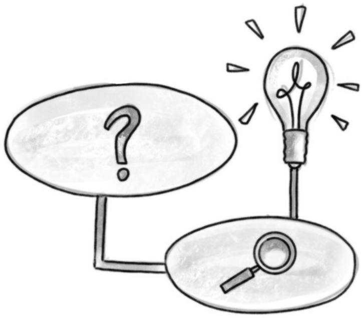

Analogical Insight and Recategorization

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Abstract

Although insight is recognized by most cognitive psychologists, the mechanisms and rationale behind its action remain unclear. Based on existing theories, this article proposes a new potential theory for understanding the role of insight. The theory suggests that insight recategorizes problems by discovering analogies. Correct categorization can lead to new and useful information, bring cognitive agents to effective search domains, and help find the right solution. Among this, prior experience and training are necessary for correct categorization. Lack of prior experience or relevant experience may result in the inability to perform effective recategorization and thus may fail to bring correct answers. Categorization theory also fits in with other theories. It can explain the difference between insight problems and non-insight problems and can be proved by several classical experiments to explain different phenomena.

Keywords: **analogies, insight, recategorization.**

Introduction

Most people have experienced in their lives that, after struggling with a problem for a while, they suddenly had a flash of inspiration and noticed a new way to find the solution. Although it is hard to describe in words, psychologists have given this "AHA!" phenomenon a name: insight. To be specific, insight is a sudden, unexpected thought that positively affects problem-solving, making the problem solver feel easeful and confident about an otherwise intractable problem (Topolinski & Reber, 2010). At the same time, problems that cannot be worked out using general or intuitive strategies and require insight to solve them are called insight problems (Shen et al., 2016).

Scholars have reached a relatively consistent view on the definition of insight, but there are still disputes over the details and mechanism behind the insight. Gestalt psychologists like Kohler (1929) believe that insight is like "looking into" a problem, which means paying attention to the problem and restructuring it. Maier (1931) proposed that when dealing with the problem, the relevant prior knowledge will transfer to the current problem and benefit the problem-solving process, which implies that insight might be related to previous experience. However, Karl Dunker (1945) believed that fixation is the blinding effect of past experience and prevents us from solving the problem, and the center of insight is how to reconstruct or formulate the goal or problem. Insight is an essential part of problem-solving and is often associated with innovation (Kheirandish & Mousavi, 2018). A better understanding of insight will not only help us understand general problem-solving processes but may also potentially improve the likelihood of innovation or the ability to solve complex problems. As for how insight leads
people to the correct solution, this essay proposes a concept named categorization to explain how insight works after reviewing all of

these theories. Notably, categorization is a long-standing concept in cognitive psychology. If we can show that insight and categorization are somehow related, then we can transfer the vast amount of research that already exists on categorization to the insight problem and thus discover more potential explanations.

The definition of categorization here is similar but has subtle differences with the object categorization. In object categorization, people can put things with similar properties into the same category according to their perception and predict other properties through the category (Rosch et al., 1976). Cognitive agents may solve problems in a similar way. For example, by obtaining additional information about the solution by categorizing problems. I claim a thesis that analogical insight can help cognitive agents recategorize difficult problems and search for relevant information and correct solutions in the correct categorization. This article will verify the existence of categorization in problem-solving based on several classical experiments and give a potential explanation of how it relates to insight. Before starting the verification, I will first comb through the relevant content from past studies and explain the complete process of categorization.

Literature Review of Categorization and Problem-Solving

Categorization in Solving Non-Insight Problems

Think back to the math tests that students complete in school. Rather than simply asking what 20 times 3 equals, the question is more likely to ask: If there are twenty students in the class and each student has three oranges, how many oranges are there in total in class? Teachers around the world tend to use semantic alignment to help students understand mathematical problems, using heuristics to help students relate situational models to mathematical models (Tyumeneva et al., 2017). The use of heuristics means that students can solve problems with limited time and information, using conventions or standard routines from the past (Kheirandish & Mousavi, 2018). In Tyumeneva et al.'s study (2017), mathematics textbooks would use discrete objects, such as marbles, to represent integer problems, and objects that can be continuous, such as water and temperature, to represent decimal and fraction problems. When objects with semantically symmetric relationships, such as tulips and roses, are mentioned, people are more likely to associate them with addition and subtraction problems. In contrast, when objects that have semantically asymmetric relationships, such as tulips and vases, are mentioned, people are more likely to associate them with multiplication and division problems. Although such mathematical problems are non-insight problems, they are relevant for analyzing the solution of general problems. We can conclude from these examples that the semantic information in the questions can help one categorize the problems by analogy.

