

Evolutionary Simulation of the Majority Rule

In a social dilemma situation (Sect. 1.2.1), free riders (peoples who ride free) occur at a fixed rate, so the society pays the cost and monitors it. Is the majority vote useful even when there are free riders?

Kameda, Tsukasaki, Hastie, and Berg (2011) have examined this issue by adding evolution simulation to the setting of Hastie and Kameda (2005) described above. In the public goods model that considers resource allocation, it was shown that in groups consisting of a small number of people, free riders do not appear because individuals can get high profits by collaborating. However, as the number of people in the group increases, it is beneficial for individuals to not cooperate with the group. In a sense, having a free rider can reduce the effort of the whole society. Researchers examined the usefulness of the majority rule when such an equilibrium point appeared.

Simulations found that the application of the majority rule increased the proportion of collaborators. If the cost of cooperation was small, the majority rule yielded higher profits, but as the cost increased, the number of participants in the decision decreased, and the best member eventually won. When a nominal group (Sect. 2.1.3) is created from the individual decisions of the participants and the decision rules are applied, insofar as the reward is higher than the cost, an equilibrium point that allows noncooperators appears, but still the majority rule provided the highest profit.

The above studies show that while majority voting seems easy, it does bring out the wisdom of the crowd. It can work effectively even if the participation rate is low, such as the voting rate. However, it requires some conditions. In experiments by Kameda et al. (2011) and Hastie and Kameda (2005), social influence was excluded, but in a real society, people may make choices that are different from their own judgment. To maintain the superiority of group decision by the majority rule, Hastie and Kameda (2005) proposed the following three conditions. This proposal suggests that the majority rule is best suited for judgmental tasks.

1. In the intellectual task, the rule that the truth wins is applied.
2. Whenever there is non-shared information, it is shared.
3. Members state the truth.

Ungar (2014) has compared the majority vote with the selection based on the evaluation average value by dividing 600 participants (40 groups) into “cooperation or competition conditions.” The experiment revealed that in the intellectual task, the decision using the average value wins, while in the judgmental task, the majority vote wins. This is because, in the case of a judgmental task, obtaining the average value without removing the overlapping information among the members, the weighting of the specific area is increased and leads to an extreme outcome. In other words, the characteristic of the majority vote that “the bias is not shared too much” is advantageous in the judgmental tasks.

4.4.2 *Collective Intelligence in Tasks with Correct Answers*

Crowd within Effect

The diversity prediction theorem indicates the existence of a trade-off between the average (average intelligence) and decentralization (diversity) in collective intelligence. Even if the average intelligence improves, too low diversity reduces the performance of collective intelligence. Then, can an intentional increase in variance alone, without changing the mean value, improve collective intelligence? For example, can one get the effect of collective intelligence even if one person intentionally repeats variable answers?

Ariely et al. (2000) called the collective intelligence effect obtained by the repeated judgment of one person "the crowd within" effect and showed that it did not affect the probability judgment. Since the probability judgment has a common bias, the error cancellation effect by averaging cannot be obtained.

Hourihan and Benjamin (2010), on the other hand, made the participant repeatedly answer judgemental tasks and showed that the crowd within effect was obtained insofar as it was repeated within the short time that one could remember one's previous answers. That is, even one person can obtain the error cancelling effect by repetition.

Rauhut and Lorenz (2011) compared the conditions under which other people's answers are provided and the conditions under which one person repeatedly generates answers by oneself.

The task was to estimate the number of crimes in Switzerland. In the experiment, if the problem was easy to predict, one's repetition improved the accuracy rate. However, the effect was limited to around three times, and if it was performed more than that, the error from the correct answer was increased. On the other hand, in the case of difficult tasks, obtaining the answers of others improved the accuracy rate. These results indicate the limit of the crowd within effect.

These studies suggest that the crowd within effect is an effect that offsets the randomness of individuals' choices of predictive models, rather than creates another model.

Correcting shared bias requires the diversity of prediction models (Sect. 4.3.1). But it cannot be obtained from within an individual. Davis-Stober, Budescu, Dana, and Broomell (2014) used the results of Rauhut and Lorenz (2011) to find out conditions in which collective intelligence exceeds individuals.

Collective Intelligence Found in Distribution without Bias

Expert groups have similar viewpoints and prediction models and are likely to reach a local optimal solution (See Glossary G-7-3-5). To escape from it, the group needs to add amateurs having different perspectives. However, the inclusion of amateurs

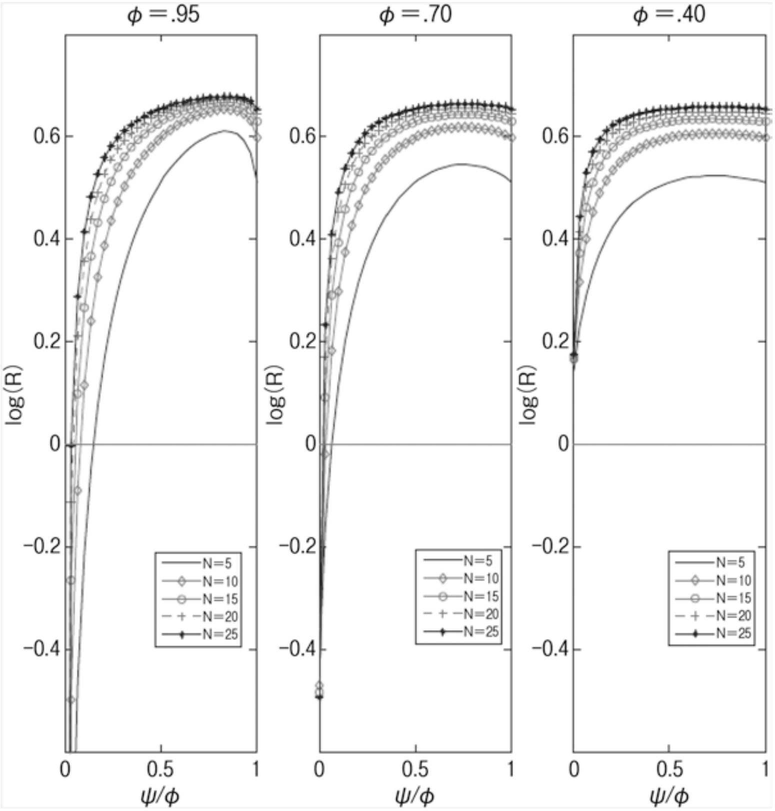


Fig. 4.3 Comparison of best member performance and collective intelligence (Davis-Sober et al., 2014)
Left graph: The correct answerability of the best member is very high, and in the case of 0.95, there is a region where the log is below 0, that is, there is a region where the best member is superior. Right graph: log does not fall below 0 if the best member correct o answer rate is about 0.04. That is, collective intelligence always wins. Middle graph: Even if the best member's correct answerability is improved to 0.70, using collective intelligence created by 10 or more people is mostly better than the best member.

who make many mistakes lowers the performance of collective intelligence. How can we avoid this type of trade-off?

Davis-Stober et al. (2014) have shown that there is a point where collective intelligence always beats the best member by using a weighted index based on the ability of each individual. Figure 4.3 shows the simulation results showing how the simple average outperforms the best members. The higher vertical axis indicates good performance, and above 0 indicates that collective intelligence is better than the best members. The horizontal axis indicates diversity within the population. The results of five conditions with different numbers of people in the group are plotted. If 95% of the best members could answer correctly, the region above 0 was larger when there was some diversity. In other words, the crowd average was closer to the correct answer than the best members. On the other hand, it is more appropriate to use the collective intelligence of ten people when the best members can answer up to 70% of the problem (center of Fig. 4.3).

This simulation is limited to the case where there is no distortion in the answer distribution of the crowd. Next, consider the case where there is a bias. When examining bias, an index called bracketing is used.

Collective Intelligence Found in Distributions with Bias

Whether there is a common bias in crowd responses will determine the applicability of collective intelligence. The bias can be expressed as the distance from the correct answer. Naturally, if the answers are distributed without including the correct answer, they cannot reach the correct answer.

A study related to such an answer distribution has been conducted by Mannes, Soll, and Larrick (2014). The researchers examined the bracketing and the differences in individual ability as two factors that affect collective intelligence. Bracketing is an index to the extent that the distribution of answers by the crowd covers the correct answers. Another factor, the difference in ability, indicates the degree of variation in individual performance. The simulation results shown in Fig. 4.4 show that the range of adaptation of the expert group is the widest. The expert group referred to here is the people selected in order of past performance, and five people are considered sufficient.

Mannes, Soll, and Larrick (2014) verified the simulation results using 40 sets of psychology research data and 50 sets of economic forecast data. In the psychology research data, the experiment participants individually answered questions which have the answers. Here, multiple question items were counted as an individual's history. The economic forecast data was the forecast data by economists from the fourth quarter of 1968 to the fourth quarter of 2012. Here five persons who had the

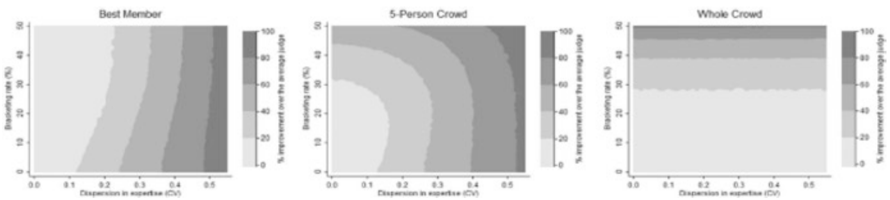


Fig. 4.4 Comparison of best members, expert groups, and crowd averages (Mannes et al., 2014)
The horizontal axis represents decentralization of ability, and the darker the colour, the better the performance.
The vertical axis shows Bracketing, and when it is high, the median value of the distribution corresponds to the correct answer.
Comparing the size of the region with moderate performance, the group of 5 experts (people with a good accuracy rate in history) is the most widely applicable.

best outcomes over the past 5 years were selected, and the average of five best members was used as the index of an expert group.

The verification using the psychological research data revealed that the expert group (five people selected in order of good outcomes) had the best performance at a rate of 53%, followed by collective intelligence (average value) at 35%. With only 13%, the best members had the best results. Data verification using the economic forecast showed that the expert group had the best performance at a rate of 68%, 30% for collective intelligence, and 2% for the best members. In each case, the crowd average was superior to relying on one expert, and following the top five was the best result. The results show that the biased-answer distribution in the problems we encounter realistically reduces collective intelligence but also reduces the performance of the best members.

The reason why the best members' performance fell below the crowd average is due to the repeated factor of "history." Even for tasks that require some ability, the performance of the best members will not last long. The athletes featured on the cover of *Sports Illustrated* are likely to slump in the next season, that is, athletes that accomplish great results are apt to return to their average at next time. On the other hand, collective intelligence (average of the crowd) can achieve stable and good performance above the best members. Repeated trials highlight the excellence of collective intelligence.

The expert groups for these experiments were individuals selected based on past outcomes. However, in an actual expert group, the judgment of each individual is not always independent, because they belong to their professional societies and they influence each other. Next, let us consider how social influence processes cause conformity.

4.5 The Social Influence on Collective Intelligence

Conformity, which reduces the diversity of opinions, could be assumed to negatively affect collective intelligence. However, conversely, collective intelligence in living communities emerged by following signals (social information) received from other individuals (Sect. 3.1.3). Here, we explore the negative and positive aspects of social influence on collective intelligence.

4.5.1 Negative Results of Social Influence

Lorenz, Rauhut, Schweitzer, and Helbing (2011) have experimentally examined the negative effect of conformity on collective intelligence using the task by Rauhut and Lorenz (2011). The aim of this research was to create an index that shows the reduction of social influence. In this research, participants receive a greater reward the closer they are to the correct answer, so there is no motivation for conformity. The

Delphi method (See Glossary G-3-5-2) was used to re-evaluate one's own answers by looking at others' answers on a PC. The experiment revealed convergence of answers by browsing the answers of other group members. Compared with the convergence rate, the group performance did not improve so much. In spite of little improvement, participants believed their answers were much better. This result shows the negative effect of social influence.

Mojzisch and Schulz-Hardt (2010) have examined the effect of the majority bias (Sect. 2.4.1.2) using a hidden profile task (Sect. 2.4.1). Participants form a group of three and are given all the information after being taught the other member's answers. After that, participants answered individually and then took the memory test that asks for the information content.

The correct answer rate was 86% under the control condition where all information was disclosed before participants knew the choice of others. Therefore, theoretically, it should have been a task that 86% of people could answer correctly. However, pre-acquisition of knowledge about the choices of others reduced the rate of correct answers and the amount of memory, even after obtaining all the information. The accuracy rate decreased to the same degree, whether the choices of others were unanimous or not. Next, the researchers compared the cases in which the other people who chose the correct answer were the majority (two people) and the minority (one person). The results showed that although the correct answer rate was high under the condition that the majority chose the correct answer, its memory capacity was lower than that under the control condition and was equal to the condition under which the minority chose the correct answer. That is, when the majority holds the correct answer, the group can reach the correct answer with a high probability, but this does not mean that the group has carefully selected the information.

This majority bias has been demonstrated in minority studies (Sect. 2.2.5). In the context of minority research, labelling of majority or minority has been thought to disturb information processing (Sect. 2.2.5).

4.5.2 Collective Intelligence when a Minority Has Valid Information

Information that people did not initially share (non-shared information), especially information held by a minority, is difficult to share (Sect. 2.4.1). Then, if the minority has useful information, can the majority rule change?

Juni and Eckstein (2015) examined the adaptability of groups to changes in the source of useful information. Researchers compared the majority rule with Bayesian rule, which changes their choice each time they get information.

Two types of tasks were used, a perceptual task to distinguish a figure from a background with white noise and a cognitive task to determine the appearance of sandstorms by looking at fictitious sandstorm prediction measurement values. The amount of background noise was manipulated as the signal strength. In the first half of the trial, all members were given the same stimulus with the same noise rate, but in the latter half of the trial, two out of three (majority) were given stimuli with many noises (hard to see), and one (minority) was given stimuli with little noise (easy to see). This created a situation where the minority had useful information. In the simulation prediction, the performance of the majority rule increased to the same level as the Bayesian rule in the first half, but the performance of the majority rule decreased in the latter half. Results from real participants showed that 96% of the groups applied the majority rule in the first half, while in the second half it changed to an average of 86%. Especially in the perceptual task, the change was significant.

In this experiment, the participants were not informed that the information environment was manipulated and the minority had useful information. The authors evaluated that nevertheless, the group was able to flexibly change its decision rules in response to changes in the environment. However, even in the latter half, 86% still used the majority rule, so there was only a 14% chance that the group would find that the minority had useful information. Information from minorities is unlikely to be shared, even without the labelling of minorities.

4.5.3 Positive Results of Social Influence

There are also reports that social influence positively affects collective intelligence.

Hertz, Romand-Monnier, Kyriakopoulou, and Bahrami (2016) compared the individual decision condition in which participants individually judge prior to group decision making and the group decision condition, in which a decision is made after group discussion. When the images were processed so one of the pairs is difficult to see, and the variance of the results was increased, the performance under the individual judgment condition decreased, but not under the group decision condition.

This experiment shows that social impacts can be positively affected if groups can aggregate perceptual information before making decisions. However, since it is an experiment using the participants of the pair, it is not enough to cause the so-called Asch-type conformity (Sect. 2.2.3.2).

Toyokawa, Kim, and Kameda (2014) examined the social influence on the selection of searching and harvesting behaviors in a group. The more people go to explore, the more information the group can collect, while the free riders who imitate others and just harvest are more profitable for the group. For each of the 30 locations, the following 3 conditions were compared: a small social influence condition given information on the number of people selected, a large social influence condition given the average rating for each location, and an individual condition without information. The results show that even when free riders exist, the social influence condition leads to a decrease in exploration time and an increase in harvest time, compared to the individual condition. The learning effect was better in the small social influence condition but decreased in the large social influence condition.

4.5.4 Experimental Models of Social Influence

Mavrodiev, Teesone, and Schweitzer (2012) showed by simulation that social impacts could act both negatively and positively.

The simulation model is based on the mean-field theory that expresses the amount of change of one's opinion at a certain time according to the social influence + individual condition at each time. While people make Brownian movements, they are attracted to the average value, and this model defines its power as social influence. Its sensitivity to social influence and individual confidence are parameters.

In previous studies, the error was calculated as a squared value, so the direction of change could not be examined. In this research, however, it became possible to examine the direction of change. The analysis revealed that social influence depends on whether or not the crowd (geometric mean) moves closer to the correct answer by moving toward the mean value. After approaching to some extent, the convergence of the crowd tends to act negatively.

The results of the previous collective intelligence study (Sect. 4.4.2.3) have shown that no matter what distribution the group answers start from, the collective intelligence outcome is better than the best members. With a certain degree of independence from social influence, the majority with a wider perceptual range is more likely to arrive at the correct answer. However, majority bias (Sect. 2.4.1.2) can disturb collective intelligence. Considering the possibility of changing to an environment where a minority has the correct answer, the group is then required to adjust and discover new answers from diversity.

4.5.5 Cognitive Toolbox

Diversity is necessary for emergence and finding a new "answer." We can understand the process through the concept of Page's cognitive toolbox.

Page (2007) defined intelligence as a cognitive toolbox.

The toolbox includes "perspective," "interpretation," "heuristics," and "prediction methods." Perspective is a method for expressing a situation or problem, and interpretation is a method for classifying viewpoints, and heuristics is a method of finding the best solution. Suppose we create a LEGO block; the perspective corresponds to attributes such as the color and size of a block, and interpretation corresponds to a method of classifying blocks. For the task of merely stacking the LEGO blocks, one heuristic is enough, but we need to try various heuristics for the complicated task of achieving beautiful modelling.

Page showed through simulation that the diversity of these cognitive tools improves the performance of collective intelligence. Since a uniform group has the same local optimal solution (See Glossary G-7-3-5), they tend to stay there. In other words, diversity is necessary for complex tasks that are often prone to getting stuck because there are many local optimal solutions. Simulations show that diverse heuristics bring small but steady improvements, and diverse perspectives cause brilliant breakthroughs. If the groups are diverse, it is considered that 6–7 members will be sufficient to create collective intelligence.

However, on the contrary, diversity may negatively affect collective intelligence. It is the axis on which to evaluate the results, i.e., the variety of preferences. When people are unable to match their preferences when evaluating deliverables, it creates conflicts.

4.6 Distributed Cognition in Teams

Distributed cognition (Sect. 2.1.3.3) means that various information is distributed among members, while the team shares the knowledge structure. Hutchins reported the most prominent example of distributed cognition supporting the division of labor. Hutchins observed how the navigation teams work efficiently by dividing labor while monitoring other members as appropriate. However, it doesn't always work. There were also cases in which the two people make false predictions that they will "spin around to the other side," resulting in a collision (Hutchins, 1991).

If people incorrectly predict the "hypothesis of the other party," the division of labor will fail. In this book, the case of emphasizing the monitoring aspect of "what others know and do" is called shared metacognition. Shared metacognition is required to accomplish distributed cognition.

For a group to express emergence, the effect of combining the potentials of members while maintaining variation by using distributed cognition is the key. At the end of this chapter, we will enter the field of organizational psychology and introduce research on distributed cognition in teams.

4.6.1 Shared Mental Model

Consider the offside rule of soccer. Players recognize what they are, where they are, and what they do next, and then take cooperative actions quickly. The shared mental model makes this possible.

Like soccer, performance in technical tasks depends largely on mental models that cannot be verbalized, such as visual images and scripts. The more difficult linguistic communication becomes, the more shared mental models are needed. A shared mental model is a knowledge structure that people implicitly share to coordinate their work.

Even in situations where communication can be achieved, high sharing of mental models can save cognitive resources. Schwartz's (1995) verification using the task of solving the movement of gears revealed that when people individually try to solve a problem by drawing a concrete image, whereas when peoples working on the task in pairs, they tend to try to solve the task using a concept with a higher degree of abstraction. As one communicates with others and tries to tackle the problem, there is a need to transform one's image into a sharable abstraction. In that process, the process loss (Sect. 2.1.2.2) occurs. However, if the images are shared in advance by the mental model, the process loss can be reduced.

4.6.2 *IPO Theory*

There are two types of shared mental models: those related to teamwork (knowledge about members and interaction rules) and those related to issues (technology and strategy). The teamwork-mental model supports shared metacognition that allows mutual monitoring. The model in which the mental model influences the performance through the team process is called IPO (input process output) theory. Figure 4.5 shows one of the typical models.

Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) have examined the effect of sharing mental models related to tasks and teams on team performance in combat flight simulators. Researchers calculated the index of shareability of the mental model using network analysis (Sect. 3.4). Team processes were evaluated by indicators such as communication volume and monitoring behavior. The verification revealed that the shared mental model influences the team process, and consequently, the performance (Fig. 4.5).

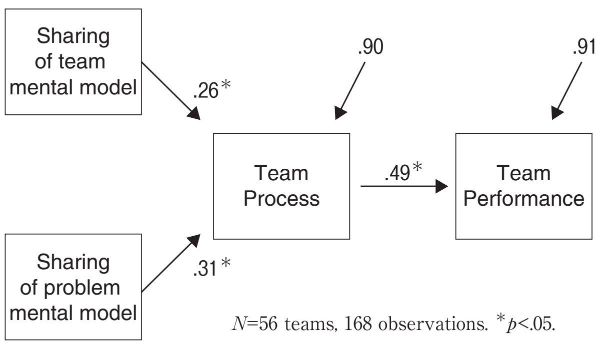


Fig. 4.5 Example of IPO Model Study: Impact of the shared mental model on team process and performance (Mathieu et al., 2000)

4.6.3 Measurement of Shared Mental Model

There are two indicators of the "quality" of the shared mental model: accuracy (closeness to experts) and similarity between members. The more accurate and the more similar they are, the better the performance.

There are various measurement methods. DeChurch and Mesmer-Magnus (2010) have performed a meta-analysis on 23 papers to examine the one with the most improved performance of the shared mental model among the following 3 measurement methods: (1) information extraction, (2) representation structure, and (3) sharedness (Table 4.3). The meta-analysis revealed that there was no difference in the performance predicting ability according to the measurement method, but regarding the team process, the predicting ability by (3) sharedness was highly evaluated. The Mathieu study introduced above also adopted this method.

Schuelke et al. (2009) have examined the effect of a shared mental model on skill acquisition in video games. Experiments revealed that a team that had a shared mental model could easily generalize from a keyboard to a joystick (Sect. 1.1.4.4). For the analysis of this experiment, researchers used the pathfinder in (3) (Fig. 4.6).

There is a study that has easily measured a shared mental model by a questionnaire. Akiu, Nawata, Nakazato, Kikuchi, Nagaike and Yamaguchi (2016) measured the sharedness of mental models in the work ranking list, which is important for opening food stalls at the school festival. Then, the relationship between those measured values and the sales amount was examined, and it was found that the sharedness of the mental model increased the sales.

Table 4.3 Measuring method of shared mental model

1. Information extraction	This is a method that attempts to measure the content of knowledge itself. Cognition of task content is measured using questionnaires, card sorting (choose how to respond to the task from cards), concept map (evaluate the relevance of the task), and so on. Here, how close the answers are to the correct answer standard (expert answers) is examined. When the knowledge of the participants and the knowledge of the expert are compared, the closer to the expert, it is referred to the better the mental model.
2. Representation structure	This method attempts to measure knowledge structure. After measuring the knowledge content, measure the script and the associative semantic network using pathfinder, UCINET, MDS, etc. this method verifies how efficient the knowledge structure was created, rather than the difference from the correct answer.
3. Shareability	This method attempts to measure a degree of sharedness within a team. Use pathfinder or UCINE to analyze each pair of members and judge based on the commonality index. This method verifies how much knowledge structure was shared. Pathfinder is a method of calculating network structure from data that evaluates the relationships among all tasks. Network similarity is an index of the shared mental model.

Fig. 4.6 Analysis of group problem-solving process using network RPG (Arima, 2017)
A scene where three team members gather in the same field and have a conversation.

4.6.4 Transactive Memory

Transactive memory is a memory system for memorizing and retrieving by integrating memories from different knowledge areas (Wegner, 1995; Austin, 2003). Wegner has proposed three requirements for establishing the transactional memory: specialization (variation in memory among members), credibility (reliability of other members' memories), and coordination (optimization of collaborative work). The concept of transactive memory is overlapped with the shared mental model, and it can be thought of as shared metacognition that holds based on the shared mental model (Mohammed & Dumville, 2001).

The DeChurch meta-analysis introduced above does not include the research of transactive memory in the analysis target. Since transactive memory refers to the effect of saving cognitive resources by integrating memory, it is better that there is less overlap. On the other hand, in the study of the shared mental model, researchers consider that the larger the overlap of knowledge, the more efficient the team process, and the better the performance. Which hypothesis is correct?

The difference between the two theories may be due to the different stages of development of the teams. A shared mental model is formed during the role formation phase (Pearsall, Ellis, & Bell, 2010). On the other hand, teams that consist of the same members for many years can easily establish transactive memory (Thompson & Fine, 1999). Regarding the developmental stage, teams need to overlap knowledge for communication in the early stages, but since the amount of information handled by the team increases in later stages, teams need to decentralize the knowledge contents. What is needed there is the transactive memory that can share the knowledge structure. As the study of collective memory suggests, sharing the knowledge structure increases the memory capacity of the group.

To reach the stage of transactional memory, it is necessary to "refine memory (associate)" to fit each individual's knowledge into the task-related knowledge of other members. The elaborated transactive memory forms latent memory (Sect. 1.1.3.1) running subconsciously. In this state, the need for verbal communication is reduced.

4.6.5 Sharing Inference Process

Maciejovsky, et al. (2013) have examined whether it is possible to share the mental model of others in the competition scene of an auction (See Glossary G-3-3-1).

For the trial, a question was created by modifying the four-card problem (Sect. 1.1.5). Participants sell their cards and purchase cards held by other participants to see if the rules hold. Participants must collect cards efficiently, but if they do not hide their intentions at the same time, other people's cards will become too expensive to buy.

The correct answer rate for the four-card problem was 9% for the participants who answered individually, but 50% for the groups who cooperated face-to-face. Even if one person repeats the trial, the correct answer rate rises only to 38%, so the cooperation probably transmitted the inference process to about 30%. Researchers investigated how much this transmission efficiency changes under competition condition. The experiment revealed that when there was success/failure feedback in each trial, the correct answer rate increased to 49%, which was improved to the same level as the cooperative condition.

This result suggests that the mental model can be shared to a certain extent even under competition and that relationships such as competition and cooperation do not affect the sharing rate of the mental model. Searcy and Shafto (2016) considered that intentional omission rather than disclosure of all information promotes inference learning. The result may be surprising for the team research that has emphasized cooperation.

4.6.6 Effect of Training

Can training develop a shared mental model?

Argote (2014) has investigated the difference in performance when training to undertake radio assembly individually or as a group. Team training has less total training time than individual training; nevertheless, the group performed best under the condition of training followed by testing. This is because members who are familiar with each other can monitor each other's work and collaborate more easily. On the other hand, however, there have been reports of cases where monitoring behavior reduces performance.

Burtscher, Kolbe, Wacker, and Manser (2011) have examined the effect on performance of monitoring behavior in anesthesiology nurse teams. The study revealed that monitoring decreased the performance when the sharing of the task-related mental model was low.

Marks, Sabella, Burke, and Zaccaro (2002) have compared the effects of training on teams among three training methods: role clarification (lecture), modelling (observation on video), and rotation (work exchange). As an index of the shared mental model, the team average of the two-person similarity measured by Pathfinder was used. The results showed that the effectiveness of each training method depends on the task. Video observation training was most effective for games in which members worked on the same screen, but lectures were more effective for games in which members worked on different screens. That is, observational training was not effective in tasks where images could not be shared.

4.6.7 Formation Process of Shared Mental Model

The author has also conducted observational research on shared mental models. Arima (2003, 2005) created a network RPG and investigated the problem-solving speed for two types of puzzle tasks. Two tasks comprised a puzzle that can be solved by sharing participant's screen and a puzzle that cannot share the screen. The results revealed that the early release of non-shared information to the team led to early problem resolution and shared a team mental model. On the other hand, the amount of communication within the team and the problem-solving speed was negatively correlated. In other words, a team that was able to share information earlier with a small amount of communication could solve the puzzle faster. Members of such a team felt that they had resolved without being aware of it, and rather, the team with more communication was more satisfied.

A more detailed behavior analysis found that the group was gathering on the same screen to chat, not to solve the problem. The group wanted a sense of screen sharing to share the context of "what the other person is talking about." The behavior observation of each member also captured behaviors such as a break in the exploratory behavior to confirm "what the other members are doing" visually. Fast resolution of puzzles that cannot share a screen required a division of labor to explore other places. Therefore, the team with more communication resulted in slower solution speed. This is one of the reasons why monitoring behavior reduces team performance.

Interestingly, even in the first meeting of the group without training, a team that can quickly solve problems by job distribution for exploring various directions has appeared. The questionnaire revealed that participants assumed different procedures to solve the tasks, so they did not share the task-related mental model. Even so, the members were found to decentralize and to explore. There may have been shared metacognition to try to explore places that no one has explored, but what caused this shared metacognition is not communication. Because the team had little communication, there was an action of naturally decentralizing and communicating only when the information was found. This process is similar to the collective decision making (Sect. 3.2.3) process that goes through the decentralize phase-aggregation phase-decision phase observed in swarm intelligence.

4.7 Summary

As introduced in Chaps. 1 and 2, there are various constraints on the cognition of individuals and groups. This chapter summarized the conditions under which collective intelligence can be generated in the face of such constraints.

Even if the answer distribution is distorted, collective intelligence will exceed the best member at a high probability. The use of professional crowds as a source of collective intelligence almost always results in a better outcome than the best members. If no expert is found, majority voting can be used as a convenient approximation.

Conformity can act positively or negatively for collective intelligence, but the majority that has a wide perception range is more likely to be correct than the others. The wisdom of crowds can be utilized extensively, so the stereotype that crowds are stupid can be denied.

On the other hand, group process studies have shown that groups rarely outperform the best members. Several possible causes led to a different conclusion between group process studies and collective intelligence studies.

1. Collective intelligence research considers repetition factors. Since the best members' performance is unstable, collective intelligence is relatively advantageous.
2. Group process research has been conducted by researchers with a sense of the problem, trying to prevent major accidents and incidents. As a result, there is a historical background that researchers have focused on events that are significant but have a low probability of occurrence.
3. Automatic processing cognition and behavior contribute to the emergence of collective intelligence. People's behaviors and knowledge are combined, and through distributed processing, a phenomenon appears to be "intelligence." However, individuals are not aware of it as an "intelligent" process because they are subliminally driven by automatic processing and solve the problems without understanding. These differences make the gap between the image of stupid crowds and that of wisdom.

4. Laughlin, Bonner, and Altermatt (1998) pointed out that the complete sharing of information is necessary for the group to reach the performance of the best member. On the other hand, with collective intelligence, distributed processing can process more information using more variables. In other words, the difference in the amount of information and the complexity that can be handled makes the difference between collective intelligence and the best members. Collective intelligence also adapts to complex problems where not all information can be processed at the individual level.

The shared mental model does not directly affect performance but improves performance through a team process. However, if there is no sharing of the same scene, monitoring behaviors that interfere with each other's behaviors may rather reduce team performance. In addition to information sharing through explicit communication, shared metacognition that implicitly creates cooperative behavior will improve team performance.

As discussed at the beginning of this chapter, gaining knowledge about the answers that collective intelligence has guided breaks the prerequisites for collective intelligence. The collective intelligence phenomenon working in society will be achieved as distributed cognition that is shared without knowing it. The next chapter examines collective intelligence in organizations and societies.

Chapter 5
Collective Intelligence in Organizations

Airplanes are made not just by companies involved in aircraft manufacturing. Somewhere in the world, someone digs and refines raw materials, and various organizations design and assemble parts. Languages and customs vary by region, but reliable products are completed. The feat is accomplished by the collaboration of ordinary humans, not the highly qualified top five experts. Such distributed processing systems are the result of the adaptation of many organizations rather than being designed intentionally by someone.

There is a limit to the amount of information an individual can hold, and there are individual differences in the semantic network (Sect. 1.1.4.1). We humans use distributed cognition without being aware of it, and it can be said that it is a kind of "automatic processing" in society. Insofar as an unexpected accident does not occur, this automatic processing continues to work. On the other hand, if the output differs depending on the individuals, a reliable product cannot be completed. The "controlling process" of making rules and adjusting meaning through communication is a necessary process for cooperation, even if it impairs diversity. How do organizations and societies maintain this balance?

5.1 Organizational Psychology

An organization is a group in which the role structure and task structure of the group are clarified and shared among its members (Sect. 2.1.1). The quality of an airplane should not change just because one member of the organization is absent. Organizations are required to be able to maintain the same outcomes and qualities, even if members are replaced. This requirement has various factors not only from members but also from the external environment involved in the organization. It is the organization, not the particular individual, that is able to handle these while maintaining the required functionality.

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5.1.1 Performance

First, describe the basic concept of organizational psychology.

In organizational psychology, a distinction is made between task performance and adaptive performance, but in this document task performance is referred to as performance. This is a general term for an index of outcomes when a group works to complete a task. Various indicators of performance can be measured such as work amount, task speed, accuracy, memory capacity, correct answer rate, etc., depending on the task. For example, in the case of a problem-solving task, to solve the problem quickly and correctly indicates high performance.

Intelligence tests can be used to assess individual cognitive ability, which promotes the improvement of knowledge and performance. However, performance does not correlate with intelligence test subscales, such as language, mathematics, and spatial cognition, but with the general "g factor" of the IQ. For more complex tasks, the predictive ability of g factor is higher than the predictive ability of any of the subscales.

5.1.2 Job Satisfaction

Job satisfaction is often used as a dependent variable with performance. However, the correlation between job satisfaction and job performance shown by meta-analysis is only about 0.17 to 0.30 at most (Judge, Thoresen, Bono & Patton, 2001). When measuring the effectiveness of intervention by organizational restructuring (Sect. 5.1.5), it is necessary to measure performance rather than job satisfaction.

A factor that correlates with job satisfaction is an organizational commitment—an organizational affinity with the organization's goals and an inclination to stay at the organization. Since personal goals such as promotion are apt to create conflicts within the organization, an organizational commitment needs to be embrace the goals as a whole. Organizational commitment increases by fairness, cognition, and leadership. However, organizational commitment cannot improve performance. Sunk cost, a perception that one cannot stop working now because of the effort and time that one has already spent, affects commitment and increases job stress.

Fairness

Whether one receives a reward that matches one's own effort in comparison with others affects the cognition of fairness.

Distributional justice theories have proposed several norms including: equality (uniform distribution in equal parts), need (distribution to a necessary place), and equity (cost-matched distribution). Among them, equity is related to fair distribution. Fairness cognition improves when procedural justice (consensus about means of distribution) fairness is satisfied. Improving fairness reduces stress and enhances job satisfaction and organizational commitment.

5.1.3 Job Stress

Stress affects the autonomic nervous system and immune system and sometimes causes an acute stress reaction. Chronic stress can also cause depression and cardiovascular disease. Job stress refers to the state where stressors—e.g., human relationships, work environment, and role stress (role conflicts and vagueness of roles—are considered to be in the workplace. Problem behaviors resulting from stress (e.g., insomnia and drinking) can mediate the increase of the retirement rate, accident rate, and suicide rate.

Due to the recent revision of the Japanese law, business operators are required to take stress check tests and respond accordingly (See Glossary G-6-1).

5.1.4 Organizational Restructuring

An organization must change its organizational structure according to the development of the organization and environmental changes. Organizations that cannot be restructured would be culled.

Since the modern age, many organizations have changed from a hierarchical structure (centralization) to a business division system (decentralization). In the industrial era, organizations promoted the standardization of knowledge and quality control, and then, with the subsequent globalization and post-industrialization, organizations adopted the hybrid type as a general organizational form (Grove, 1983). The hybrid type consists of multiple business units and a functional organization that controls them. Businesses that must respond quickly to the environmental changes will be separated, but this creates issues such as resource distribution competition between business divisions and lack of communication. Therefore, to deal with the issue, a matrix type of organizational form was created in which a temporary team was double-affiliated. In the matrix type, functional teams are placed across business units. For example, this corresponds to the formation of a university-wide committee that covers all departments of a university.

In recent years, information has accelerated the speed of change, so it is difficult for even the matrix type to respond to change. Therefore, recently, some organizations (mainly IT companies) have adopted the network-type organization that uses the informal network, or organizations are doing business while rearranging the teams as a temporal organization.

5.1.5 Organizational Development

Organizational development means investment in human capital to improve performance. This also aims to reduce stress and improve job satisfaction. It is often conducted by consultation by a person in charge outside or within the organization. This enables the discovery of the problems in institutional design and provision of training to work on human factors. Training methods include the small group training type that originates in group dynamics research, the research type that provides feedback through surveys, and the action research type that performs surveys before and after interventions such as leadership training. Although each of them is based on organizational psychology, a poor training effect is pointed out.

Inside the organization, the personnel department, manager, and labor management staff are responsible for organizational development, and in recent years, a method called coaching has attracted attention. In coaching, managers use one-on-one interviews to listen to the problems faced by team members and provide specific feedback to improve performance. Here, the emphasis is on observing the growth of team members and making an appropriate delegation of tasks.

For leaders to give specific feedback to team members, they are required to have professional abilities (knowledge and skills) equal to or higher than those of team members. If there are leaders who lack the ability, training must be provided. The upper management of the organization also needs to find and develop leaders lacking the specialized ability.

When the environment changes drastically, leaders are forced to enhance their knowledge and skills constantly. The higher the position in the organization, the more knowledge and skills there are to learn, and the state of lack of ability can become a bottleneck for the development of the organization. In many cases, the job rotation system that trains generalists is adopted as an executive training system, but it is also reported that training specialists from the beginning improves performance because it avoids bottlenecks.

5.2 Organizational Science Applying Collective Intelligence

Kellerman (2012), who founded the leadership center at Harvard University, summarized the failure of the leadership training business.

One example is the case where a business magazine's most acclaimed leadership training program had been introduced by a financial company that was criticized for offering huge bonuses during the financial crisis. One cause of failure was that the training effect was measured only by the degree of satisfaction of the participants.

Job changes often diminish the performance of talented investment bank analysts because environmental factors are involved in this decline. To remove environmental factors and examine the performance, changes before and after intervention should be compared to controls. To allow this, the organization must always gather sufficient data from the workplace. In recent years, performance-based goal management has been abandoned (Bock, 2015), largely due to the promotion of evidence-based organizational development by US companies. The following part is a description of Google's evidence-based system of management.

5.2.1 People Analytics

Google's human resources department uses an approach called people analytics to analyze performance with data. The Google website "re:Work" contains current information about people analytics (https://rework.withgoogle.com/). Bock (2015) introduced some of the ways Google uses people analytics.

Recruitment

An interviewer selected from all employees individually conducts structured interviews (interviews in which question items are specified in advance), and the final hiring decision is made by the human resource's recruiting committee. The best indicators for predicting work ability were (1) work sample test (contribution rate 29%), (2) general cognitive ability (26%), and (3) structured interview (26%). A follow-up survey of the achievements after recruitment revealed that the interviewers' evaluation average (collective intelligence) correctly evaluated the applicant's ability rather than the interviewer with the highest evaluation ability (best member). The correlation between the school from which one graduated or academic performance and work performance decreased within a few years after hiring.

Educational information is apt to influence an interviewer's evaluation as signaling at the time of reverse selection; when there are too many applicants for one post. However, Google has stated that they do not consider the educational background, based on the idea that the most important task of organization is recruitment.

Leadership Evaluation and Training

A long-term follow-up survey on performance revealed that transferring a manager to a team who is highly evaluated by members improves the performance of subordinates and lowers the retirement rate. This has led to the recognition of leadership as an important environmental factor.

Google requires a manager (leader) to have the same or more technical capabilities as team members, so the technical capabilities are almost the same among the managers. In other words, factors other than technical ability influence the performance of the leader. The analysis revealed that two factors, coaching skills and empowerment, determine team performance and member retirement rates. Based on these findings, managers with low scores for coaching and empowerment undergo a training program. Google created a training system within the organization since they consider training by outside consultants useless. Not only middle managers but also senior managers are evaluated anonymously by team members.

In the cases introduced above, Bock (2015) may describe only the good aspects of Google. Nevertheless, scientific verification of performance does show the effectiveness of collective intelligence and that even large corporations can improve performance by empowering its members. However, the projects that had not been decided as an organization, Larry Page, ex-CEO of Google, was supposed to decide it alone. In other words, a flat organization requires a gentle lifelong dictator. However, there may be a risk that it cannot be corrected when the final decision-maker's perception becomes distorted.

Organizations that utilize collective intelligence intervene in highly influential factors based on data rather than theory and make corrections while observing their effects. Actually, the basis of their way of thinking is a data-first approach to search by matching with a model, rather than hypothesis verification, which is advocated by psychology. A statistical approach using social physics is used to make meaning of the data.

5.2.2 Social Physics

Social physics is a field that uses statistical methods to predict behavior by measuring people's behavior quantitatively on a time series. Even if an individual human behaves with free will, the average probability of specific behaviors can be calculated for a large number of cases. Quetelet (1942) proposed the term social physics from an early stage and pointed out that similar distribution patterns appear every year in the number of murders and the methods of murder. In the United States, where machine learning is advancing, attempts are being made to strengthen patrols by predicting areas where crime is likely to occur.

Statistical Physics

The basis of statistical physics is the law of large numbers. The large number effect means that an increase in the number of elements with independent fluctuations brings the sum of fluctuations/N closer to zero. For instance, the Brownian motion causes the speed of molecules to be normally distributed. The speed change of molecules is measured as temperature. In the case of water molecules, the state changes to ice or gas at a specific temperature. Such a phenomenon is called a phase transition. As the molecule approaches the phase transition, the independence of fluctuations is diminished, and order emerges from the fluctuations (See Glossary G-7-1).

Although not all human beings are uniform and exchangeable, if the interactions of a sufficient number of elements are combined, it is possible to make a model of replaceable elements.

Give it a Try: Phase Transition

Searching videos for self-organizing search terms gives us a variety of interesting examples. The phase transition (See Glossary) created by the magnetic field can also be seen in macroscopic magnetic frustration. Let's observe the process and structure of particle interactions reaching phase transition.

Collective Intelligence in Social Physics

The less the conformity derived from the information cascade and social influence, the higher the group diversity and the effect of collective intelligence. However, conformity does not necessarily lead to maladjustment. The imitation of good strategies of others will improve group performance. What degree of conformity is the most adaptive as a group?

Pentland (2014) has analyzed the behavior of traders in online financial transactions to clarify this issue. Pentland asked traders of the study's participants to trade while communicating on social networks and analyzed the relationship between the ratio of the traders imitating the trades of others and the resulting profit.