The benefits of categorizing problems are similar to that of categorizing objects. Just as categorizing objects allows for predicting their properties (Rosch et al., 1976), categorizing problems allows for having more information relevant to solving them. For example, categorizing a problem under a semantic scenario model as a multiplication problem allows cognitive agents to be accessed to multiplication tables, multiplication exchange laws, multiplication distribution laws, and other laws or solution techniques. This theory

presents a pattern that is similar to the information differentiation in object categorization and recognition. In object categorization, the categorization can be classified into different levels. If an object is at the basic level, then it is likely to have a superordinate level and some subordinate levels (Murphy & Brownell, 1985). For example, the superordinate level of a chair could be furniture, while the subordinate level could contain barstools, quad chairs, rocking chairs, gaming chairs, and so on. The different levels of categorization contain different information. The subordinate level has more specific information and can list more attributes to the object, while the superordinate level contains more information that distinguishes it from other categories, but also makes the subordinate categories less distinctive (Murphy & Brownell, 1985). Therefore, if problems are miscategorized, the information that can help solve them will not be obtained and processed correctly, and the problem will become difficult. If this theory is applied to the insight problem, the reason why it is difficult to solve may be due to the wrong categorization. I will provide more details and discuss this hypothesis further in the subsequent parts of this article.

Categorization in Solving Insight Problems

Reviewing analogical insight is a good starting point to understanding how insight can help achieve ingenious categorization and bring the cognitive agents to the right answer. In many experiments which examine insight, scholars have found that participants rarely transfer relevant information to an insight problem without explicit prompts (Needham & Begg, 1991). The lack of spontaneous analogical transfer may lead to the inability of cognitive agents to put valid information and insightful questions into the same category, and therefore the problem cannot be solved correctly.

Two classic cases of insight can prove this thesis. The first case is Duncker's radiation problem (Duncker, 1945). In this scenario, doctors need to treat tumors with laser radiation, but the needed laser power can also damage other normal tissues. The medical problem about radiation is difficult for most people to address because few of them have information about radiation and medicine. However, a story of military action could cause insight (Gick & Holyoak, 1980). When attacking a fortress, the entire army cannot follow the same path. The army was therefore divided into small groups, which marched along different roads and eventually met up at the target. After providing hints about the military problem of the army occupation of the fortress, the participants were able to draw an analogy between the radiation problem and the military problem and solve it (Gick & Holyoak, 1980). In the process, participants likely placed both problems into the same category and therefore received more information about the dispersed transport. Another example is Rutherford's discovery of the nucleus. Although other theories already existed, Rutherford's pioneering analogy between the hyperbolic motion path of a particle and the motion path of a comet led to a theory that was later verified to be correct (Dietrich, 2010). Where most people are unable to make the connection between atoms and comets, Rutherford was able to see the two problems as the same category and apply the known information of comets to the atomic problem. This unique analogical insight made it possible for him to crack the puzzle. Some researchers have shown that analogy and categorization are highly similar and that they both contain similarity-based migration mechanisms (Ramscar & Yarlett, 2003). There are also studies that unify the two, arguing that analogy-making is a type of categorization, while spontaneous analogy generates insight and new knowledge (Dietrich, 2010). Thus, the argument that what insight brings to a cognitive agent may be a new understanding of problem categorization, which in turn helps to solve the insight problem, is reasonable. Next, I will apply this theory in several classical experiments.

Application of Categorization in Classic Insight Problems

Changing Categorization in Mutilated Checkerboard Problem

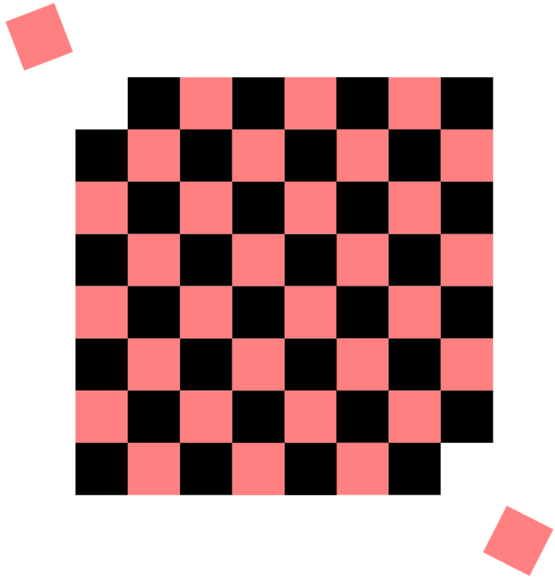

Figure 1. *The mutilated checkerboard problem.*

In the mutilated checkerboard (MC) problem experiment, the two opposite corners of the 8 x 8 board were removed, and subjects were asked to cover the entire board with rectangular dominoes which could cover two adjacent squares (Kaplan & Simon, 1990). If this was not possible, subjects needed to explain the reason. In the experiment, the researchers gave four representations of the board to manipulate the cues. The four representations included a completely blank board, a board colored in black and white, a board marked with "black" or "pink" on adjacent squares, and a board marked with "bread" or "butter" on adjacent squares. As the researchers predicted, the bread-and-butter hint group solved the problem the fastest, followed by the black-and-pink group, the black-and-white group, and the blank group. The researchers believed that the participants were inspired by the problem setting and the experimental cues, which made them realize that two adjacent squares of the checkerboard represented some parity. As a result, the insight about parity helped participants extend their searching space by changing the representation of the board, prompting them to solve the problem.