Simulations predicted that traders would be most efficient when they spent 90% on social learning and 10% on personal learning. However, experiments on actual trading behavior yielded a 30% higher profit than the isolated state when the trader's conformity was moderate. Figure 5.1 shows the results. The optimal conformity rate

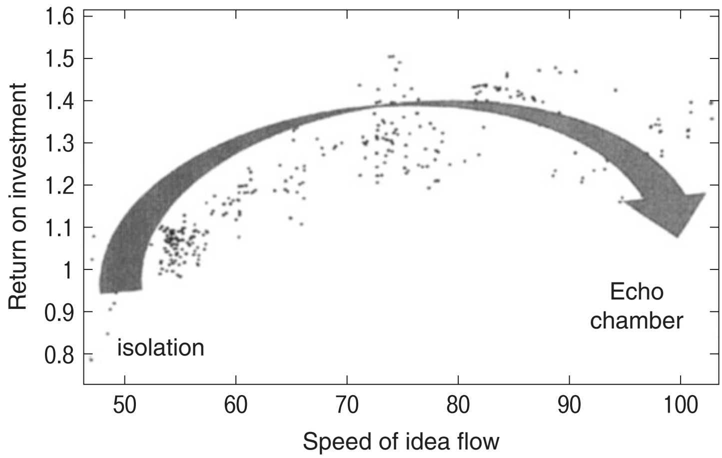

Fig. 5.1 Relationship between conformity and profit ratio: Social traders vs. Non-social traders (Pentland, 2014)
Each point represents the average of the trading performance that the trader got in one day. The vertical axis shows the return on investment in social trading, and the horizontal axis shows the speed of idea flow in social networks. With a moderate level of idea flow, social trading increases the return on investment by 30% compared to when trading individually

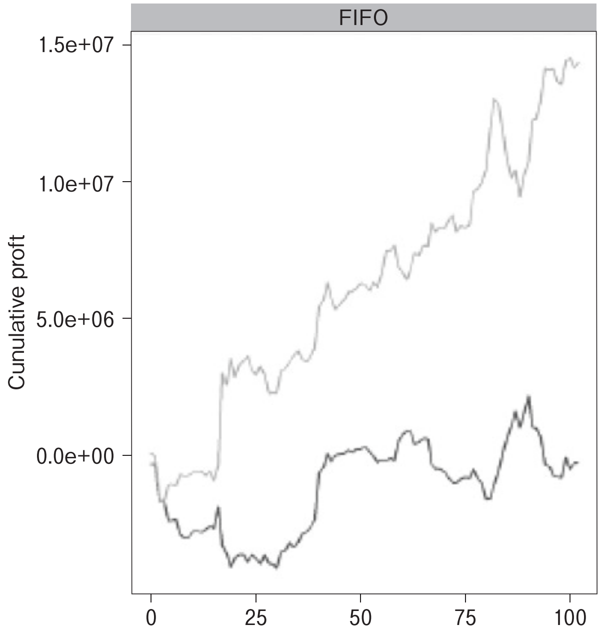

Fig. 5.2 Relationship between conformity and profit margin of stock trader (Romero, Horvat, & Uzzi, 2015)

will probably vary depending on the task and environment, but there must be an optimal value in the middle that is neither complete conformity nor complete independence.

Romero, Horvat, and Uzzi (2015) have analyzed the data of short messages sent by hedge fund traders over 2 years. After the stock price fluctuated, they examined the latency of the first person sending an IM and the latency of the recipient sending an IM to the next person. Then, it was found that the quicker the reaction to stock price movements and the more ambiguous the content of the message, the greater the influence. Figure 5.2 showed "message contents (positive/negative)," "profit from collective intelligence that simulates trading from the ratio of mentioning the same stock (light line)," and actual profit of the fund (dark line) as stacked graphs (Fig. 5.2). This graph shows that it is more profitable to follow collective intelligence. Based on research in recent years, machine trading has come to be used instead of human beings making judgments on stocks and trading them.

Pentland's Social Physics

Pentland (2014) has argued that economics and sociology, which have attempted to explain people's behavior by dividing them into social categories, are no longer able to capture change. Besides, Pentland entered the field of social science by using mobile sensing (data obtained from smartphones, etc.) as his method.

The data collected by mobile sensors is not limited to email and SNS, but is diverse, such as the distance to other people one faces, the pitch of voice, and body movements. These data were averaged at short intervals to analyze the influence relationship in interpersonal situations. Here, a machine learning method was used in which sampling was repeated from the data to verify the model. As an example, when the audiences were asked to evaluate the business plan of management students, the audiences highly evaluated students with high consistency of gestures and voices. Surprisingly, the content of the business plan itself was not related to the audience's evaluation. Pentland argued that the intuition that people have gained from nonverbal communication is more "correct."

Pentland's field study on group problem-solving, nonverbal communication responses gave the correct answers faster than verbal reports. Experimental results such as the gambling task also have shown that automatic processing precedes conscious decision and supports human decision-making (Bechara et al., 1994) (Sect. 1.1.6.1). On the other hand, it has also been shown that automatic processing causes bias in various inferences (Sect. 1.1.5). Therefore, it is necessary to investigate further whether the unconscious conformity phenomenon of the group can increase the accuracy rate.

Rather than the synchronization of nonverbal responses directing people toward smart decisions, emotions associated with decisions can also trigger nonverbal responses. Falk (2014) examined whether advertising success rates could be predicted by brain activity. The subjects were presented with photographs showing positive, neutral, and negative emotions and predicted the success rate of the campaign using the photographs. The result revealed that average brain response correlated with campaign success rate. In particular, the effect of the emotional campaign was the highest. Falk called this unconscious collective cognition. Although it is difficult to examine the causal relationship because the brain process has not been completely clarified yet, it is remarkable that Pentland'study clarified that a group also has an automatic unconscious process. These findings are also applied to the organization study.

People Analytics Using Mobile Sensors

Organizational research by Waber (2013) using mobile sensors has found that increasing the amount of communication through informal networks improves the performance of the entire company. Informal networks are identified by communication (frequency of conversations and messages). The higher the cohesiveness, the more open the information and the higher the performance. The cohesiveness referred to here is an index indicating a network with a high density and a large amount of communication.

In the analysis of results, Waber (2013) revealed that the effect of being on a highly cohesive network on individual performance is 30 times higher than the influence of years of experience. On the other hand, Waber found that individual performance did not relate to the number of network links and betweenness centrality (Sect. 3.4.2.2). In other words, increasing the amount of communication rather than increasing the number of relationships contributes to improving business performance. In the field study, promoting the communication between departments by means such as having lunch breaks for members at the same time and enlarging the lunch table improved performance.

In addition, Waber (2013) has found that when a person with a high degree of specialization came into the network, rather than a person with broad experiences, the overall performance of the network improved. Therefore, Waber concluded that a personnel system based on job rotation is outdated and that training professionals will improve business performance. While the outcomes of members who have gained connections with highly professional members will increase, the highly professional individuals themselves tend to lose performance due to the time spent educating team members. Therefore, Waber recommended that bonuses for achievement improvement should be given on a team basis, not on an individual basis.

5.2.3 Team

A team is an interdependent group that shares the same goals. In many cases, this refers to an internal organization such as a project team created for each task, but in a startup company, the entire organization can be treated as a team. According to Google's case report, 20% of working hours can be used freely by individuals. For example, you can set up a demo site for a new idea and have your colleagues rate it. This aims to repeat the "trial and error" within the organization, in which the threshold for starting a team is set low and a team with poor performance disbands immediately. Although this procedure is the same as natural selection, the cost for the company and the risk for the employee would be low because the employees are not selected, but only the ideas are selected.

Factors that Improve Team Ability

In recent years, even Japanese companies have come to respect diversity, and a certain percentage of women are added to teams that are mostly men. Nevertheless, sometimes there is resistance to the entry of new members who are perceived by the original members as having inferior abilities or different values.

However, MIT's collective intelligence research shows that diversity of members improves group wisdom. The wisdom referred to in this study is the ability to solve a problem with a correct answer, such as a puzzle, quickly and accurately. Woolley, Chabris, Pentland, Hashmi, and Malone (2010) made groups perform various tasks, such as inference tasks, idea creation tasks, and skill tasks, and found general intelligence factors for groups. Woolley and colleagues called this the "general intelligence c factor of the group." For simple understanding, we call the general intelligence g factor score measured by the intelligence test as "individual intelligence" and call the c factor score as "group intelligence."

An analysis of the effects of group intelligence, best member intelligence, and the average of individual intelligence on other group performance (e.g., computer vs team checker match) showed a correlation of 0.52 between group intelligence and performance, whereas a correlation between members' average intelligence and group performance was 0.19. These results indicate that group performance cannot be predicted by individual intelligence, but can be predicted by group intelligence.

Member satisfaction and cohesiveness (solidarity among members) were not related to group intelligence. Communication has been found to be the key to improving collective intelligence. The key factor was not the amount of communication, but the variance of the amount of communication. That is, speaking equally among members makes the group smarter. Even in online situations, group intelligence decreases as a small number of people do most of the talking (Engel et al., 2014).

Also, increasing the ratio of women in the group improves the intelligence of the group. This is an effect mediated by social sensitivity. For example, the facial expression decoding (reading subtle emotions such as shyness and guilt from the pictures displayed with both eyes) is correlated with collective intelligence (Aggarwal et al., 2015). This correlation remains the same in both face-to-face and online groups (Fig. 5.3) (Engel et al., 2014).

However, a reanalysis revealed that the contribution of the group intelligence was overestimated because an appropriate hierarchical analysis was not performed in these studies (Crede & Howardson, 2017). Collective intelligence indicates what remains after subtracting the knowledge and ability required by a task. What matters is the equal participation and social sensitivity to achieve it, rather than satisfaction and commitment that were traditionally emphasized in organizational psychology.

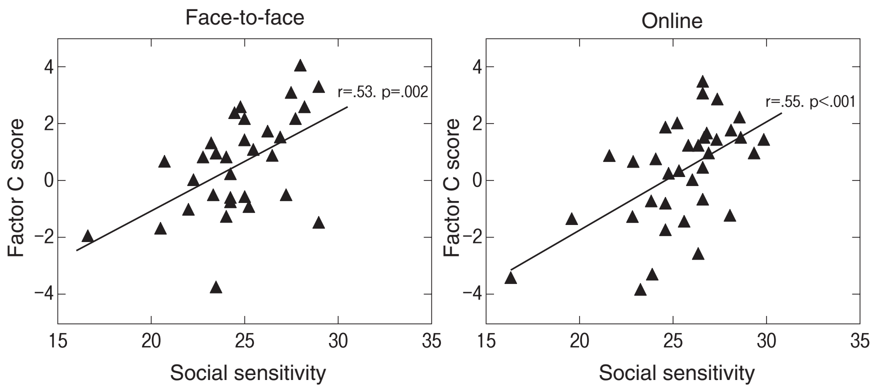

Fig. 5.3 Relationship between social sensitivity and collective intelligence (Engel et al., 2014) The horizontal axis represents the score of the test of reading facial expressions from the eye photograph, and the vertical axis represents the collective intelligence score

5.3 How to Select Experts

In some cases, temporary team members may be gathered from outside the organization. It may be useful in selecting experts to think about the best way to collect "knowledge."

5.3.1 Collective Intelligence by Experts

Wolf, Krause, Carney, Bogart, and Kurvers (2015) verified the usefulness of collective intelligence for the diagnosis of breast cancer. The specialists were shown the mammographic images and asked to decide whether to order a reexamination. Since it is already known to be malignant, the correct answer is to judge that reexamination is required. The researchers made nominal groups after asking specialists to make a diagnosis and compared a majority rule, a quorum rule (determined by a certain number of votes or more), and an index weighted by past diagnostic results. As a result, no matter which index was used, the group of three or more specialists performed better than the best members. The larger the group size, the more accurate the diagnosis, but when the number of specialists reaches nine, the results did not change. Although the index weighted by past performance was the best, the quorum majority rule was sufficient even when past performance was not available.

This image diagnosis task is a kind of perceptual task in which subtle differences must be found, and since the correct answer was close to the average, an error cancelling effect was obtained without weighting. For such tasks, machine learning trained by using past diagnosis will be useful.

Dunbar (2000) investigated the inferences of scientists and obtained 126 different conclusions from the same assumption. Even though diversity contributes to collective intelligence, it is difficult to choose an expert from 126 different conclusions. How should experts be selected for tasks that are difficult to average?

5.3.2 Signals of Experts

When selecting an expert, it is generally useful to select the position and achievement in each area as an index. However, these signals and self-evaluations and other-person evaluations based on the signals may not be reliable.

Burgman et al. (2011) conducted an experiment on experts (13–25 people each) gathered at six workshops on biology, environment, and medicine. The subjects were asked to answer 5–10 specialized questions individually, and then the answers of all were displayed on a PC for discussion, and they were asked to answer individually. Information on jobs, years of experience, and the number of papers of each member was presented to all participants.The results showed that the accuracy of the responses did not correlate with self-assessment or other-persons' assessment, but showed a negative correlation in four of the six workshops. That is, the higher the self-evaluation, the worse the performance was. Through the group discussion, those experts also noticed their mistakes and changed their answers, so the group's performance improved. However, even after the discussion, there was still a tendency that the evaluation for the wrong expert was high. In other words, people did not evaluate the abilities of others from each other's remarks, but rather the professional status of them.

Grove et al. (2000) also found that 46% of 136 papers in the fields of psychology and medicine (such as IQ prediction and heart attack prediction) were less predictive than statistical prediction. McAfee and Brynjolfsson (2017) have introduced a report that a crowd performed a task of annotating genetic information outperformed the research institute. They considered that the cause was the speed of scientific progress—knowledge becomes old in a few years. When selecting experts, rather than relying on past signals, it is better to weigh them using recent task-related performance.

Weighting Method for Answers

Various methods are being searched for as a method of weighting highly reliable answers. There are already known methods for weighting by using the metacognition of the person's certainty factor or the consistency of responses as an index (Sect. 4.2.4). However, Steyvers and Miller (2015) claimed there is a low degree of correlation between certainty and correct answers. Consistency is also impractical because it requires repeating a task multiple times at intervals of about a week. Therefore, the Cooke's (1991; Bedford & Cooke, 2001) method is recommended. This requires first performing a task called a seed item first on the subject and to weight the actual task performance based on the outcome of the task. The seed item must be a task with a correct answer not known by the participants. The research on mammography diagnosis (Burgman et al., 2011) is an example.

5.3.3 Forecast Market

There are two reasons why "experts are useless." The first is that the ability of experts is unstable and the second is that signaling are useless, and therefore true experts are hard to be found. Especially regarding future prediction, it is difficult to know in advance who is the best member, still, there is a method called the predictive market that uses collective intelligence.

In the forecast market, forecasts such as numbers and events at a specific time in the future are traded like stock trading. Once the results are known, payment is made to the buyer of the hit prediction. For example, if people think there is a 50%

chance that they will receive $2, people will only buy for less than $1. But the likely hits are bought at high prices.

In this way, the average of the participants' beliefs converges on the transaction price.

The Hewlett-Packard Company created a forecasting market (sales forecasting) system for general employees and had a 75% chance of making a forecast that was closer to the correct answer than the marketer (Lazear & Gibbs, 2014). The stock market is one of the forecast markets. Following the Challenger accident (Sect. 2.2.1.1), the stock of the company that manufactured the tiles that caused the accident went down before the cause was clarified.

Machine trading on the stock market is now an issue. Malone (2018) conducted a predictive market experiment that predicts soccer wins and losses and reported that it had the highest predictive ability under conditions where bots and humans were mixed.

5.3.4 Reputation

Without complete sharing of information, good products may be expelled from the market, and only poor products may be listed. For example, if a consumer who cannot evaluate the value accurately discounts all used cars, the dealer cannot set an appropriate price. In such markets, signals of reliability are required. One of them is the reputation. If one can make people share the reputation of "a human who does not betray," one can easily cooperate and bring benefits to each other.

Yamagishi (1998) has found that a closed network with low relational mobility (Sect. 1.3.1.2) creates a system with a high sense of security: "There are few traitors." However, such communities incur opportunity costs when trying to connect with outside communities. On the other hand, open networks allow poorly reputed members to flee to other communities. Therefore, when dealing with them, the community must pay the cost of monitoring. This monitoring cost (McAfee & Brynjolfsson, 2017) is considered to be a reason why companies are still able to keep up even as online transactions between individuals increase.

Yamagishi and Yoshikai (2009) have pointed out that for a society that creates an open network, positive evaluation(people do not want to lose accumulated evaluations) is more effective than negative evaluation(people want to escape and update their evaluations), and meta-reputation such as Like! or stars, which is a signal of the credibility of reputation, is necessary.

Alsina, Rand, and Lerman (2015) examined the effect of Q and A site diversity on the number of stars given to respondents. In the community dealing with technical issues, there was a correlation between the diversity of members and the number of stars. On the other hand, it was not clear whether diversity acts positively on the tasks without correct answers.

For tasks without a correct answer, both the reputation and the meta-reputation bring positive feedback (if a certain answer has many stars, it makes it easier to get more stars). To maintain the diversity necessary for collective intelligence, a mechanism to generate different perspectives and opinions is necessary, but the reputation system may hinder diversity. How, then, can we share a complex knowledge structure with diversity for tasks without the correct answer? Part of the hints lies in collective intelligence in the society.

5.4 Society and Collective Intelligence

Language consists of multiple layers, and nonverbalized knowledge is called implicit knowledge. There is a marked difference in the knowledge structure between individuals, and the region of tacit knowledge is large. Nevertheless, people can operate huge systems and utilize collective intelligence. Since people have shared knowledge, they can use collective intelligence without being particularly conscious of it. The shared knowledge structure is rebuilt every day.

5.4.1 Language and Cognition

In front of one landscape photograph, some people pay attention to the historical background of the landscape, or some read the ecological problems in the landscape. The individual differences in the semantic networks that are evoked from the stimuli make the difference in meaning. Norretranders (1999) took the idea of information redundancy (See Glossary G-1-6) a step further and considered that "the amount of information that cannot be told" is the depth of meaning of words. The amount of information folded into one word (which can be implicitly understood even without speaking) is an index of interest. If this is expressed by a semantic network, the path of length (Sect. 1.1.4.1) (the size of the distance on the network) varies individually. For example, some people recall the animation from the movie title *Ghost in the Shell*, while others further recall "the ghost in the machine" (written by Kestler). Even if one does not recall those contents explicitly, a person having a wider connection with the semantic network will feel more implicit meaning.

Text Analysis

Language also evolves, as words acquire new meanings and combinations of words change. In text mining (See Glossary G-1-7), the features of speakers and groups are investigated based on words that are likely to appear at the same time (co-occurrence relationship). Figure 5.4 shows an example depicted by Adamic (2012), which is the result of the analysis of words related to food ingredients. The features of the knowledge structure are extracted by expressing the words as a network. This figure shows that there are two language networks divided according to cokking. If

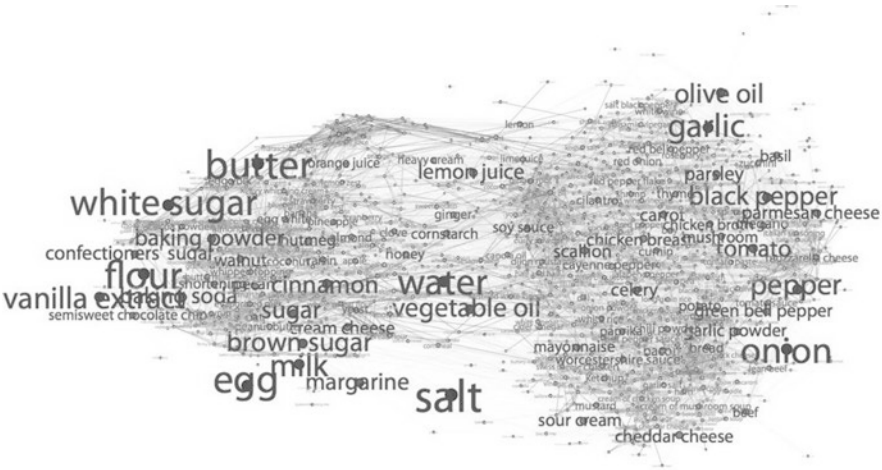

Fig. 5.4 Example of text analysis (Coursera "Social Network Analysis" Lada Adamic 2012)

the division seen here occurs in political beliefs or academic discussions, people who belong to one cluster will not fully comprehend the meaning of the other cluster's words.

Construal Level Theory

Construal level theory (Trope & Liberman, 2003) has demonstrated that abstract language is easy to use for objects with a psychological distance far from one, and concrete language is easy to use for objects with a close psychological distance. For example, in a familiar story such as "going to school," it is easy for a person to imagine how a person is walking. However, when it comes to an unfamiliar story for Japanese people, such as "entering the army," people's attention will be directed to why. It is easier for people to understand and persuade people to use words that match their psychological distance. The findings of social neuropsychology suggest that the activated regions of the brain also change depending on the form of "how" or "why" questions (Sect. 1.5.4.1). Based on this finding, it is expected that cognitive resources can be saved when reading sentences at the same construal level already activated.

Recently, the manipulation of psychological distance, which has been studied in the marketing field, uses spatial distance (such as Japan or the United States) and time distance (such as today or 10 years ago). Regarding the level of abstraction, the higher-lower concept of the category is also used. In the example of the category "liquor → beer → Suntory → malts," for the words "he wants to drink," one would think from an abstract (consistent nature and desirability) perspective, such as "why." However, for the words "he wants to drink a malt," one would think from a concrete point of view "where" (context dependency and its feasibility).

There is also a method for dividing the level of language abstraction by part of speech. The language categorization model (Semin, 1989) divides language into four levels from highly concrete to highly abstract. The degree of abstraction increases in the order of verbs (e.g., call) that express concrete actions that do not include interpretation, verbs that include interpretation (ask), state verbs (need), and adjectives (helpless). Social cognition such as causal attribution changes depending on the degree of abstraction of the language used. When the behavior is specifically described as Tom calls Bob, the tendency is to pay attention to the Tom or the situation surrounding Tom, but an increase in an abstraction such as Tom asks Bob and Tom needs Bob, we pay attention to Tom.

Tuning for the Group

The degree of abstraction people choose depends on the communication situation and purpose. As in cognitive tuning (Sect. 2.4.2), even in the case of groups, people select the language that suits the message recipient. For example, the wording of SNS messages tends to change depending on the number of followers and their social categories.

Joshi and Wakslak (2016) examined the degree of message abstraction for individuals or crowds based on construal level theory and language categorization models. The researchers asked the participants to write a statement recommending recycling. Before writing, the experiment participants were asked to choose whether to emphasize the desirability of the purpose (high abstraction example: social sustainability)or the feasibility of the methods (low abstraction example: can be done in 5 minutes) as the "reason to recommend recycling."

The results show that when participants persuade a crowd, they are more likely to choose an abstract reason than when they persuade an individual and often use abstract words in sentences. However, when the participants were instructed that "the homogeneity of the crowd was high," the difference disappeared. It seems that people use abstract words that are easy to apply in any context to the crowds with highly diverse. The participants themselves also reported that they could use the language fluently when the number of audiences and the abstractness matched.

Libet (2004) has argued that we can't talk if we think all words consciously, and we are not using the language by free will. Although the language generation process has been thought of as a "conscious" process, Libet's hypothesis suggests the involvement of automated processes in language generation processes.

5.4.2 Pluralistic Ignorance

It has long been known that when the perception of opinion distribution is biased, the attitude tends to change in the direction in which the prediction is realized. For example, in the spiral of silence (Noelle-Neumann, 1991), or the bandwagon effect, once either side is perceived as superior before the result is known, the losing party becomes silent, and the winning party becomes advantageous. Illusionary public opinion may be realized (Sect. 1.1.5.1).

The phenomenon that everyone misunderstands that "everyone has a certain belief (or attitude) that oneself cannot believe in it" is called pluralistic ignorance (Miller & Nelson, 2002). Pluralistic ignorance is easy to maintain in a society with low relational mobility (Sect. 1.3.1.2) (Iwatani et al., 2018).

The perception of opinion distribution is affected not only by the current perception but also by perception that is different from the past (shifting direction). The mass media will pick up the news all at once and set an agenda for what is currently the problem. It has been considered that the influence of the mass media is lower than the impact of interpersonal communication, but it has become known that the time to touch the media (e.g., the length of time watching TV) influences the attitude. Furthermore, in recent years, the influence of SNS such as Facebook has been drawing attention. Information that a person continuously receives from a medium with which he or she is in daily contact has a latent (Sect. 1.4.7.1) effect of which the recipient is less aware.

5.4.3 Language as Culture

The difference in cognition brought about by culture is the difference between analytical thinking and comprehensive thinking (Nisbett, Peng, Choi, & Norenzayan, 2001). For example, when one takes a hidden picture test, it appears as a difference of global-local cognition such as "recognize the whole first" or "recognize the target of details." Kitayama, Duffy, Kawamura, and Larsen (2003) found that people with a field-dependent collectivism background begin with global cognition, whereas people with a field-independent individualistic cultural background start with local cognition.

Not only culture but also situational factors influence language usage. For example, a person who is imitated by others changes cognition to a field-dependent cognitive style (Van Baaren, Horgan, Chartrand, & Dijkmans, 2004). Oyserman, Sorensen, Reber, and Chen (2009) argued that the differences in cognitive styles proposed by Kitayama et al. (2003) were not fixed by culture, but rather evoked by contextual cues. This hypothesis was tested in eight experiments conducted in four regions: South Korea, the United States, China (Hong Kong), and Norway.

The test participants put x on all pronouns in the sentence and then took a memory test asking about the contents of the sentence. The researchers compared the memories of the participants under the condition that the pronoun of the sentence was set as "I, me, and myself (individual condition)" or "we, us, and ourselves (group condition)." As a result of the comparison, the memory of the position (framework) was better under the group condition than under the individual condition.

In the oriental culture area, there are many field-dependent stimuli, while in the Western culture area, there are many field-independent stimuli, hence, resulting in a difference in cognition among people. One of the stimulating factors is language. In languages such as Japanese where pronouns can be omitted, the reader tends to pay attention to the context. In contrast, in languages such as English where the subject is necessary, the reader's attention tends to the subject. In the case of bilinguals, they change their cognition style to fit the language structure when speaking Japanese or English.

5.4.4 Collective Memory

Collective memory (collective remembering) refers to a common memory that many people have, especially events, people, and places that are easy to recall and hard to forget. For example, it is reported that many Americans clearly remembered "what they were doing when they heard the news of the assassination of President Kennedy or the news of 911." Those memories are not necessarily their own. Repeated broadcasts of the same symbol by mass media, such as sounds and photographs when landing on the moon, cause people to recall common memories. Memories related to social identities such as the military prostitutes' problem are also easy to recall repeatedly, and each time they stimulate the emotions of the crowd.

These trends are also found online. Garcia-Gavilances, Mollgaard, Tsvetkova, and Yasseri (2017) have considered that reconfirmation of similar events forms collective memory. For example, when an airplane accident occurs, the reader of the Wikipedia article is likely to read the article of the related accident. The phenomenon of increasing the browsing frequency of articles related to similar events in the past that is triggered by new events was significantly found even if links between articles were excluded.

Aiden and Michel (2013) have analyzed the appearance frequency of words and phrases in 30 million books digitized by Google (published from 1800 to approximately 200 years).

For example, if the frequency of use of 147 inventions (e.g., telephones, jeans) was divided by age, the speed of word spreading and forgetting was more rapid in the new age (Fig. 5.5). Every 10 years, the time required to reduce the frequency of the use of a word to 1/4 of the maximum was shortened by almost 2 and a half years. Researchers called the patterns found in the appearance frequency of such words collective memory and collective forgetting. We can see that periodic change (Sect. 3.4.1.1) also exists in the pattern in which knowledge spreads to society and is forgotten.

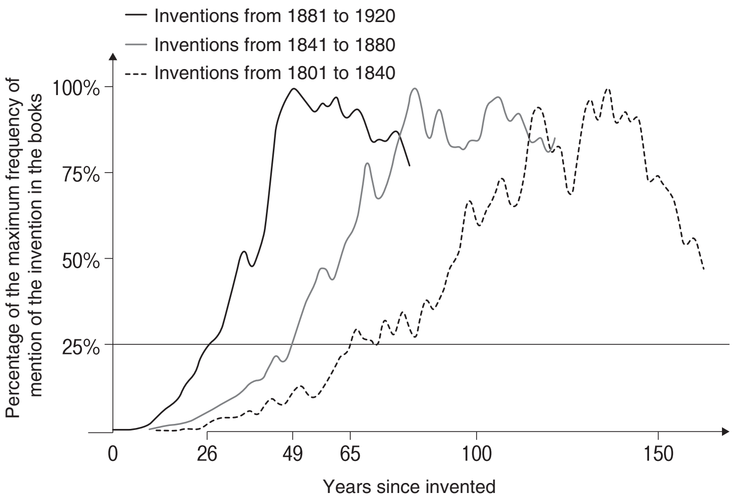

Fig. 5.5 Collective Memory and Collective Forgetting (Aiden & Michel, 2013)

Give it a Try:"Text Analysis"

When analyzing the interaction of face-to-face groups, the analysis work of voice data is very costly. However, the interaction on the net can be easily performed by using the log. In the author's class, students collect chat logs and conduct text analysis with machine learning with MatLab. You can find a free software such as FreeMat is used to examine the correlation of words.

5.5 Summary

At a station with a large number of tourists, such as the Kyoto Station, it is difficult to fix the behavioral habits such as which side of the escalator to stand on. This is because the network needs to be closed to some extent for the fluctuations created by chance to become shared through the learning after repeated experience. When this reaches the level of shared knowledge structure that cannot be observed from the outside, we could call it the formation of a new culture. It is a complex contagion proposed by Barabasi (2016) (Sect. 3.4.5.4). To maintain the culture, the organization must also reduce social mobility to some extent. The high shareability of knowledge structure facilitates distributed cognition that contributes collective intelligence.

Marks et al. (2002) considered the shared mental model itself as an emergent phenomenon caused by interaction. Yamaguchi (2008) pointed out that sharing a mental model could improve the emergent performance of the team.

On the other hand, as the sharing of knowledge structure progresses, it becomes difficult for the group to obtain a new perspective. The more implicit knowledge there is in a group, the easier it is for the group to form their original "common sense." Tett (2015) has called this tendency of organizations to build their own shared knowledge the silo effect. In this sense, sharing mental models may not bring about emergence in the group.

Members of organizations and expert communities have similar knowledge structures. Such a closed network has a high threshold for obtaining information from the outside; thus, it is difficult to change by incorporating new concepts. Therefore, it becomes necessary to include various members. Increasing diversity increases the cognitive load for understanding the perspectives of others. Moreover, diversity cannot resolve conflicts that result from differences in the final goals, such as economic development or happiness (Sect. 4.5.5). To share a goal, we need leadership.

The animal species with a habit of flocking are equipped with a mechanism to imitate other individuals. Also, for humans, conformity may be considered the default. However, for the survival of the entire herd, it is necessary to let members collect and bring back a wide range of information. We require strong leadership at this stage. On the other hand, in the decision stage, equal participation by all members enables the group to make wise decisions. To achieve this, the group must reorganize the organization so that members can alternate between cycles of exploration and decision-making.

However, demotion of the leader at every decision phase is not practical. Therefore, IT companies have come to set up a system that allows members to make equal decisions in advance. The middle manager transfers the tasks to the members (empowerment) while educating the members as a coach. Even senior managers are required to be excellent as professionals; job rotation was not recommended to senior managers. Such successful cases cannot be applied directly to every organization. It is necessary for each organization to make institutional designs based on data and constantly modify for each environment.

Among the knowledge structures shared by organizations and cultures, language has the most influence. An analogy can be drawn between language and ant pheromones. An infinite combination of tens of thousands of pheromones conveys a variety of messages (it was lucky for humans that such an ant did not appear). We can also see the emergence in the structure of the language. The collection and analysis of languagesused in daily communication reflects the flow of concepts in society. It would be an exciting field if future research could capture self-organizing changes in knowledge structure.

This chapter introduced the view that in an organization that shares a knowledge structure, the disadvantages such as silo effects are observed in exchange for the advantage of the amount of memory that is maximized. Then, what are the characteristics of the open network, the Internet? In the next chapter, we will consider collective intelligence related to the Internet.

Chapter 6
Collective Intelligence on the Internet

The number of website is about 1.8 billion, and the number of internet users of 2021 was approximately 5.2 billion, accounting for 66% of the world population (source: www.internetworldstats.com). The decrease in *opportunity costs* (Sect. 3.4.3.2) brought about by this huge network narrowed the between-regional disparities in the world and instead widened the within-regional gaps. The flat world brought a society that was not flat.

Computer-mediated communication is called CMC, whereas face-to-face communication performed by humans is called FTF. One of the advantages of CMC over the FTF network is low transmission cost and easy route search. Although people are connected to the whole world through the small world (Sect. 3.4.1), it is difficult to find the link. However, on the Internet, it can be easily found by searching.

The web (World Wide Web) is the largest auto-growth database that stores knowledge and is now an information environment that is indispensable for human knowledge. Furthermore, crowdsourcing and open source are also being studied as a matter of collective intelligence. The Internet has changed the way people work and share information and will affect the structure of organizations and society in the future.

6.1 The Internet

The Internet refers to networks interconnected by the Internet protocol, and among them, the web (World Wide Web) refers to a mechanism for mutually referencing pages via hyperlinks.

The web service started by Netscape in 1994 acquired interactivity and provided a forum for consensus formation (e.g., blogs, BBS). At the same time, the web became an automatically growing database called *Web 2.0* (Sect. 6.1.1). Since the 2010s, Social networking service (SNS) has made interpersonal networks visible.

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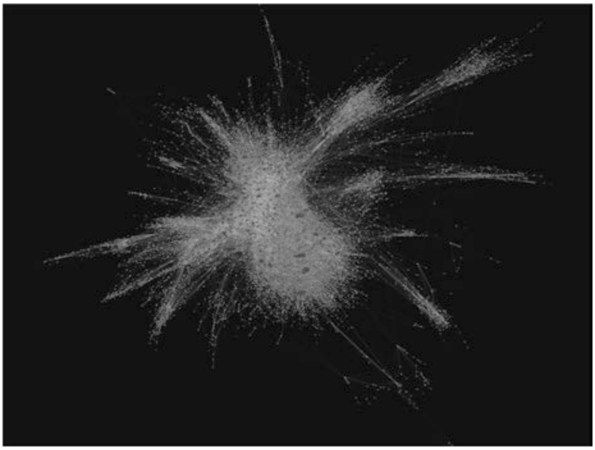
Services with community functions, typified by Facebook, and viral (information spread like an outbreak) functions, typified by Twitter, have expanded (Fig. 6.1 and 6.2).

In the twentieth century, companies were competing for the hegemony of operating systems that run apps. Since Apple's music distribution success in 2003, the

Fig. 6.1 Web network



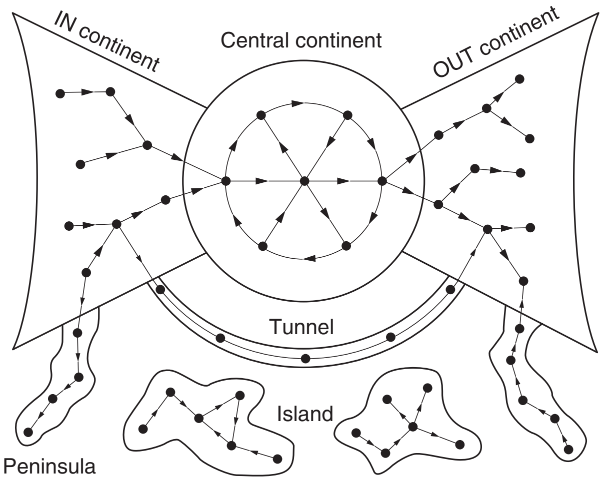


Fig. 6.2 Web link relations (from Barabashi, 2002)
Links among webs are directional, so they are referred to as directed networks. The core consists of a "central continent (strongly linked component)" that is connected to each other and can always be reached, an "IN continent" with only links coming in from the core, an "OUT continent" with only links going to the core, and isolated "islands." Such a structure can be understood from the block model. The block model is a model that classifies into cores that are closely connected to each other and peripherals that are connected in one direction

companies that built the platform have grown by gaining first-hand profits. Here, companies can benefit from a *network effect* (Sect. 3.4.5.4) as the increase in the number of people who take the same action (e.g., adopting the same application) further enhances the convenience for using the platform. Currently, the representative companies that are benefiting from the network effect are Google, Apple, Facebook, and Amazon, which are called GAFA. Since the platform also mediates transactions, the boundary between business and consumer has weakened. However, while the companies that built the platforms make huge profits, the profit margins of content providers remain small. The increasing amount of content for the purpose of income gain also brings negative aspects such as stealth marketing (articles that do not specify that it is an advertisement) and fake news.

In the future, Fintech, which fuses finance with the Internet and machine learning, and the IoT (Internet of Things), which implements network functions for home appliances, are expected to bring new developments. In recent years, cloud and API technologies are erasing the boundaries between devices and platforms. Automatic translation systems are also erasing the boundaries between language. Data that connects and merges across devices, OSs, and apps will benefit users. On the other hand, however, there are still problems that are difficult to solve, such as security problems and how much information should be shared.

6.1.1 Web 2.0

Web 2.0 proponent Tim O'Reilly has written on his blog what Web 2.0 was (What Is Web 2.0-O'Reilly Media 2005, https://www.oreilly.com/pub/a/web2/archive/what-is-web-20.html). O'Reilly (2005) has pointed out that the meeting to try to show the turning point from the dot-com bubble burst in 2001 was a trigger for the word Web 2.0.

Netscape was the bearer of Web 1.0, while Google became the bearer of Web 2.0. Netscape tried to establish a market for server products by leveraging its advantage in the browser market, but the business model of offering services by buying servers failed. Google did not sell hardware or software, provided free applications, and established a mechanism for indirectly earning advertising revenue. The technology of searching the entire web by crawlers made it possible. It can be said that Web 2.0 was one of the turning points that changed the "raw materials" that generate corporate profits from substances to data (user activities). The server rental business, where Netscape failed, has now transformed into AWS, a cloud service, and is now Amazon's main source of profits.

Services that grow according to user activity will have the advantage of not competing when the number of users reaches a critical mass. The point where Amazon gained a strong position was that Amazon recommended products based on user activity, while competitors displayed products based on the company's advertising costs. It is estimated that about 25% of this recommendation contributes to Amazon's sales. Companies with a large number of users frequently update their services and release new features in an attempt to keep users in check. This is because the data collected from users become corporate assets. Those data constitute collective intelligence.

6.2 Collective Intelligence on the Internet

The data aggregated on the Internet can be obtained through smartphones—the collective intelligence in my hands. However, it cannot be said that mankind has become as smart as Buddha. Rather, modern society seems to be becoming more unpredictable.

Recently, the predictions by social surveys are apt to fail—for example, the US presidential election or the referendum on Brexit. One of the causes of the misprediction was social influence such as SNS.

Information provided by the Internet has two characteristics: (1) *information cascade* (Sect. 3.4.5) is likely to occur, and (2) information filtering narrows the personal information environment. Both are factors that promote the extremization on the Internet, but the latter (2) can be a factor that maintains *decentralization* (Sect. 4.1.3), so the evaluation of the impacts of these factors is difficult.

Information cascade is a negative factor for collective intelligence. Given the popularity ranking information of a product, a person tries to obtain what other people think is good, and thus a *positive feedback loop* is created (Sect. 3.4.3). A well-known experiment is by Salganik, Dodds, and Watts (2006) created eight music download sites and compared the social influence condition in which the download count was displayed and the independent judgment condition in which it was not displayed. In Experiment 1, the song order was the same between the two conditions, but in Experiment 2, the larger the number of downloads, the higher the display position, and thus the social impact was strengthened. As a result, the correlation between the ranking obtained in Experiment 2 and the ranking obtained from the independent condition was low, and it was impossible to predict the top songs. Positive feedback produces hit songs (Fig. 6.3).

6.2.1 Social Networking Service (SNS)

Since the characteristics of communication on SNS differ greatly depending on the service, generalizations are difficult. For example, users can set their own network, such as open/private/anonymity. People tend to express positive emotions in SNS with low anonymity on an open network to control their public image. In private networks like LINE in Japan, this often causes net interdependency, as a reciprocity norm is formed in response speed. Communication, when there is an immediate response, is called synchronous communication, and when there is a time lag in the response, such as emails, it is called asynchronous communication.

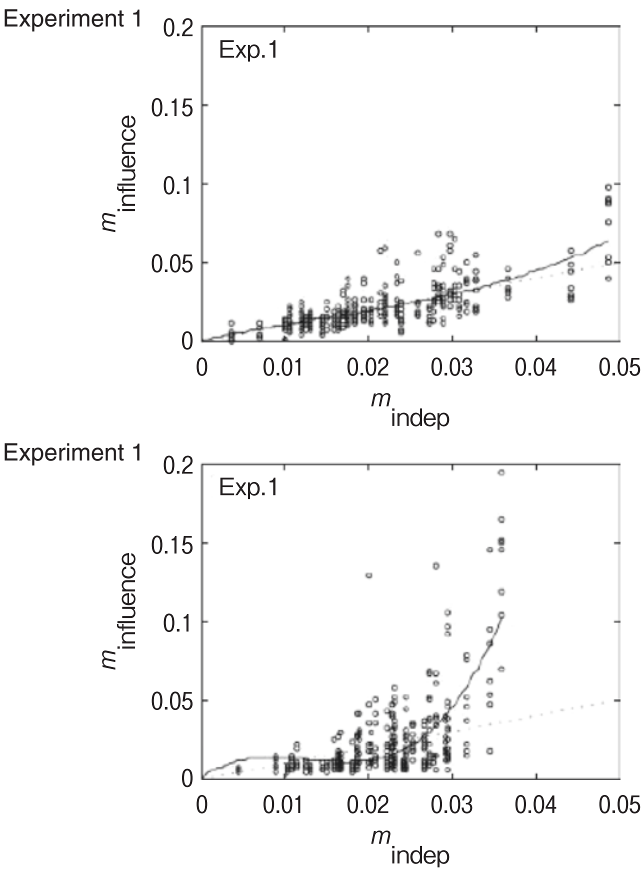


Fig. 6.3 Effect of ranking information on evaluation
Experiment 1 shows an example of weak social influence, and Experiment 2 shows an example of significant social influence. The horizontal axis shows the evaluation of each song independently judged by the participants, and the vertical axis shows the evaluation of each song by the participant who has acquired the knowledge about the ranking information. Experiment 2 shows that the higher the score of the song under the independent condition, the greater the variance, which means that the evaluation depends on the accidental factors

The characteristic of SNS as an information medium is that users can select the people they follow and build an information environment. Furthermore, machine learning may recommend and learn the user's favorite information, which creates a different information environment for each individual.

With SNS, linked relationships can be easily formed with people who are unlikely to meet in person, but most of the relationships are short-term. In fact, the average number of acquaintances on Facebook is about 150, which is within *Dunbar's number* (Sect. 3.4.6.1). Among them, the number of friends who interact frequently is about four, which is no different from face-to-face (Fig. 6.4) (Easley & Kleinberg, 2010).

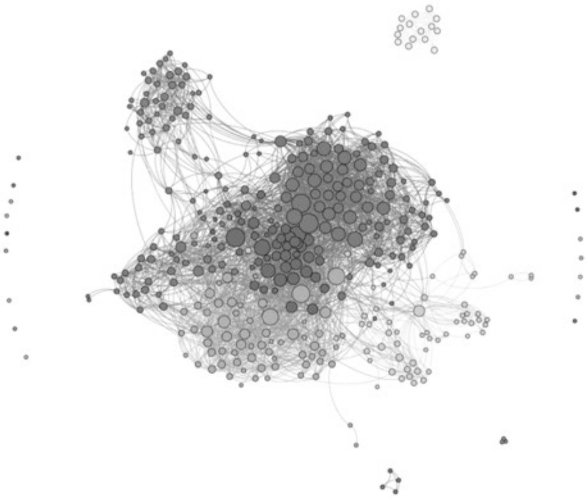


Fig. 6.4 Example of Facebook network (Michigan University, School of Information Coursera "Social Network Analysis" Lada Adamic 2012)The network is divided according to categories such as university friends and colleagues at work. From here, as shown in this figure, the retention of only strong links that are frequently contacted reduces the number of people on the network to a very small number

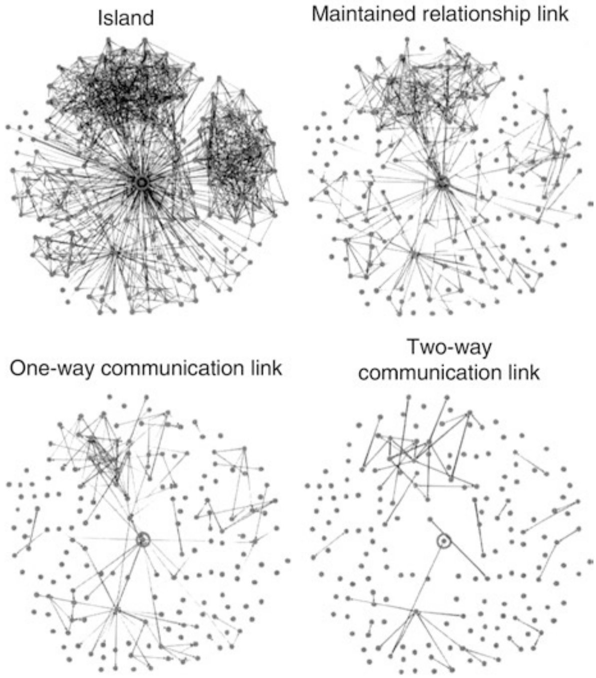


Fig. 6.5 Strong links in the Facebook network (Easley & Kleinberg, 2010)
A graph of two-way communication of messages and a maintained relationship depending on the information check frequency. Even within a connected component that has a triadic closure, few people actually continue to interact. The number will be around 10–20 out of 500 friends

The network created by social networks is closer to the small world than scale-free (Sect. 3.4.4). Its growth is similar to the extension of neural networks. Among the links established in the early stages of group formation, links with poor communication are deleted, and links with a large amount of communication are further strengthened (Fig. 6.5).

The essence of the difference between the Internet and the face-to-face network is the low cost of delivering messages across clusters. Interpersonal relationships on SNS, are not different from face-to-face relationships, but the size of the network behind which we can connect is different. It is difficult to predict the spread of communication content as even content that seems to have been forgotten may be reused in various contexts. Sometimes this causes an aggressive phenomenon called "Internet flaming."

Belief Polarization on SNS

Recently, extremization on the Internet has been focused as a cyber cascade phenomenon (Sunstein 2012). The cyber cascade is a phenomenon in which conformity is expanded by the information cascade, even if there is a minority opinion. Sunstein has argued that the Internet is a kind of echo chamber in which homogeneous information repeatedly echoes, and it makes people's attitude polarized.

However, investigating Google's search terms, Stephens-Davidowitz (2017) found that opposition parties are being searched to the same extent as supporting party by search engines. A phenomenon in which attitude extremization occurs while obtaining the opposite information is called belief polarization (Sect. 1.4.7.3). Furthermore, the attitude of the crowd becomes polarized as they go through a group process involving conformity (Sect. 2.5.2).

Attitude extremization Belief polarization also occurs face to face, but on the Internet, people's attention is easily dispersed, and their cognitive resources are limited. Hightower and Sayeed (1995) suggested that the cognitive bias brought about by the shared knowledge effect is more significant on computer-mediated communication than on a face-to-face basis. The difference is remarkable under a large amount of information flow.

For the whole society to share locally generated knowledge, it is necessary to verbalize it, including background information, that is, implicit knowledge (Nonaka & Takeuchi, 1996). However, it is difficult to convey the entire knowledge structure that can activate a semantic network covering deep steps (Sect. 5.4) of background information.

For messages sent to an unspecified number of crowds, abstract messages are more likely to be used than concrete evidence (Sect. 5.4.1.2). We can observe online a process in which the original message is translated into a knowledge structure sharing by the wider society and a process in which it converges on a simple confrontation axis.

It is pointed out that only a small number of users actually conduct cyberbullying, spread fake news, or earn illegal profits (Tanaka & Yamaguchi, 2016). Nevertheless, a cybercascade can be started with a small number of people (Sect. 3.4.5.1), so a single person can start the cascade using multiple IDs. Currently, that defense relies on reports from users (i.e., collective intelligence). Machine learning is still weak and ineffective at common sense reasoning.

6.2.2 Machine Learning

Collective intelligence on the Internet is mainly brought about by machine learning. The online environment is a field suitable for machine learning because it is supplied with a large amount of data every moment and the target feature to be optimized (such as increasing sales and the rate of user access) are clear.

Machine learning is an algorithm that adjusts a model from learning data using various statistical methods. Psychological research first forms a hypothesis and then collects data, but if the data comes first and researchers want to use it for prediction, they must search for a model (hypothesis). For model verification, there are methods such as dividing the data and using half for model search, and the other half for verifying the goodness of fit of the model. The learning data must be able to be converted into a numerical value or a logical expression (even if it is a sentence, the number of words and their occurrence probability become data), and a model with a clear purpose is required. Spam filters, searches, voice responses, news fields, etc. are modelled recursively based on past data and output for the next data. Such machine learning that continues to aggregate time series data is a method of optimizing collective intelligence for the desired purpose.

The data flow used is often referred to as big data. There is no clear definition of big data, but it can be thought of as a general analysis method that merges multiple data sources and connects them to prediction. MapReduce technology (e.g., Hadoop) that divides huge data obtained from various devices and OSs processes it on multiple servers and aggregates it again, making it possible to merge data groups.

The disadvantage of analysis using big data is that too many irrelevant associations are made between variables due to *overfitting*(G-5). Although there are various statistical methods used here, cluster analysis, principal component analysis, regression analysis, text mining, etc. should be familiar to those who study psychology. For example, the method used by machine learning is automatically applied to the SPSS principal component analysis.

Deep learning and reinforcement learning (a method for automatically repeating a model search by giving positive/negative feedback) have come to be described as *artificial intelligence* (G–4). Artificial intelligence development is enhounsed by deep learning based on neural networks after the failure of rule-based AI (symbolic approach). This is suitable for tasks such as correct classification, diagnosis, and prediction. Furthermore, in deep learning, overfitting can be adjusted.

However, we need to pay attention to what exactly machine learning learn as the correct answer.

If AI sees the increase in the number of web accesses as the axis of optimization, it may reduce the quality of web pages. Even if AI uses "evaluation by human" as the correct answer, human preference changes with time and society. Humans can always adjust their knowledge structure according to their environment, but machine learning does not have a system that dynamically changes the knowledge structure as humans do (Asakawa, 2015). If machine learning learns a bias that we cannot be aware of, there is a risk of fixing that bias by a feedback loop. To avoid that risk, checks by various groups without shared bias are needed.

Give It a Try

Let's create a simple site with a Google account and try A/B testing on that site from Google Analytics. Those with knowledge of psychology will understand that this is a simple hypothesis test. It's all free. If possible, try using Google Cloud Platform to experience using AI.

6.3 Task Solving by Online Groups

Computer-mediated communication has less nonverbal communication information than face-to-face communication. As a result, the emotional contagion that is transmitted physically, such as *empathy* (Sect. 1.5.2) or imitation, is small, and conversely, attention tends to be directed to one's own emotions. Since the text information is interpreted in CMC without sharing the context, misunderstandings of the intentions and emotions of the other person often can occur. Even with the use of video and VR (virtual reality) space, it is difficult to share attention with others because their gaze cannot be shared. While CMC has such disadvantages, it has the advantage that it is easy to share the accumulated information and refer to it at any time. Computer-mediate communication can be expected to achieve high performance by information sharing and local distributed processing, even for complex tasks that exceed the individual's information processing capability.

As introduced in Chap. 5, the emergent effect of exerting the abilities of one individual or more by becoming a group is likely to be obtained from a group that can efficiently use the memory of others by doing the same work for a long time. However, the group that constructs such a closed network also suffers from silo effects that are difficult to adapt to the environment. Today, an organization needs a team that changes members adapting to the environment and combines different kinds of knowledge. Then, is it possible to obtain emergence even for a short-term team on the Internet where it is easy to accumulate and share data?

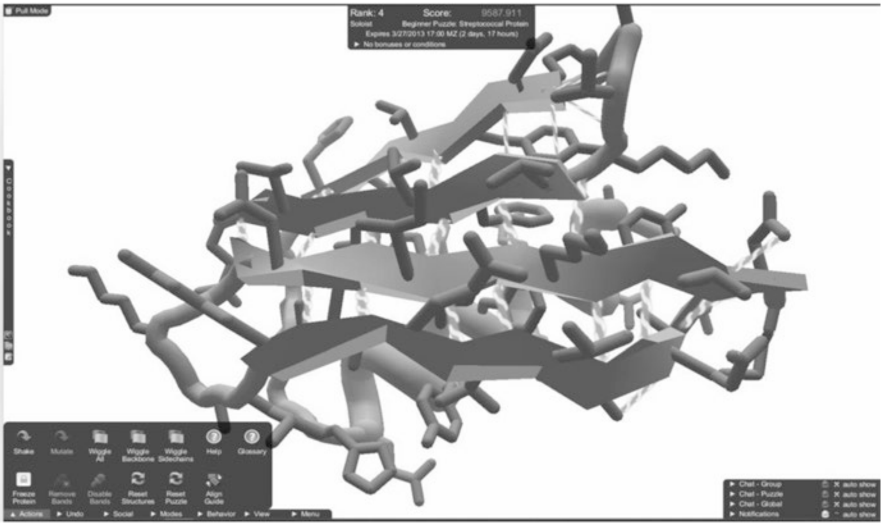


Fig. 6.6 Example of Foldit site screen

6.3.1 Decentralized Task Solution

A common example of successful collaborative tasks on the Internet is Foldit's work of finding a new protein structure. In just 3 weeks, Foldit found the structure of an AIDS-related enzyme that scientists missed for 15 years (Malone, 2018).

The UI (user interface) design of data visualization determines performance. Foldit has excellent visibility of the position of each individual in the whole and makes it easy to understand and share the changes (Fig. 6.6) visually. It is designed to be a UI that allows mental models to be shared naturally.

Foldit was devised to visualize easily the whole information while working on tasks in a distributed manner, but there is a limit to the number of people who can work at the same time. The optimal network is different depending on the amount of information on the network and the task structure.

6.3.2 Interaction Between Information Volume and Issues

Depending on the structure of the network, the task on which a group can exert intelligence is different. For example, if a group has to reach a unanimous consensus, it is better to have a complete network of connections, but if local group independence is required, it is better not to be too connected.

Mason, Jones, and Goldstone (2008) examined the influence of network structure by using an inference task that predicts an increasing rule of sequences. The subjects were informed of the answers of others connected through the network and their rewards. A range of noise was added to the information. Experiments showed that complete problems (a network in which all nodes are connected) can be solved quickly for easy problems, but small worlds are suitable for difficult problems that have multiple optimal solutions. In the case of a complete graph where all nodes are connected (Fig. 6.14), all members tend to conform to the first solution found even if there are other good solutions, but in the small world, the search can be continued appropriately.

Foley and Riedl (2015) examined the effect of the number of links on performance using an agent model. At each step, the agent moves to the position of the agent with higher fitness than itself (if not, it moves randomly). Simulations have found that a network with few links can reach an optimal solution, although it requires more steps. On the other hand, it was found that increasing the number of links speeds up problem-solving, but tends to lead to local optimal solutions (G-7-3-5). The situation can be improved if there is a member who takes the risk of moving away from the local optimal solution, but its contribution was slight, and rather the reducing the number of network links improved outcomes. This simulation shows that the effect of the number of links depends on the difficulty of the task (whether there are many local optimal solutions). In other words, groups with closer relationships are more likely to get stuck in Silo (local optimal solutions) when facing difficult problems. On the other hand, the small world can find an optimal solution with an appropriately distributed processing capability.

Combinatorial Optimization Problem

The combinatorial optimization problem of arranging multiple colors so that the same colors are not next to each other is a problem known to be difficult. Solving this on the net becomes a task of selecting a color different from that of the neighbor on the link.

Kearns, Suri, and Montfort (2006) have examined the optimum network form that can solve this problem. In the verification, the participants simultaneously selected the color while looking at the screen. In one of the seven trials, participants were given the information on the entire network (Fig. 6.8), but in six trials, only low information (only the choice of the person in the linked neighbor node was visible) or medium information (the number of links of neighboring nodes) was given.

The researchers compared the results by changing the shortcut links of the circular/scale-free network and the number of hubs. A simple circle has the largest *maximum path distance* (Fig. 6.13) from node to node, and a short link is used to create a small world with a short path length. In addition, a priority selection (scale-free) network with the shortest scale-free path length was also available.

As a result of this experiment, 82% of people were able to solve the problem in less than 5 minutes. Although it is difficult for one person to solve, it can be solved quickly by using distributed processing. Even if the average number of links and the path length were the same, the shape of the network affected problem-solving. In the circular network, there was a correlation between the average path length and

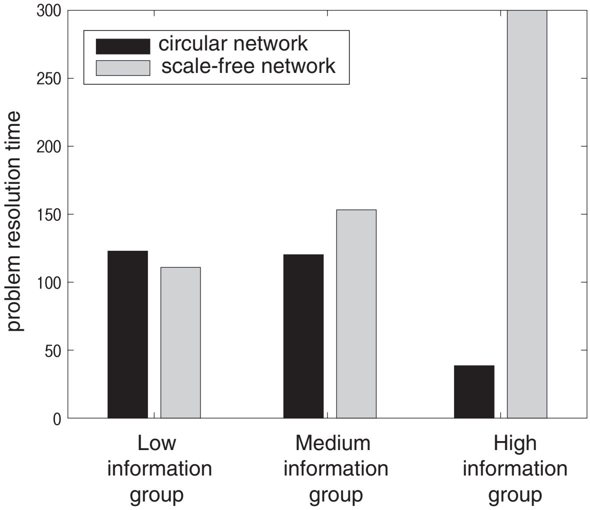


Fig. 6.7 Relationship between information volume and problem resolution time (Kearns et al., 2006)
Comparison of the circular network (black bar) and scale-free network (grey bar)

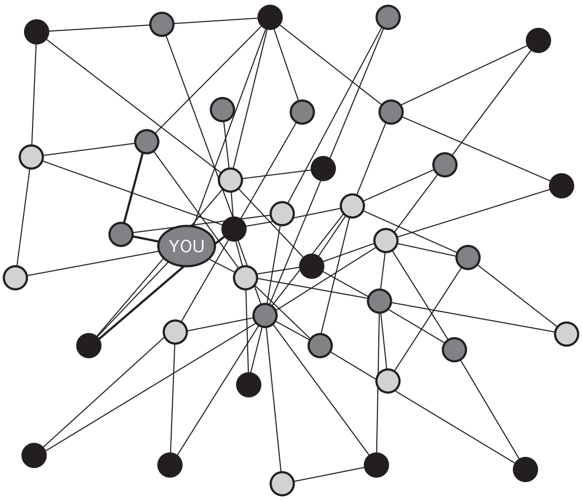


Fig. 6.8 Example of a monitor screen displayed in high information group (Kearns et al., 2006)
The screen changes each time the participants select. The thick line indicates that the color selected by one overlaps with the neighboring network and needs to be resolved. However, changing the color that one chooses may overlap with other neighbors

the problem-solving time (r = 0.45). In the small world, the increase in the amount of information on the monitor screen seen by the experiment participants improved the performance. On the other hand, in scale-free networks, increasing the amount of information slowed down problem-solving speed (Fig. 6.7). These results show that the optimal network shape depends on the information processing ability and cognitive resources of the individual.

6.3.3 *Online Shared Knowledge*

Online collaborative works can handle complex problems, but the amount of information an individual can process is limited. Solving complex problems requires the complexity of the knowledge structure that provides a crowd with a diversity of perspectives.

Shore, Bernstein, and Lazer (2014) have reported the results of having subjects perform a search task using the Internet. In this experimental task, the efficiencies of the four networks were compared. Unlike the previous experiment, in this experiment, the amount of individual knowledge affected the search work. In such a task, a more centralized network was able to find more information than a lower one. However, participants shared only the results there, and they could not share the background knowledge that led to the answer.

Sharing of Inference Process

Rahwan, Krasnoshtan, Shariff, and Bonnefon (2014) have examined whether it is possible to learn inference methods online using a deductive inference task called cognitive reflection test (Table 6.1) (Frederick, 2005).

This task can be solved by elementary math, so anybody can think slowly and come up with the correct answer, but it is easy to make an error by intuitively answering it. Participants will be given four opportunities to review their answers by referring to the answers in the neighborhood connected by the network. There were five types of network conditions: a control group that answered alone, fully connected, random, scale-free, and small world. Figure 6.9 shows the experimental results for Q1, Q2, and Q3 from the left. Under all conditions, repeated trials had improved performance when compared to the single baseline trial. However, even if outcomes improved in Q1, the accuracy rate in Q2 and Q3 returned to the original 25%. In other words, the participants were not able to utilize the method learned in Q1. From this result, Rahwan et al. pointed out that the reason why the correct answer rate increased was that the participants imitated other people's answers, not the reasoning method.

It is easy for people to remember information online as truth until it proves false. Sparrow (2014) dispersed information and examined the group memory and correct

Table 6.1 Cognitive reflection task

Q1	Water lily floating in the lake doubles and spreads twice a day. When a water lily takes 48 days to cover the whole lake, how many days does it take to cover half the area?
Q2	A five-minute operation of five machines produces five parts. How many minutes do 100 machines need to produce 100 parts?
Q3	It costs $1.10 to buy a bat and a ball. The bat costs $1 more than the ball. How much does the ball cost?

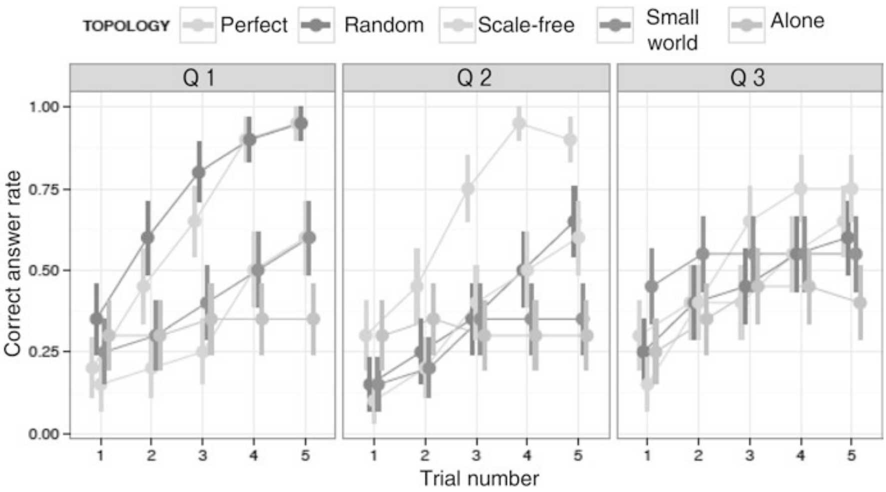


Fig. 6.9 Comparison of learning effects through networks (Rahwan et al., 2014)

answer rate of online groups and reported that the increase in memory capacity reduced the problem resolution rate because it allows handling incorrect information.

Increasing the amount of information via the Internet does not necessarily make us "intelligent" (Sect. 6.6.2.1).

6.4 Human-Computer Interaction

Information can now be easily obtained on the Internet. However, learning the background knowledge and inference process of others tends to be difficult because it requires cognitive resources. Today, services that technically support that disadvantage are being developed.

Groupware is a system that supports collective work. It uses a multiuser interface (a system that visualizes the members involved in the work), applications that support communication, workflow, file sharing system, etc. These fields are being researched as HCI (human-computer interaction) (Okada et al., 2016).

6.4.1 Web Services and Collective Intelligence

Web services that support collective intelligence are roughly divided into navigation services and community services (Omukai, 2006). Navigation services include search (G-2-5), bookmark sharing, price comparison, and Q&A. The utilization of metadata such as "recommendations" by which users evaluate products and "tags" added by users to content improves search efficiency.

Community service is one of the platforms for carrying out projects by the collaborative work of the members or for accumulating the information by the collaborative work of the independent workers. Wiki and Git are utilized as a system to support collaborative projects. The following methods are available for dealing with discrepancies in the process of collaborative work: the "gentle dictator," which is ultimately decided by the responsible person; the "committee," which is decided by highly contributing member;, and the "appointment members," in which decision-makers take turns (Omukai, 2006). Linux founder Linus Torvalds, for example, plays a final coordinating role, whether or not he wants it, and is called the "gentle lifelong dictator."

6.4.2 Crowdsourcing

Crowdsourcing is a method of outsourcing in which the purchaser outsources part of the work. Crowdsourcing uses a system that divides work into smaller pieces and allocates work to multiple workers. In the online community, there are various human relationships as in the face-to-face society, but in crowdsourcing, the interaction between users is relatively small, and it is easy to identify the system factors that determine performance. Therefore, crowdsourcing is being analyzed as a collective intelligence study.

Issues in Crowdsourcing

User ratings for Amazon products do not necessarily reflect the facts. Then, how can we get accurate information from the crowd? As introduced in Chap. 4, collective intelligence cannot be achieved unless the group is distributed around the correct answer. To achieve that, many participants are needed. Therefore, the first problem with crowdsourcing is the lack of attractiveness that gathers many workers. Bigham, Bernstein, and Adar (2015) evaluated that the current situation is that for crowdsourcing, workers can only get low income, and from the ordering side, they can only expect performance according to the low income. Salehi and Bernstein (2015) have launched a crowdsourcing site for college students and investigated the behavior of cloud workers. Although the strength of crowdsourcing should be to connect strangers, the probability of asking an online acquaintance to work is only 5%, and there is a strong tendency to ask a person who is already acquainted or introduced to work. As a reason, they interpreted that we cannot find who we do not know. Also, the average monthly income earned from digital contents was a small amount of $47 (see their site, INK system http://ink.stanford.com).

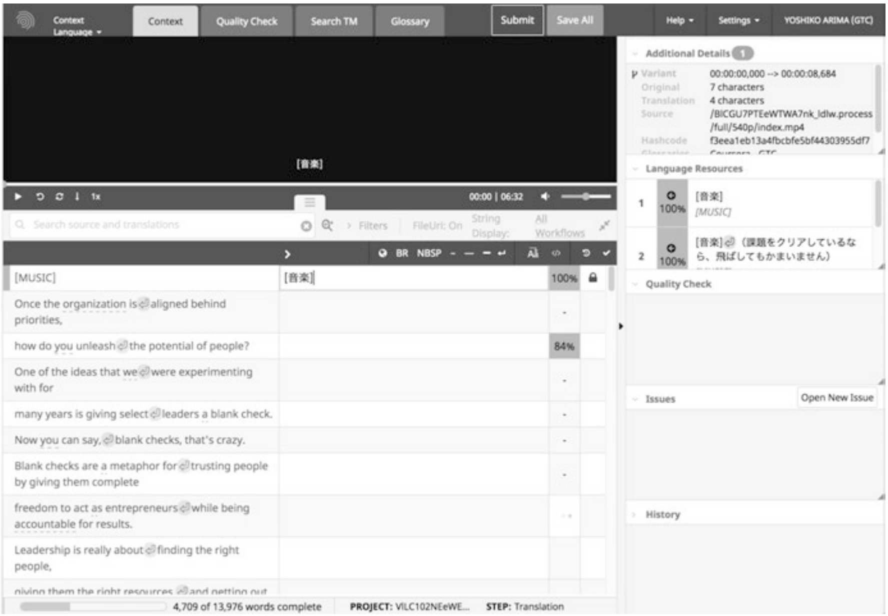


Fig. 6.10 A screen for Coursera collaborate translation work

Bigham et al. (2015) have pointed out that reward as an incentive affects the amount of work, but not the quality of work. What lowers the quality of work is the low attractiveness of the work itself. For example, most of the workers who participate in Amazon Mechanical Turk are engaged in tasks (microtasks) that are divided. Microtasks are tasks such as answering prepared options, tagging images, and writing or proofreading short texts. In such work, it is difficult for workers to grasp their roles in the whole work, and it is difficult to keep their motivation.

To address this problem, Bigham et al. (2015) found that crowdsourcing needs to incorporate collaborative systems that provide workers with the opportunity to grow while being rewarded. Therefore, crowdsourcing has begun to provide workflow systems and map systems that encourage workers to learn.

A successful example without a reward is Coursera's translation work by e-learning that utilizes a volunteer crowdsourcing system. The work orderer is also a volunteer, and the orderer selects classes that require translation and recruits participants. This process provides a community and task map to interact with a group of participants (Fig. 6.10). Workers have the advantage of being able to take paid classes for free, and this can be used as an incentive to attract participants.

Machine Learning Used for Crowdsourcing

The problem of crowdsourcing arises due to a lack of reliable information, as in the used car market. That is, crowdsourcing requires a reputation system or an alternative expert selection system. Therefore, crowdsourcing also uses machine learning (Sect. 6.2.2) to find simple mistakes of workers and adjust workflow.

In the "pull-type" approach, workers choose their jobs as seen in Amazon Mechanical Turk; clients cannot allocate jobs according to their abilities. In the "push-type" approach in which the client allocates the work to the workers, machine learning can refer to the data of the past history of the workers and can assign the work to the optimum workers (Weld et al., 2015).

As a procedure, the work is divided into a search phase and a harvest phase. In the search phase, an assessment task is prepared, required knowledge areas and skills are extracted, and the reward is weighted according to the worker's reaction. In the harvest phase, work with rewards begins. Even in the pull-type, the use of reinforcement learning, which rewards workers and makes them learn gradually from the search phase, is being considered.

In order to distribute the work and rewards that the participants can satisfy, researchers also investigated distributed collaborative groupware based on the worker's agreement.

Peer Production

Among collaborative crowdsourcing, a type in which voluntary contributions are gathered and task execution is performed without an orderer is called "peer production." Wikipedia and Linux OS construction projects are considered peer production. On Linux, participants are free to diverge versions, and they can be merged if the previous version's holders approve. Such a mechanism and its credibility raised people's interest in collective intelligence, and in fact, it built highly reliable deliverables as a whole.

Knowledge aggregation efforts such as those used by Wikipedia and Linux are typical examples of collective intelligence, but there are few cases where only automatic aggregation works effectively. Successful peer production involves various factors such as reciprocity, desire for growth, and sociopsychological factors. Most are case studies of successful sites, and few studies have compared failure cases. Therefore, it is difficult to identify the success factors of cooperative crowdsourcing.

Benkler, Shaw, and Hill (2015) have pointed out the above problems and then reviewed community research that has been sustainable over the long term. According to their review, the motivation of participants was a significant issue also in peer production. To reduce the departure of participants from the community, a system is often used in which participants give each other evaluations. However, even if the system is effective at the initial stage, it will be an ineffective incentive because conflicts occur among participants after the mature stage of organizing.

Taking the case of Wikipedia as an example, the number of articles grew steadily in its early days, but now, that it has grown, more time is used for discussions among the participants. In other words, having a larger number of participants does not necessarily lead to production of higher-quality products, so the peer production community needs a gatekeeper (a person who evaluates the quality of products).

Issues in Wikipedia

Wiki is a system for collaborative editing on the web. Wikipedia is an encyclopedia constructed by the general public using MediaWiki, one of the systems. Although its accuracy has been questioned, the scientific articles were evaluated as accurate as Britannica (Glies, 2005). However, to improve the quality of each article, the direct involvement of an editor with editing authority is required.

If the writing members share a particular perspective, the necessary diversity, which is a requirement for collective intelligence, is impaired. On the other hand, if the members remain dispersed, a conflict over the "truth" will occur between them. Shi, Teplitskiy, Duede, and Evans (2019) have examined the impact of political trends in Wikipedia editors on article quality. Researchers compared teams with editors with extreme political tendencies to the teams with moderate editors and found that the articles by the extreme teams were of higher quality. Analysis of extreme team conversations showed few examples of semantic diversity among members, but many examples of lexical diversity. The results show that for Wikipedia, conflict-causing diversity has a rather negative effect on outcomes.

Kittur (2014) examined the relationship between the interaction among editors and the quality of articles, after controlling the timing of the publication of Wikipedia articles and their quality. The experiments showed that the more editors that participated in the edit, the better the outcome, and the quality of the article improved as more questions were asked to one editor. For tasks that require individual background knowledge, rather a centralization type problem-solving (Sect. 6.3.2.1) was more suitable than decentralized problem-solving.

6.5 Collective Intelligence Research Using the Internet

All data obtained from the Internet has already been used by companies and is currently applied in various directions. The number of page accesses is compared in *A/B tests* (Sect. 6.2.2.1) and used for web marketing. In many cases, companies use user Q&A communities as an alternative to support services. Since it is difficult for companies to predict all bugs in advance, users who ask questions are a source of collective intelligence. Information that visualizes individual movements (geographical) is also used as collective intelligence data. For example, using mobile phone movement data, the shortest distance to the target person can be found. A web that uses the technology to add metadata to content is also called the Semantic Web. Collective intelligence created by tags is called *folksonomy*, which can visualize the occurrence ratio and co-occurrence relationship (Sect. 5.4.1.1). These technologies continue to evolve day by day, and this book cannot keep up with all of them. Therefore, this book will only introduce studies that are closely related to psychology.

6.5.1 Task Resolution Using a Wide Area Network

Collective intelligence research, which collects data in a contest format for recruiting participants on the website, is being conducted mainly at US universities. A prominent example is the Red Balloon Contest held by DARPA, a US Department of Defense Research Institute (Tang et al., 2001). This is an experiment to search for red balloons scattered throughout the United States (Figs. 6.11 and 6.12) using collective intelligence. Participants were rewarded $3000 for each balloon they found. The MIT team that won the contest paid not only the individuals who actually found the balloons but also the recommenders of those individuals. In this way, the mechanism that rewards not only the individuals who achieve the purpose but also their friends and friends of friends is applied to various purposes such as fitness (Sect. 3.4.6.5).

Fig. 6.11 Positions where the balloons were placed in the experiment (Tang et al., 2001)

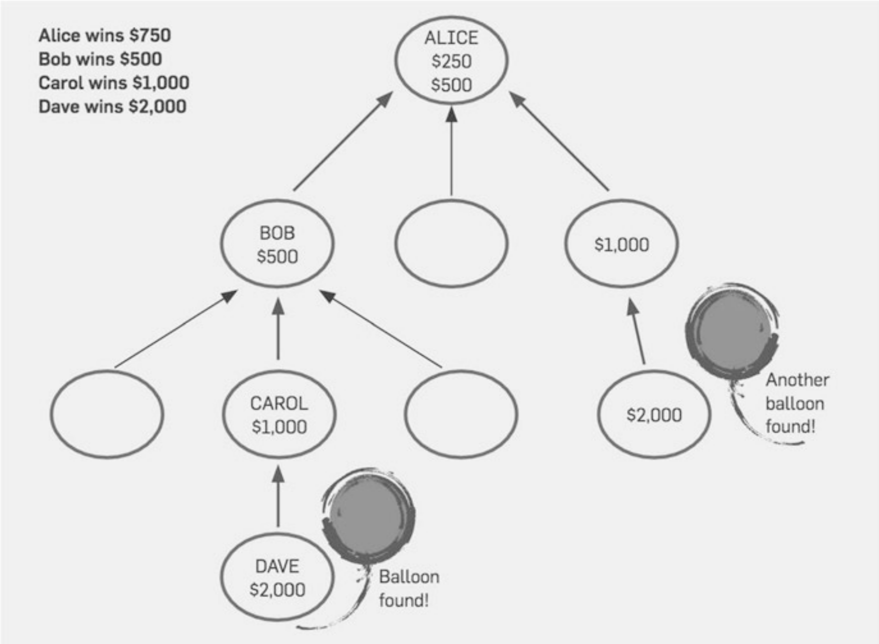


Fig. 6.12 Reward system paid by the MIT team (Tang et al., 2001)
Even if DAVE finds a balloon, the MIT team will also pay the prize to ALICE, which has a third-order connection

6.5.2 Creativity

Creativity requires a flexible cognitive schema. It is facilitated by being stimulated by the new perspective of others. Brainstorming is one of the methods that use this mechanism. Using electronic brainstorming (members work individually on CMC while sharing ideas) reduces *process loss* (Sect. 2.1.2.2) and provides better performance than face-to-face brainstorming.

Even creativity doesn't start with a tabula rasa.

Variations are created on the existing framework so that animators will acquire originality while imitating past works. Collaborative work such as Wiki and Github that can refer to previous articles is also suitable for creativity.

With regard to the usage of the three tools, Kittur (2014) compared verification of creativity of groups between conditions for presenting participants with examples of their use, and conditions for teaching a mental model of usage and then instructing them to use them for certain purposes. As a result, Kittur found that the number of new ideas increased with sharing mental models.

On the other hand, there are cases where it was better not to let the group members share the mental model. NASA has called for ideas to improve the efficiency of space station solar panels and reported that the best members provided better solutions than NASA experts (Sect. 4.2.1) (Lakhani, 2014). In this case, the contest method with high independence (participants cannot know the answers of others here) had a better average performance. For tasks that require such completely novel ideas, sharing mental models could be an obstacle to creativity.

Even if many ideas come up, not all can be done. The question that arises here is how to choose from many answers when we do not know the correct answer. Lee, Goel, Aitamurto, and Landmore (2014) have examined this issue using creative-type crowdsourcing. In this study, participants voted to rank a randomly selected group of ideas from 41 tasks (each task has 2 to 15 ideas). It was predicted that the decision would be difficult because the opinions were divided even if they tried to choose from many options. However, in this study, the *Bolda scoring method* (G-3-2) made that decision possible.

The next method, crowdfunding, is the use of collective intelligence at the stage of selecting ideas.

Crowdfunding

Crowdfunding is a mechanism to realize the idea of a startup without funds. Participants donate a small amount to their favorite product idea, and when the idea is realized in return, they get benefits such as the right to purchase the product.

Hu (2015) investigated the motivation of participants in crowdfunding and found "I want to use the product" was the most common reason for their investment. However, it is not always because the participants carefully considered the idea. An analysis of which impact, the information signal or the behavioral contagion, has the higher effect reveals that the influence of the information signal diminishes over time, while the effect of the behavioral contagion persists. In other words, early users evaluate the products themselves and make donations, but in the second half, participants donate because everyone is making donations. Results feedback is also needed to improve the quality of ideas selected by the crowd.

Mitsui, Takahashi, and Horita (2015) have examined the effect of feedback on social support groups. About 6 participants, about 40 participants, and about 15,000 participants were evaluated on the result report. The feedback improved the evaluation of the next report, however, the degree of comprehension of the contents decreased as the number of participants increased.

6.5.3 Near Future Prediction Research

Prediction market (Sect. 5.3.3) is efficient for near future prediction. Since there are various aggregation methods, researchers have investigated what kind of task and how to calculate collective intelligence are optimal for improving future prediction.

Intelligence Advanced Research Projects Activity (IARPA) and Defense Advanced Research Projects Agency (DARPA) use a tournament-type virtual laboratory (machine learning + human collective intelligence) to explore how to apply collective intelligence to future predictions. Data from over 10,000 participants can be found in the papers posted on the Scicast.org website. The issues to be predicted range from politics to science and technology to medical problems. Participants are first provided with international information in advance, and then they predict what is likely to happen within a year (Servan-Schreiver & Atansov, 2015).

Matheny (2014) reported the results of a 4-year experiment in which 20–25 people formed a team that talked in asynchronous communication and achieved sufficiently good performance with an unweighted simple average collective intelligence index. However, individuals who surpassed collective intelligence appeared, called super forecasters, and performed consistently after 3 years of follow-up. Superforecasters have more communication with team members, and over time, they learn and become smarter.

The topics for which the crowd average exerts a high predictive power are the growth in stock prices (Penna et al. 2015) and reputation (number of likes, etc.) (Taylor et al., 2015). In particular, when a prediction is started immediately after the appearance of an anomaly, the crowd works well because the phenomenon itself has the property of regression to the average value. On the other hand, collective intelligence is considered unable to generate specific content such as "what will happen in the future." When the second emergence (changes in the sense of values, etc.) occurs in the future, the information shared or weighted at the present point becomes meaningless. In other words, collective intelligence is unsuitable for predicting events involving factors with unstable values.

6.6 Split Networks

Emotions and actions are easy to spread through contagion on the network, but the contexts behind them are difficult to spread. Even in a community that initially began as a crowd of experts, an increased number of participants can distort the distribution of answers. If past logs are visualized, it is possible to participate in the community after acquiring knowledge first. However, SNS, which only shows the latest log, became a main platform of the Internet. Blocking others to avoid conflict, or filtering information according to past history, splits the knowledge area of crowds. Pariser (2011) refers to the latter as a filter bubble.

The split of information areas is not necessarily a negative phenomenon for collective intelligence because they maintain diversity.

We need collective intelligence today because we need to re-aggregate them and capture the whole flow. However, collective intelligence cannot reintegrate split information areas.

Farrell (2014) conducted a simulation that examined whether communities with different amounts of knowledge could have the same perspective. In this simulation, agents learn with decision trees and try to reach agreement on one evaluation axis while facing repeated problems. As a result, different solutions were selected as the optimal solution between non-elite groups and the elite group who could know predictive information. This result shows that when members have different amounts of knowledge, they are divided into communities and arrive at different optimum solutions. In a situation where the evaluation of the results differs for each community, even the answers provided by collective intelligence will not be able to achieve consensus.

As shown above, the centralized network composed of the best members can exert higher performance for tasks in which the amount of knowledge varies significantly among individuals and the axis of evaluation of results varies. However, historically, it cannot be expected that the dictator will remain gentle.

6.6.1 Need for Education

Considering the negative side of the differences among people's knowledge, a mechanism that promotes learning as a social system, education, is required. We cannot be effective in finding information for which we do not know the search words. The role of education is to create a knowledge map to reach unknown information.

On the web, knowledge structure spontaneously occurs due to tagging, etc. Regarding the influence of controlling the knowledge structure, the influence of experts has been weakened, and the self-organized influence on the Internet has been strengthened. Current universities are becoming cloistered and isolated from society.

Finally, let's consider how online learning can convey a complex knowledge structure.

6.6.2 Online Learning

In recent years, open education, that is, the provision of educational opportunities via the Internet, has advanced worldwide. If one has the literacy of utilizing teaching materials from all over the world on the Internet, one can develop a lifelong sustainable ability. In writing this book, the author also benefited greatly from programs such as Coursera.

However, education using online learning is not always successful. The graduation rate of online universities has been reported at about 5%. One of the successful cases is the Waseda University e-school, which is 39%. The Japan society for e-learning states that e-learning is not always successful and that the burden on teachers is greater than in face-to-face lessons. In a few successful cases, more staff members who support students were assigned than in face-to-face classes, and there was individual support by email and discussion board (Nishimura, 2007).

Teaching methods that convey knowledge from person to person have various restrictions. In educational settings, it is necessary to verbalize even background information that belongs to implicit knowledge. Besides, learners must reconvert their semantic knowledge into implicit knowledge in their own actual experience. Therefore, reversal learning carrying learned materials together to solve problems is expected as a new educational system. The difficulties of e-learning are the necessity in sharing attention (Sect. 1.1.2.1) and the medium characteristics in which the attention tends to be dispersed.

Dispersion of Attention

In the author's experience, it is difficult to maintain attention while watching a video. As a result, most of the video ends with picking up the necessary information from the text material without watching the video.

Consider the cause of e-learning difficulties from the research of *goal contagion* (Sect. 1.4.5) in the automatic process. Bargh et al. (2001) showed that participants who were exposed to goal-related words (effort/success) improved their performance in the word search task than the participants in the control group. Participants who were given goal priming showed not only improved performance but also motivational tendencies such as the resumption of tasks when they were interrupted.

For the comparison of visual goal information, e-learning materials are better than face-to-face situations. E-learning has many contacts with goal information so that goal priming should work well in online learning. However, it does not work as well as expected. Carr (2010) has argued that a multitasking environment might interfere with people's attention. On-screen links and buttons to change the goal result in priming for a different goal, causing the person to stop progress toward the original goal (Shah et al., 2002). Even the browser's back button can be one factor.

Ophir et al. (2009) revealed that people who can multitask tend to perform bottom-up attention control rather than top-down attention control. Frequent switching of attention in response to multitasking impedes the rehearsal required for remembering. For example, dispersal of attention reduces the reading comprehension of the hypertext (embedded links) because it requires more cognitive resources than the text that does not (DeStefano & LeFevre, 2007). Learning performance is lower when using videos that require continuous attention (Rockwell & Singleton, 2007).

On the other hand, the phenomenon of being "absorbed" that is being engrossed in a specific task and reducing interest in other activity is well known along with the term "Internet addiction." People spend endless time interacting with each other just by syncing with messaging apps.

Synchronous communication with "others" who share time makes people continue their attention. In the educational setting, the presence of others who learn together is necessary, but at the same time, they can also be an obstacle to learning (Sect. 2.1.2.3).

Distributed Cognition and Education

In the field of developmental psychology, there is an idea that group intelligence develops first, which promotes individual intelligence. Vygotsky (1935) considered that social interaction is essential in the process of intellectual development.

The knowledge zone that can be understood only with others is called the zone of proximal development. In the field of educational psychology, distributed cognition such as jigsaw learning has been shown to promote learning effects. Distributed cognition is cognition that uses not only the shared mental model within the team (Sect. 4.6.1) but also information embedded in the environment (G-4-3). From these viewpoints, the design of the environment and the interaction between members influence the educational effect.

The Presence of Others Online

The problem with online learning is the lack of presence of others.

To make up for this lack, functions such as adding interactive elements in feedback and target management by AI, incorporating game elements (gamification), etc. have been added. Gamification is a system that divides the task up to the achievement of a goal into small parts and gives feedback such as evaluation and level up each time the task is achieved. This is an application of a mechanism such as role playing games.

Avatars can also make people feel the presence of others. Dalton et al.'s (2010) chameleon effect study showed that observing the appearance of others causes behavioral contagion. Bailenson and Yee (2005) investigated the chameleon effect (Sect. 3.3.2) using virtual reality space. They found that people perceived avatars that were automatically set to take the same action programmatically as being more favorable and persuasive than avatars that did not take the same action.

Kang and Wheatley (2017) reported that in an experiment of mental coupling measured by pupil dilation, synchrony was observed with voice without visual information. These research results show that interpersonal interaction in virtual reality space has a behavioral contagion effect equivalent to that in real space.

Schroeder (Schroeder, 2002; Schroeder & Axelsson, 2006) found that users' attention in virtual reality space is sometimes distributed to interfaces, virtual environments, interactions, tasks, etc., but as they became accustomed to the environment, users focus their attention on interactions with others. When synchronous communication with others begins, subjects centrally distribute the resource of attention to it. It is possible to obtain a realistic educational environment by virtual reality using shared gaze technologies.

6.7 Summary

The Internet has played a significant part in the advances of humankind in recent decades, with far greater positive impact than a negative impact. Nevertheless, various concerns have been raised.

Now, it is faster to know the damage situation of earthquakes and typhoons with SNS (social networking system) than with news. The way that the same information is repeatedly quoted on SNS and spread to people is similar to the process in which the synchronization of nerve firing spreads through the brain and goes up to our consciousness. Simple information can quickly spread over a wide range, but it is difficult to convey background knowledge. Many of the concepts that spread across clusters result in simplistic, emotional beliefs that can form an opposing axis. As a factor that polarizes political beliefs, the Internet's ability to spread information over a wide area immediately cannot be overlooked.

Human networks with small-world characteristics can perform distributed processing when performing complex tasks, but there is a limit in individual information processing capabilities. We often get the answer from the web and tend to assume that we understand the reasoning process too.

Although each scientific method has its own drawbacks and limitations, researchers are continually questioning and rejecting errors. Science has secured a certain level of reliability with this built-in evolutionary system. Education has attempted to enhance the scientific literacy of citizens, but with mixed results at best, including university education. Now, educators need to innovate further.

While learning that requires conscious effort is difficult to establish, learning that seems not to require conscious effort is progressing rapidly. Humans today are quickly learning and adapting to new devices and apps that require the acquisition of new knowledge and skills. People who were only information recipients or consumers are now senders, putting products on the market and actively trading with strangers.

Machine learning of a type that constantly aggregates data generated by people (search, etc.) is a kind of collective intelligence. Collective intelligence aggregated by machine learning can provide more accurate prediction than experts. The effects of collective intelligence have been confirmed in various fields such as crime and education and are being applied in the field. However, there have also been reports of cases in which unfair biases were incorporated without people's attention (O'Neil, 2016).

The process of making humans smarter involves changes in the environment and resulting changes in concepts. The Internet environment and machine learning using their data will be essential requirements for the future society. Depending on its design, human intelligence will change.

Our motivation is subconsciously triggered by environmental stimuli. Even on the Internet, the "other" is the stimulus that makes it easy for us to focus our attention. For "smart" collective intelligence brought about by distributed processing to beat "stupid" collective intelligence that easily spreads like wildfire, each individual is required to hold a complicated knowledge structure.

The solutions to many of the problems and dilemmas facing the human race are highly dependent on specific contexts and therefore vary across time and space. The power of human intelligence has always been enhanced by collaboration. Resolving the discrepancies among us will be required of human intelligence, which machines do not have.

Glossary

Since various concepts are involved in the concept of collective intelligence, it is necessary to review basic science in order to understand the terms used in experiments and theories. The knowledge listed here is only a small piece of the vast science, but it will help the reader to understand some of the concepts introduced in this book.

1. Information Science
Information is one of the patterns of external signals (1.5). A 1/0 sequence of signals can represent all information. When a system such as living things or organization responds to those patterns, it will be processed as "information" that contains some meaning. An essential question in the discussion on statistics, which is the basis of psychology, is the basis of randomness. Randomness is required for statistics to calculate predictability. This is because the statistics is used to judge whether the analysis target is a predictable pattern based on the fact that it deviates from the probability distribution that randomness will bring. This is the task of extracting the signal from noise.

1.1 Randomness
There is no random factor in classical physics. The reason why coin toss is used as a symbol of randomness is because of the randomness due to the lack of information. Even with a coin toss, it is not impossible to predict whether it will be heads or tails if all mechanical factors, including air resistance, are calculated.

Randomness in signal theory is called noise, but noise is not truly random but follows various probability distributions. For example, white noise is a frequency having a uniform distribution. The randomness used in the simulation is also generated by the algorithm.

1.2 Brownian Movement
Brownian movement is the most reliable source of randomness that humans can obtain. Brownian movement is an irregular movement that appears when a large

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number of particles collide with each other repeatedly. It is not random if there is an entity that can capture all the movements (which is called Laplace's devil). Many phenomena just appear random because there are limits to what humans can measure and perceive, and the idea that all have been actually decided is called determinism.

Since the moving distance of particles is proportional to the square root of the elapsed time, each particle cannot move far. When the moving distance follows a normal distribution, the particles draw a trajectory called a random walk. When the movement distance of particles makes a long-term jump according to the power law, it is called Levy flight. While Levy flights have been thought to be observed in real bird flights, actual individual bird observations have revealed that birds behave more like Brownian movements. However, the appearance of a few jumping individuals causes a Levey flight in the herd. The search behavior performed by such "outlier" individuals brings new information to the herd.

1.3 Chaos Theory

The chaos phenomenon is a phenomenon in which a slight difference in initial values causes a large difference, as it is said that the flapping of butterfly wings causes a typhoon. Numerical formulas can predict the locus, but no matter how far they are tracked, the numerical values do not settle into a constant position or periodic fluctuation and continue to indicate different positions. It is understood that chaos is created as a result of Baker's transformation of stretching (moving away from points that are near) to folding (pushing into a certain range). When folding, the center of convergence is usually called the attractor, but in the case of chaos, it does not converge to only one point, so it is called the strange attractor.

Chaos can also be observed in the way organisms grow. The next-generation population is calculated as follows: (constant × increase rate × decrease rate due to environmental deterioration). A periodic phenomenon occurs in which the number of individuals decreases after the number of individuals increases. However, if the constant exceeds a certain value, chaotic fluctuations occur, so the normal period does not appear.

Even with the chaos phenomenon, if the initial value can be confirmed, the subsequent position can be calculated. That is, chaos theory is a kind of determinism, but it is also associated with complex system phenomena. In the cellular automaton simulation, the layer with the highest mutual information (a chain of rare phenomenon occurrences) can be observed at the boundary between the steady-state (the area where the state is fixed and does not move further) and chaos (the area that keeps changing). This layer is called the edge of chaos and is interpreted as a self-organization phenomenon.

The application of thermodynamic models to naturally occurring structures such as those found in crowd flow is called self-organization. That structure may disappear in a short period of time or persist for a long period of time, depending on the energy flow to the environment.

1.4 Quantum Entanglement

In quantum mechanics, particle positions and velocities can be predicted only stochastically because they are based on the definition of the wave function. This position is indeterminism. An interesting phenomenon in quantum mechanics is the phenomenon called quantum entanglement, which can determine the state of B no matter how far apart the two interacting particles A and B (photons, electrons, etc.) are from each other when the measurement result of A is obtained.

Experiments have confirmed that the state of the B particles is not determined when the A and B particles interact, but is determined when the A particles are measured. The particles, before being measured, are placed in a stochastic state.

In the stochastic problem called the Monty Hall problem, the participants attempt to choose the winning box from the three boxes; however, if after making a choice, they get information that one of the unselected boxes is empty, they are more likely to get the correct answer by changing their choices.

This presupposes that others had knowledge (a box with prizes) that one did not have. However, if one measures particle B before getting information about particle A from others, quantum entanglement does not occur. That is, if one opens other boxes by oneself before getting information from others, one does not have to change its initial choice. When others open the boxes, the uncertainties converge, and the probabilities are updated. This is called the quantum Bayes theory.

1.5 Signal Theory

What kind of message a signal is converted to depends on the cognition of the sender of the message and the recipient of the decoding. Signals can be regarded as symbols if the content can be shared by the sender and the receiver. C. Shannon described the amount of information as a result of reducing uncertainty (Gleick, 2011). The amount of information in a coin toss (head or tail) is 1 bit. For a large number of options, logarithm with base 2 is used for calculation. When selecting from 32 pieces, the amount of information is 5 bits. In other words, the amount of information increases as the probability of an event is less likely to occur. This definition is equivalent to the equation of entropy (messiness). Even if there are many choices, the amount of information will be 0 if the choices are the same. Since particles in a random state cannot be distinguished from each other, they can all be treated as the same particle.

1.6 Logical Depth

If there is a repeat in the signal sequence, the repeated part can be replaced with one signal to compress the information amount of the message. The range to search to find a repetition depends on the human or device's perceptible range or computational power. Therefore, it is not easy to prove that it is completely random.

Even if there is no difference in the amount of information, the computational complexity required to reproduce the sequence varies. Comparing the "random sequence of a coin toss with 1 million coins" with tails that are aligned 100 times, the latter seems to occur rarely. However, the algorithm of arranging 1 million tails is actually simpler. Rather, the depth of meaning (pattern) frequently occurs in the middle degree of disorder. The number sequence that can find the pattern is expressed as "deep logical depth" as the number of steps of the calculation algorithm is large.

1.7 Text Mining

One of the text mining methods is latent semantic analysis. This analysis seeks a semantic matrix that decomposes a document x word matrix into (document x meaning) x (meaning x meaning) x (meaning x word). The components of the meaning x meaning matrix are called singular values, and solving this matrix is called singular value decomposition. Singular value decomposition allows accurate determination of 50% of synonyms without learning the meaning or grammar. This mining method is utilized to recommendation services.

Fukaya (2008) pointed out the double contingency problem in which the meaning cannot be determined precisely (in a one-to-one correspondence between information and representation) in interpersonal communication. During communication, people refer to each other's memory chains to make sense each time. Text data analysis performed from this perspective is called socio-semantics.

1.8 Meme Theory

Problems in socio-semantics have been dealt with for a long time in symbolic interaction theory, ethnomethodology (Garfinkel et al., 1987), social representation proposed by Moscovici (Moscovici, 2001), memetic theories, etc.

Meme self-replicates "meaning" in the same way that genes do. Richard Dawkins (1982) in his book *The Selfish Gene* defined meme as the unit of information that "is a unit of cultural inheritance, whose phenotypic effects select for survival and replication of itself." A characteristic of meme is that it does not distinguish between representation and information.

Examples of memes are melodies, ideas, catchphrases, fashion, and building methods. Dawkins states "Memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation."

Following this concept of Dawkins, anthropologists and philosophers have examined memetic theory (Aunger, 2000). The subject of memetics is culture, where culture is viewed as the self-replicator itself or its phenotype. The replicator itself has no will or purpose, and therefore the organism is also only a carrier/mediator of the replicator and has no intention of replicating.

From a psychological standpoint, it is not possible to assume the brain as a medium that can perfectly copy memes. This is because there is a gap in the semantic network among individuals. Therefore, the meme should be an externalized text, thing, action, or the like. For example, the Japanese macaque's potato-washing behavior is inherited across generations even after the individual who started it died. In other words, the behavioral contagion leaves memes in other individuals in the herd, even without the gene for potato washing. The meme from this perspective overlaps with the information present in the environment, which is consistent with the concept of distributed cognition described in this book.

2. Science of Networks

The main method used for analysis is graph theory. Using the principle of structural equilibrium called triadic closure, a model is examined to analyze how a network is divided at the local level.

2.1 Terms

The graph contains nodes and edges (branches; network links). In this book, the latter are called links. The graph is divided into a directed graph and an undirected graph depending on whether the link contains direction information. The distance between nodes is called the path length. The path length represents the number of links between nodes. The number of links each node has is called the degree, and the probability that randomly selected nodes have degree k is called the degree distribution. A scale-free network has a power-law distribution of links.

The path is a route from one node to another node. Clusters that are closely connected by paths are also called components or cliques, but in this book, they are unified into the general term cluster for easy understanding. If there is a structural gap with many nodes where no path exists, the graph can be partitioned into connected components. An edge that is divided into different clusters by removing itself is called a bridge edge. Large graphs are often divided into one large connected component and small clusters. The maximum threshold that causes a complete cascade (the lower the threshold, the more easily the information spreads) is called the cascade capacity of the network. When the cascade capacity is less than 0.5, the information does not spread to the whole network.

2.2 Graph Theory

Graph theory allows treating a network mathematically, ignoring the geographical positions. A cluster coefficient is produced for each node. For example, the probability that two people randomly selected from the friends of node A has a link is the cluster coefficient of A.

The small-world experiment conducted by Milgram was an example of the decentralized search for finding a destination in a network. The efficient decentralized search uses the nested structure of the network. First, transfer to a distance of half the total path length, and then repeat the similar repetition for that half and then half. Such repetition can be observed even in the actual experimental results of Milgram (Fig. 3.3).

2.3 Graph Partitioning

Graph partitioning problem is a research that distinguishes strongly connected clusters and bridges from the actually obtained data. Figure 1 is one of the cases in which a naturally occurring community is identified in an interpersonal relationship graph, where one club is divided into two clusters.

The network is often nested and can be divided into lower-level clusters. First, the bridge (weak bond) is identified, and the cluster to be divided is examined by removing it. A popular method is Girvan-Newman algorithm. The traffic that flows information to all edges is calculated, and the edge with the largest traffic is removed and analyzed.

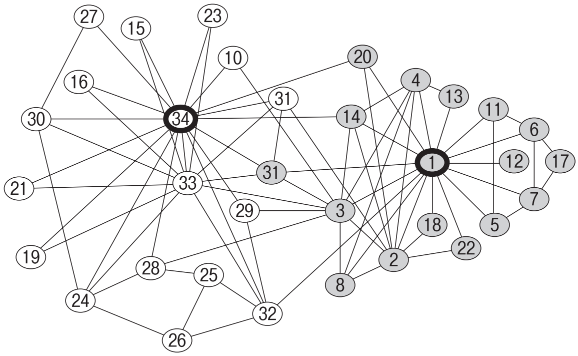

Fig. 1 Example of Judo club interpersonal network (Earsley & Kleinberg, 2010)

2.3.1 Balance Theorem of a Signed Graph

If the complete graph is balanced, then all pairs of nodes are friends or split into two opposing groups (Harary, 1953). Owing to Harary's work, Heider's balance theory was generalized to network theory.

2.4 Online Network

Web includes navigation links with hypertext functions and transaction links for launching executable programs. The distribution of navigation links is not a normal (Gaussian) distribution but a power-law distribution. The proportion of web pages with k links is directly proportional to 1/k2 and is scale-free.

The strict scale-free model has a short average distance but lacks clustering, so it is not practically applicable. On the contrary, the small world (having a short average distance and high cluster property) is more applicable. A model with high clustering property based on the scale-free model is being researched (Masuda & Imano, 2006).

2.5 Search Engine Technology

What makes Google search different from other search technologies is collective intelligence that regard the number of links as the number of votes. It is called the page rank system. Page rank is basically calculated by the following procedure. First, each web page is normalized by adding two types of scores: authority (the number of links from other pages) and hub (the number of links to other pages). The authority score is in proportion to the sum of hub scores linked to the page. When there are n nodes (web pages), give a page rank of 1/n to the initial value of each page. Therefore, the total number of page ranks in the entire network is 1.

The page rank value for each page is equally divided by the number of link (to other pages) output and passed to the link destination. The convergence value when the page rank is updated k times is equal to the probability of reaching a particular page after performing the steps of random walk (G1.2) k times. If the values are the same even after updating, it means that they are balanced. However, since the page rank value is stored in the page with only input links by this alone, the total page rank is reduced by s (about 0.1) at each update, and the remaining 1-s is distributed equally to all nodes. This reduction rule indicates that the probability of jumping randomly to another page is 1-s. However, the actual search algorithm used is more complicated. Since web advertising companies look for loopholes according to the search algorithm, search algorithms are modified frequently.

Search words are also used as data and are used for the purpose of giving frequently used related terms and search term suggestion. The frequency of the use of those sessions also becomes a feedback loop of the validity of the suggestions, improving the learning efficiency of the search engine.

2.6 Outbreak Model

In the infection model, we believe that diseases are transmitted stochastically. In many infectious diseases, the infection is terminated, while the antibody is maintained, but when the antibody is inactivated, there is a periodic phenomenon in which the infection spreads again. This is an oscillation that occurs locally in the network. The structure that makes it easy to synchronize oscillation in the entire network is the small world.

When the probability of relinking the small world C (3.4.1) reaches a specific range, the oscillation that the total number of people infected with the disease increases and decreases, and the synchrony that coincides in each cluster is observed. This phenomenon is observed due to the simultaneous firing of fireflies and synchronization of neural networks, but it has not been completely mathematically analyzed (Fig. 2).

3. Concept of Decision-Making Research

Unlike continuous variables, which are handled by psychology, only the order is often treated in economic sciences. "Preference" is an order of individual choice.

Fig. 2 Example of network with the outbreak (Earsley & Kleinberg, 2010)
The outbreak of infectious disease (tuberculosis). This is also a form of cascade behaviour in networks. The similarities and differences between outbreaks and social infections are an interesting subject of recent research.

The degree of satisfaction obtained as a result of choice is called utility. Utility is subjective; however, a utility function is expressed with external indicators (such as money). The utility does not increase linearly. For example, the satisfaction when 1 million yen increases to 101 million yen is inferior to the satisfaction when 10,000 yen increases to 20,000 yen. Here, the increment of utility when 10,000 yen increases is called the marginal utility. The marginal utility is the partial derivative coefficient in the utility function. When allocating expenditures from a fixed total budget, the most satisfying optimal solution is where the marginal utility and price ratio are balanced.

The selection items have various attributes (e.g., when choosing a workplace, salary, location, office hours, etc.), and therefore a utility is given to each attribute. Addition to each utility in consideration of the factor "which attribute is weighted" determines the selection of each individual. Under uncertain circumstances, a subjective expected utility is used, which is a utility function multiplied by probability. If one subjectively expects to get 1 million yen tomorrow more surely than to get 1.01 million a year later, it feels more useful to one, even if it's not necessarily the objective truth. People make choices that maximize their expected utility. When the expected value changes depending on the result of the behavior of others, game theory is applied.

Kahneman and Tversky (1979) have shown the prospect theory and suggested that since humans respond to changes from reference points, human beings behave out of risk avoidance when profit is expected (one chooses one that can certainly make a profit), but behave risk proactively when a loss is expected (one tries to avoid losses, even at risk).

3.1 Social Choice

Making a decision as a group, or group decision-making. is called social choice in the context of economics. Here, the rules for summing the preferences of each individual are searched. The rule that maximizes the sum of individual utility functions is called utilitarianism. The principle of utilitarianism is the greatest happiness of the greatest numbers. It is also possible to consider the sum of expected utility under uncertainty, assuming a veil of ignorance that cannot predict under what circumstances a person will be born. In reality, policymakers will determine the utility function. Utility and subjective happiness are not the same. For example, even if the utility increases due to the acquisition of goods or the increase in income, the correlation with the feeling of happiness disappears when one becomes accustomed to the situations. As a subjective happiness scale, a questionnaire method and a time measurement method (reporting the feeling of happiness at a specific time with a mobile phone, etc.) have been tried, but an effective scale as a social index has not been found yet. If the group cannot make a decision, an option to minimize the loss is considered. Gilboa (2010) has argued that social policy should focus on minimizing unhappiness, not maximizing happiness.

3.2 Paradox of the Voting System

The voting system adopted in elections and majority voting have some fundamental flaws. If there are three or more options, the Condorcet paradox is inevitable. This means that even if individual preferences are transitive (the order can be fixed like a>b>c), the ranking of actual voting results is not transitive (the order is cycled like a>b>c>a).

Arrow's impossibility theorem is a well-known theorem of social choice theory. This theorem states that if there are three or more choices, it is impossible to make a group decision that simultaneously satisfies the following conditions. (1) There is no one with dictatorship. (2) When all individuals think X is better than Y, the group decision must be the same. (3) The third option must not affect the outcome.

As a decision method to avoid dictatorship, we can apply scoring rules. In this rule, for example, there is a Boulder scoring method in which points are scored in the rankings, and the total points are voted. Majority voting is also one of the scoring rules by considering votes as points. A method of evaluating 0/1 for each item, such as a confidence vote for a judge, is also a kind of scoring rule. The confidence voting method can prevent a phenomenon in which a party that has not been split wins due to the split of one party among multiple parties that are supported to the same degree.

3.3 Economic Concept Related to Collective Intelligence

In neoclassical economics, research has been carried out on the premise that equilibrium can be predicted based on the behavior of individuals to maximize their utility. The equilibrium is brought about by the market (free market).

3.3.1 Market

The market is a system that aggregates confidence and expectations as a market price. The market derives the correct probability by aggregating individual expectations. The efficient predictive market hypothesis mathematically demonstrates how collective knowledge is integrated into the market. In a prediction market, the payout at the time the outcome of a bet is known is called the "state price". The state price is a weighted average of participants' beliefs. If the participants with the same weight independently gather, it will converge to a truer probability as the number of participants increases.

The market is the best proof that collective intelligence defeats a hierarchical society. Even if all the past and present information is available, we cannot continue to profit from the market in the long run. The market itself always calculates as collective intelligence for a market in which an uncertain event occurs, so it exceeds the individual's prediction.

Ideally, a completely competitive-free market reaches a Pareto-efficient equilibrium (any change will cause somebody to lose). However, due to factors outside the market, this state is not actually achieved.

The general equilibrium model created by the free market has no convergence result. Beauty contests are an example where the value (utility) to be obtained is created by the people's choices. To predict who will win first place in a beauty contest, we must predict the favor of the majority, not oneself's. This can also be applied to stock investment, and the prediction of "which stock price will rise" is equivalent to the prediction of "which stock does the majority buy." The nature of this prediction causes a bubble. Moreover, the equilibrium result does not necessarily indicate the true price of the company or product. If the information is asymmetrical, a signal is required because good products will be expelled from the market and only poor products will be treated.

An auction is a market when there is an intermediary. This system is also used in the pricing system for search ads. If the participant bids at the desired price + α, the winner must pay the highest price—the curse of the winner. To lower this price, a second price bid is used, and the winner buys at the runner-up bid.

3.4 Dominant Strategy

When a particular option has a higher profit, it is expressed as "higher options dominate lower options." The strategy that maximizes the gain regardless of the choice of the opponent player is called the strictly dominant strategy. The strict dominant strategy in the "prisoner's dilemma" is betrayal (noncooperation). However, if the participants betray each other, they will suffer disadvantages from each other. The situation in which it is difficult for everyone to choose Pareto dominance cooperation is called a "dilemma situation." In the economy, it is supposed that Pareto optimal solutions—win-win relationship—is a better solution for societies.

Nash equilibrium in the prisoner's dilemma cannot be the Pareto optimal solution. That is, in the dilemma structure, a win-win relation cannot be balanced. To derive the optimal solution, we will need rules to change our beliefs. In a repeated game, if one uses the same strategy many times, the opponent will be aware, so one should change the strategy stochastically. A combination of probabilistic strategy is called a mixed strategy. In the mixed strategy, the behavior of the other party is stochastically captured, so the payoff matrix is equal to the expected value. Here, a selection is made to maximize the expected value. When one is confident in the opponent's strategy, his or her own strategy is called the optimal reaction.

After knowing the other party's choice, one can think about the temporal development that changes one's strategy according to that information. A game in which one has all the information about past choices, such as chess, is called a complete information game. In a complete information game, the player's behavior can be traced in the opposite direction based on the final result (how the score was).

3.4.1 Two-Person Zero-Sum Game

For example, set the options in Fig. 1.8 to (A) eat at home and (B) eating out. Bob doesn't feel like going out, so he wants to eat Alice's cooking at home. On the other hand, it is best for Alice, who works for the company, to buy side dishes and eat at home, but she also thinks it is okay to eat out on the way home, in which case it is easier for Alice to eat alone rather than to call Bob who does not want to go out.

What is the most satisfying answer to the question "What will you do with dinner today?" Alice's choice of A or B doesn't change because the total is three points, but if Alice chooses to eat out every time in anticipation of Bob eating out, Bob will choose to eat out because it will be better than cooking alone. The strategy here is to set the probability of changing the choice. According to the minimax principle, the point difference for the opponent can be utilized for the ratio of the mixed strategy. Even if Bob changes his choice, Alice's point difference is two points in each case, so the best way for Bob is to change his choice by 50-50. Bob's point difference is three when Alice chooses A and one point when she chooses B, so Alice's best strategy is to choose "eating out" at a rate of one out of four times. Alice and Bob's strategies are expected to be balanced there.

3.5 Nash Equilibrium
The Nash equilibrium is a condition in which the strategies of both players are fixed in the repeated game. The number of strategy pairs that can be in the Nash equilibrium is not necessarily one. For example, in a game of "hawks and pigeons" where there is a strategy of conflict and peace, there can be two Nash equilibria where either one becomes a hawk and one becomes a pigeon. Unfortunately, the strategy that both become pigeons (peace) is not the state of the Nash equilibrium.

The Nash equilibrium does not exist in some games, but it is always present in games that use a mixed strategy in which players behave probabilistically. When a player does not have a strictly dominant strategy, the combination of the optimal reactions falls into the Nash equilibrium. In other words, by convincing each other's strategy, the players' strategies are fixed.

The game theory is a theory of behavior, but the Nash equilibrium is the equilibrium of belief in the reaction of the opponent. The advantage of the game theory is that the equilibrium point of shared cognition can be expressed by choice behavior.

3.5.1 Shared Knowledge
The concept of shared knowledge has been considered in the context of philosophy, game theory and computer science before being verified by social psychology.

There is a paradox in the language system (e.g., Cretans say all Cretans are liars). To avoid this, it is necessary to limit the level of logical types to a single level, as Russell points out. Therefore, information theory does not consider the existence of real objects outside the symbol system and the existence of the subject who recognizes them. However, Godel pointed out that it is impossible to completely prove that true = true within the same logical type.

The reason why we can say "sharing" is that other people can perceive it as sharing information. In the game theory, when people take a strategy of the Nash equilibrium, it is premised that people share the knowledge that "others also take an equilibrium strategy." Considering that it falls into an infinite nesting structure.

Halpern (1995) had proposed a method of defining shareability as a global variable for multi-agent simulation when considering how to express shared knowledge. In this case, shareability can be recognized from the outside (from the programmer's point of view) regardless of whether the agent itself recognizes it. The author believes that collective synchronization creates an information sharing state, but individuals may not consciously recognize the shared meaning.

3.5.2 Delphi Method
In recent group experiments, there are few experiments in which participants discuss face to face. This is because, when participants freely talk face to face, various factors such as the appearance of others and nonverbal communication are involved. Therefore, today, the Delphi method is often used, in which one looks at the answers of others on the computer and changes one's own answers. In this method, the

participants of the experiment enter individual booths, answer individually, and then obtain information about others' answers through the PC monitor. It is possible to control the distribution of opinions of others by making the participants think that there are others that do not actually exist.

3.6 Evolutionarily Stable Strategy

An important concept in evolutionary game theory is an evolutionarily stable strategy. This is a strategy in which once it spreads, it is decided that it will survive as species. Even if groups with different strategies invade, they will eventually disappear.

A strict Nash equilibrium (all players have the only best response) always leads to an evolutionarily stable strategy. The difference between the Nash equilibrium and the evolutionarily stable strategy is that the former requires the inference ability of each player as a premise (the confidence of the strategy taken by the opponent), whereas the evolutionarily stable strategy does not require that ability.

3.7 Genes for Flocking

The genes that form the herd have not been explicitly discovered, but if individuals that weigh social information are more likely to survive, the species that make up the herd will eventually remain. Various hypotheses have been devised for how genes are inherited that not only form a herd but also help each other.

Ants are a typical example of organisms that form colonies. An ant colony consists of a queen, which is responsible for reproduction, and male and infertile females and their reproduction occur in colony (one nest) units. Males are born from non-fertilized eggs. The queen's daughter gains genetic variation by breeding with a male from another colony, thus increasing the colony. In other words, colonies change the environment and increase the probability of survival as a species. From such an example, a multilevel selection hypothesis that suggests that natural selection occurs at the individual level, and the population level has been proposed, but it is still under discussion.

Gene successors are individuals, not groups. All ant colonies are made up of relatives who share genes, so they can inherit their genes by helping each other. Here, both direct fitness for inheriting one's own gene and indirect fitness for helping relatives are involved. This idea is called comprehensive fitness.

Sexual selection, which selects genes for the occasion of spouse selection, is also involved in evolution. Sexual selection can be understood by the following example. If a female frog has a genetic mutation that makes it hard to hear the higher notes, the female will give birth to a male offspring with a low-pitched voice. Her children can't even hear the high notes, so the males with more audible low notes are selected and eventually form a herd of bullfrogs. The human brain is also considered to have become huge as a result of sexual selection (Miller, 2001). In cases where cooperating individuals are preferred, the genes underlying their intelligence will likely be inherited. Modern women tend to prefer androgynous faces rather than the average male face, which has also been interpreted to reflect the tendency of women to prefer supportive males for child-rearing.

4. Artificial Intelligence
Artificial intelligence is roughly divided into model-driven type (driven by a pre-programmed algorithm) and data-driven type (driven by machine learning). Today, attempts are being made to create "smart" (providing the correct answer required by humans) artificial intelligence by making full use of technologies that mix these two types.

4.1 Frame Problem
A "frame" is a framework for selecting necessary information for taking action. Humans can utilize various cognitive frameworks unconsciously, whereas robots cannot distinguish between relevant and unrelated information for commanded behavior. The frame problem refers to a problem in which the objects to be considered are explosively increased when trying to deal with all situations by encoding all things, which is also called a combination explosion. The frame problem is also considered to be related to the symptoms of autism.

4.2 Artificial Intelligence
J. McCarthy, who first pointed out the frame problem 45 years ago, first used the term AI (artificial intelligence). Without finding a solution to the frame problem that had been raised from the beginning of the development of artificial intelligence, efforts were continued to symbolize the entire world and write it down in a program. Rodney Brooks is a researcher who criticized this approach and developed behavioral robotics.

Brooks created a robot with a structure in which multiple modules react with each other and demonstrated a walking motion avoiding obstacles without programming that was impossible with programmed robots. Pattern formation by behavior-environment interaction has resulted in behaviors that adapt to the environment (Brooks, 2002). Suchman (1987) considered that what makes communication between humans and machines difficult is that the question and its purpose are embedded in the situation. In this sense, Brooks made an attempt to make robots discover information embedded in the environment.

4.3 Affordance
These ideas originated in Gibson's affordance theory (Gibson, 1966). In the mainstream of cognitive psychology in the 1960s, the brain was thought to calculate input stimuli and create a model for the environment. But Gibson objected to this premise. Gibson (2014) thought that human intelligence is expressed by the combination of information in the environment. Affordance means that the environment has a meaning as information by the behavior of living things. Since then, it has come to be considered that for the solution of the frame problem, the physicality of being able to use the information buried in the environment is important and not the intelligence to judge the importance of the subject.

Besides, a robot development method has been attempted in which a robot installed with only the minimum program is thrown into the environment to cause the robot to repeat trial and error and adapt to the environment. Currently, robot development on the movement side is progressing well, but regarding natural language interpretation, a robot that can act based on “common sense” is incomplete. Taniguchi (2014) points out the need for artificial intelligence research that bridges the gap between physicality for interacting with the real world and logical thinking to symbolize the world and search for solutions.

4.4 Neural Network

A neural network is a learning simulation that combines an input layer, a hidden layer that extracts features, and an output layer that combines and classifies features. When the sum of the input × the weight of the connection is equal to 1, it is inputted to the next layer. Weighing is done by repeating the training to backpropagate the error. Such neural networks have been used for recognizing images and handwritten characters. Today, they have also come to exhibit high accuracy in deep learning. In recent years, this is sometimes referred to as artificial intelligence.

5. Bayesian Statistics

In Bayesian statistics, consider how the acquisition of new information changes the probability. If one rolls the dice repeatedly and the 1 appears ten times in a row, people would expect another number to appear on the 11th time. This is called the gambler’s fallacy. That is, since each trial is independent, the probability of getting 1 at the 11th time is 1/6, which is the same as other numbers. This is the position of frequentism. However, frequentism is a probability judgment based on the assumption that it will be repeated infinitely. Bayesian statistics maintains that this idea cannot be applied to a single trial. In other words, from the viewpoint of Bayesian statistics, the dice in which 1 appears ten times in a row has been crafted (the prior probability changes).

To calculate the probability that the cause of high fever is influenza (posterior probability), multiply the probability of getting influenza (pre-probability) by the probability of getting high fever with influenza (conditional probability), and divide it by the value of all diseases that produce high fever. Since the probability evaluation is changed after the onset of high fever, the calculation is causally reversed. If the prior probability is unknown, start with the probability of 50-50. It seems that the reason for setting the probability to 50-50 is scarce, but if the calculated posterior probability is added to the a priori probability and the calculation is repeated, it becomes a plausible probability. This calculation work is called Bayesian updating.

Fisher advocated frequentism because the assumption that the initial probability of Bayesian statistics starts from 50-50 is too strong. In other words, statistics based on frequentism is newer than Bayesian statistics. In frequentism, the probability distribution of the population is derived from the law of logarithms, and the actual data is considered as a sample randomly extracted from it. The errors that occur during sampling are independent (do not interact with other factors) and are assumed to follow a normal distribution. This assumption is also strong.

Currently, there is a tendency to return to Bayesian statistics. Since Bayesian estimation without prior knowledge is equal to the maximum likelihood estimation, the position of how to evaluate prior knowledge makes a difference between the two statistical methods. In the case of frequentism, repeated experiments diminish the correctness of the hypothesis—thus the test criteria must be raised. However, in the case of Bayesian statistics, applying the experimental results to Bayesian updating and repeating the calculation improve the accuracy of the experiment.

The analytic hierarchy process is for hierarchical data such as group experiments and surveys from several categorical groups. In the case of Bayesian analysis, the lower hierarchy can be analyzed by starting the Bayesian update from the whole data. This is called the hierarchical Bayesian model. After calculating the posterior distribution, Markov chain Monte Carlo methods are used to extract samples and obtain confidence intervals. The advantage of the hierarchical Bayesian model is that it can also be used for time series data when there is no correspondence (such as panel data performed without specifying individuals).

Besides, the advantage of Bayesian statistics is that more parameters can be set than the number of data. In frequentism statistics, too much explanatory power of data rather reduces predictive power. This is called overfitting. For example, if all variables are inputted to the regression equation for collective intelligence calculation, overfitting will occur that explains the variance of errors.

6. Mindfulness-Based Cognitive Therapy

In recent years, mindfulness-based cognitive therapy has been attracting attention as a treatment for depression due to stress or prevention of recurrence of depression (5.1.3). One of the symptoms of depression is the inability to concentrate on the work at hand. Repeatedly thinking about worries is a typical symptom of depression, but poor concentration also activates default mode networks, causing endless concerns about interpersonal relationships or other things (1.4.4).

Mindfulness is a training method that recovers the ability to control decreased attention and is effective in improving chronic pain and improving memory (Kabat-Zinn, 2007). Unlike the so-called meditation, it is a live meditation method that does not evaluate what one feels. Since it involves verbalization, it can also attenuate the activity of the amygdala. This is called the emotional labelling effect.

Mindfulness-based cognitive behavioral therapy (Kaitani et al., 2016) is the third generation of cognitive behavioral therapy. The purpose of this therapy is to improve self-regulation by focusing on body sensations, such as breathing, while reflecting on cognitive distortions (Ohira, 2017). This therapy has been used for organizational development since it was introduced at the 2012 Davos Conference. The efficacy of the therapy as a preventive treatment for depression recurrence was evaluated to be comparable to the evidence of medication (Davis & Hayes, 2011).

6.1 Stress Check System

To deal with stress, it is necessary to know the cause of the stressor and consider possible coping actions. In the case of job stress, we must approach both individuals and organizations. These approaches are called stress management and are divided into three stages. The primary prevention is stress reduction in the workplace and is carried out through power harassment training for bosses. The secondary prevention is the early detection of stressed members by a stress check. The tertiary prevention is a temporary retirement and reinstatement support for members who have already developed some illness.

In the approach to individuals, after the onset of illness, doctors mainly provide counseling on medication and stress-coping behavior. Stress coping is roughly divided into emotion-focused coping and problem-focused coping. Problem-focused coping is a direct way to deal with one's hindrance problem. Problem-focused coping is more effective, but it may be difficult to change workplaces immediately. Emotion-focused coping is a method of listing behaviors to reduce stress and using it when one feels stress. In recent years, the third-generation cognitive behavioral therapy has attracted attention. Due to the shortage of cognitive-behavioral therapists, group-based cognitive-behavioral therapy is now being developed, and it has been shown to have a certain effect on the prevention of recurrence of mental illness (Kanto society for cognitive-behavioral group therapy, 2011). Group-based cognitive-behavioral therapy consists of psychoeducation, cognitive-behavioral therapy, and social skill training.

7. Simulation Research

7.1 Science of Complex Systems

Complex systems are created as a result of the interaction of many elements, such as life and society. Even if each element follows simple rules, their interaction can cause unexpected emergence. This is called a phase transition.

The mechanism by which oscillation (repetition with a constant cycle) occurs can be explained by Shioshi-odoshi; water-filled bamboo tube, which is often seen in Japanese gardens. When water accumulates in a bamboo tube, the bamboo tilts under its own weight, draining the water inside and jumping up. This is an example of linear-nonlinear conversion. Nerve cell firing occurs in the same way. The positive feedback that water gradually accumulates and then the interaction that negative feedback works cause oscillation.

The interaction between the oscillating objects causes "entrainment" in which their oscillation cycles are synchronized. As seen in the firefly swarm (3.4.1.1), synchronization of the entire network is called collective synchronization, and nodes that oscillate are called coupled oscillators. This is one of the phase transition phenomena. When particles approach the phase transition, the law of large numbers is broken, and the fluctuations are no longer independent. At this time, in the network, the interacting path length is extended, and the power law is observed.

Magnetic force is a well-known phase transition phenomenon in physics. The spin direction of the electron of the iron atom takes two values: upward or downward. Physical systems have the property of trying to minimize energy (increasing entropy). Following that property, the energy can be reduced by moving in the same direction as the neighboring atom. Therefore, if a certain number of iron atoms are oriented in the same direction, a phase transition occurs in which the entire orientation is aligned at once. It has been proved that spontaneous phase transition is possible by modeling in two dimensions.

When a phase transition occurs, an explanatory concept that cannot be reduced to lower elements becomes necessary. For example, in order to shift from the quantum mechanics-level to the Newtonian physics-level explanation concept, tricky explanations such as renormalization to prevent divergence and statistical mechanics are required. In the first place, the reason why academic disciplines are divided into physics, chemistry, biology, psychology, sociology, etc. may be one reason that the phenomenon is divided by the phase transition.

If a nonlinear phenomenon can be mathematically completely described, it can bridge the gap between them, but at present, the behavior of complex system networks has not been completely elucidated mathematically.

Therefore, a simulation of observing time development is used to understand the nonlinear phenomenon. Here, researchers will perform a “multi-agent simulation” in which a program is installed in a virtual agent to interact with it, and the model will be modified following the measured values. Such research methods are called constructive methods.

However, it is impossible to make a comprehensive description using either mathematical methods or simulations. The mathematical method shows that the numerical value reaches a stable state regardless of the initial value, and the route information is missing. On the other hand, the simulation requires trials from many variations of the initial values, since simulation only knows the result from one initial value. To overcome the gap between these two methods, visualization of model behavior in spatial representation is being performed.

7.2 Simulation
Researchers in fields such as physics have used simulations to understand nonlinear systems such as chaotic phenomena. In the social sciences, simulation has been used since the early 1990s to understand the emergence of complex system phenomena.

When dealing with problem-solving in simulation, as in the case of Page, the simulator searches for the route from the initial state to the goal state in the problem space. A reliable procedure for problem-solving is called an algorithm. However, the goal state is not always reached directly, and even if an algorithm is used, it may remain an approximate solution.

7.3 Techniques for Social Simulation
The simulation involves the model, its parameters, and the random number generation algorithm. The same kind of random number gives the same result.

The simulation study is conducted according to the following procedure (Gilbert & Troitzsch, 1999).

1. Defining the object to model: Observe the object and set parameters and initial conditions.
2. Hypothesis setting: Program.
3. Validity verification: Debug.
4. Adequacy verification: Consider matching with real data.
5. Sensitivity analysis: The robustness of the model (how accurate data is required) is examined by changing the parameters and initial values. If random elements are included, run the simulation multiple times, and examine the distribution of results.

7.3.1 System Dynamics

System dynamics is a method of formulating the time-series using a differential formula. The solution is obtained by approximating with a difference equation using discrete time.

7.3.2 Cellular Automaton

In a space represented by a uniform grid, cellular automaton is a simulation that varies depending on the state of neighboring cells at each time step. Assume that both ends of the grid are connected to each other. This simulation can make a one-dimensional to a multidimensional experimental space. Methods for setting neighboring cells include von Neumann neighborhood with cells on the top, bottom, left, and right and Moore neighborhood with eight cells.

As a one-dimensional cellular automaton, S. Wolfram's classification that finds the edge of chaos is known, and this automaton can also draw fractal figures. Fractal (self-similar shape) is a nested structure in which the entire structure is found in detail. A power law is observed between the length of the contour and the scale factor of a two-dimensional figure, which is considered to be infinitely repeated near the phase transition where the value is close to 1.

When a certain number of people give the same opinion, human cognition tends to follow the majority. In a cellular automaton, if we make a majority model in which the sum of neighboring cells changes state, even if the first opinion is randomly distributed, it will be unified into the same opinion or split in half, and then, it stabilizes (2.3.1). This process has been described as a kind of phase transition (Siegfried, 2006).

7.3.3 Multi-Agent Model

This is a simulation that gives intelligence to the automaton (agent). Each agent has goals and plans and reacts to the environment and acts by interacting with other agents.

As a practical example of a multi-agent, Epstein and Axtell (1996) have created a simple evolutionary model "Sugarscape" in which agents with different fields of view move around looking for sugar. Even if the simulation is started with a uniform distribution of wealth among agents, the distribution will be distorted. The introduction of "trading" to this model further magnified inequality.

To study emergent phenomena of human society using this simulation, it is necessary to model two or more layers. The second emergence is a factor that creates the difference between human society and animal society. This corresponds to further changes after recognizing the pattern created by the agent.

7.3.4 Genetic Algorithm

Genetic algorithm is a simulation that improves fitness by mating agents with excellent fitness. For example, the strategy in a dilemma game is regarded to be a chromosome, and the combination of them is regarded as an agent gene. The chromosomes of agents with good competition results are combined to generate their offspring, and the competition is repeated between the offspring. Continue the competition until the fitness reaches the maximum, and search for the ratio of strategy/property at the equilibrium point.

When many agents are involved in the simulation, it becomes a problem of the complex adaptive system. Individuals with excellent fitness are selected from the parental generation, and the calculation to create the offspring is repeated after mutation and mating (gene exchange) operations. The probability is the same regardless of whether it is set as the selection probability of each player or as the proportion of members who take each strategy in the group. In other words, the Nash equilibrium based on the mixed strategy is established here.

Genetic algorithms has also been applied to simulations of problem-solving in groups. For example, in the case of application to problem-solving, a group searches for multiple solutions, crosses more valuable solutions, and creates diversity. Here, low-value solutions are filtered out.

7.3.5 Fitness Landscape

A fitness landscape is a visualization of how an agent with a strategy approaches the correct answer. From a large number of factors, we select features to be used in the model and assume them as state space and analyze how the influence of the features changes with time development. Figure 3 shows an example. If the fitness (described on the vertical axis) increases linearly as the parameters change, it is a landscape that has only one mountain, so it is a simple problem to solve. On the other hand, if there are multiple peaks, the value may remain at the local optimal solution (local optimum: low-fitness peaks at points a1 and a2 in Fig. 3.

To climb a mountain with higher fitness, it is necessary to lower the fitness once. However, when the parameters are gradually changed from the points a1 and a2, the fitness decreases, and there is a stagnation there, which makes it impossible to reach a really good solution. Therefore, jumps with high fitness due to diversity or genetic algorithms (mutation or mating) are required. The more peaks there are, the more difficult it is to solve, and the diversity of collective intelligence is essential.

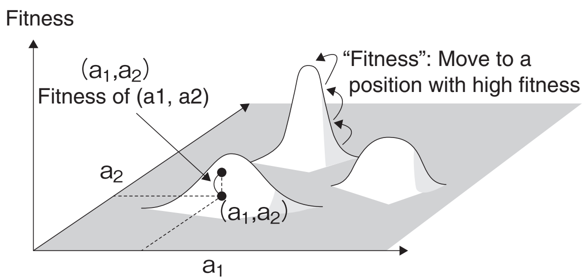

Fig. 3 Fitness landscape example (Iba & Fukuhara, 1998)

Concluding remarks: Humans as Coupled Oscillators

Human beings live in a two-layer network structure consisting of interpersonal networks and intergroup networks. Furthermore, a neural network exists in the substructure. The science of consciousness is only at the stage of hypothesis, but the synchronization phenomena of neural networks are thought to involved in the process (Koch, 2004). In this process, when the synchronization of a nerve cell firing spreads and an acquires extensive synchronization, information reaches a narrow window of consciousness. At that time, network nodes oscillate, and entrainment that synchronizes with each other induces a phase transition.

Then, what does collective synchronization of human-to-human networks generate? Just as individual nerve cells are probably not able to sense "consciousness," individuals may not be able to sense the results of collective consciousness. But, in fact, just as the behavior of nerve cells is not unrelated to "consciousness," whatever it is, it could not be unrelated to human beings. Here, let's assume that collective consciousness is the meaning created by human interaction.

Human neural networks are randomly set up shortly after birth, and the neural connections are both expanded and eliminated adapting to the environment in which they were born and grow. Given this, it should be no surprise that different individuals recognize different patterns and perceive different meanings to stimuli. However, humans have the ability to share cognition and collaborate through distributed cognition. What makes this possible is the innate communication ability of human beings, who are born with a neural basis for imitating others. Even after growing up, behavioral imitation becomes the default; in essence, human beings are naturally "coupled oscillators." By Synchronization with others, a state of sharing the situation emerges at a level beyond the individual's consciousness, and its superstructure again affects the individual. This is "common sense" and the "power of the situation," while not necessarily conscious, works implicitly as cooperative behaviors and distributed cognition.

We can unknowingly utilize the information stored in our own brain, the brains of others, and the information embedded in the environment. Collective intelligence

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is an emergent phenomenon that is a result of interaction without intention. Despite the fluctuations in customs and differences in information interpretation, the transportation, economy, and other systems that run the world maintain sufficient reliability. The collective intelligence highlighted in Internet technology shows the way to measure one aspect of it, not the whole picture.

The more complex the problem, the more reliable is the collective intelligence. This is because there is a limit to the capacity of knowledge and the complexity of knowledge structure that one person can have. Collective intelligence outperforms the best members in the long run. A group can achieve a linear-nonlinear shift by weighing shared information to narrow down the choices and applying a majority rule with conformity. The majority vote has made humankind survive in this world by working as a simple approximation of collective intelligence. On the other hand, linguistic communication, which requires adjustment of the semantic network, becomes simpler as it spreads widely. This process form an easy-to-understand axis of confrontation and make people's attitudes polarized.

From an individual's point of view, understanding vast amounts of information with a common knowledge structure becomes a difficult task. Even if the mechanically precipitated collective intelligence contains complexity, it is not necessarily readable as it is. The interpretation of the answers produced by the collective intelligence is returned to each individual's point of view.

Whether or not the answer from collective intelligence—which we receive—is correct at any given time in the future is determined when the future is reached. Each person's action can create new synchronization. As humans continue to remodel our environment, the optimization axis will change as well.

The reason why we need "knowledge summaries" in university education and in this book, for example, is that we cannot fully understand the knowledge structure by only accessing the necessary information as needed. I hope this book will be useful as a knowledge map for readers to develop the ability to think indelendently and set their own judgment criteria when they face problems without a correct answer.

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