This explanation is reasonable, but how insight motivated subjects to change the representation of the problem and how it expanded the search domain still needs to be discussed. Categorization theory can further explain this process. Using the bread-and-butter group as an example, it is more likely that insight is what brought them to an analogy. After comparing adjacent grids to bread and butter, subjects would find it more appropriate to categorize the MC problem into the parity problem rather than into a coverage problem. In fact, how they name this category of problem is not the most important. The crucial point is that information about the parity is pulled out after the subjects have recategorized the questions. Subjects may recall knowledge about parity, such as pairwise occurrences and remainders. If the problem is not recategorized, subjects may still use the knowledge and information used to solve the covering problem to try to solve the MC problem, and then they will not be able to approach the correct solution.

Analogical insight and categorization also explain the differences created by the four sets of board representations. Since bread and butter was a more common parity imagery, it was more likely to allow for analogy and knowledge transfer, which also accelerated the rethinking of categorization. In contrast, the blank group, due to the lack of examples that could be used for analogy, made it difficult for subjects to spontaneously form analogical insights and to recategorize.

The example of the MC problem brings up an additional thought. If subjects do not have knowledge about parity, will they never be able to solve the problem? Intuitively, the answer is yes. Because without knowledge about the category of parity, subjects cannot classify MC problems as parity problems and cannot obtain new information. Regarding this assumption, the 9–dots problem and its training may give more support.

Changing Categorization in 9–Dots Problem

In their paper on examining fixation, Weisberg and Alba (1981) conducted a series of experiments on the 9-dots problem. This experiment gave a three-in-three nine-point diagram and asked the participants to connect all the dots with four straight lines without lifting the pen. Weisberg and Alba (1981) found that despite being given hints to get out of the square and being told that they had exhausted all possibilities in the square, the subjects still had difficulty finding the correct answer. However, if some simple training is provided to familiarize subjects in advance with how to solve concatenation problems in a non-dot-to-dot pattern, the success rate will increase. This phenomenon is consistent with the analogous insight and recategorization about parity in the MC problem. Recategorization of problems and gaining additional information was possible only after subjects had known the basics of parity and were able to see analogies in the hints. However, most people have only experienced solving dot-to-dot pattern concatenation problems, for example in a cell phone gesture password unlocking, and they lack experience with non-dot-to-dot patterns. This goes some way to explaining why training is helpful in solving insight problems. Past experience in fact provides the necessary conditions for analogy and categorization, increasing the likelihood that the subject will correctly recategorize

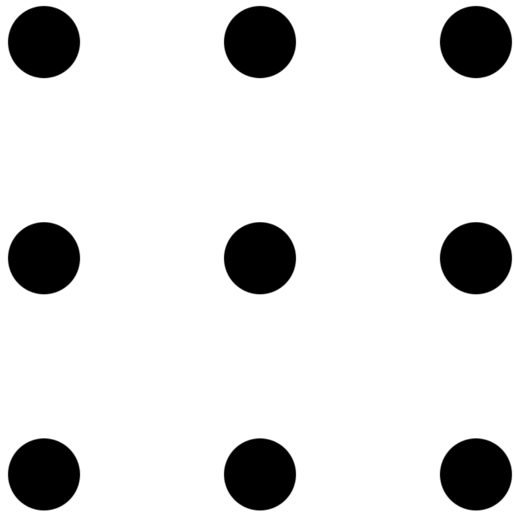

Figure 2. *The 9-dots problem.*

the problem. In their paper, Weisberg and Alba (1981) argue that removing fixation does not produce an immediate solution, and they refute the theory that fixation makes the insight problem difficult. But the delay in the emergence of a solution could also be attributed to the fact that, even if the problem is correctly categorized, the cognitive agents still need time to search for and integrate the solution under the correct categorization.

In Weisberg and Alba's follow-up experiments (1981), they also tried different training situations. They found that if the training provided was still in a dot-to-dot pattern but had the same shape as the actual problem, subjects could still improve their problem-solving skills. Conversely, if the training was in a dot-to-dot pattern but had a different shape than the actual problem, not only did it not improve problem-solving ability, but it had a negative effect. The researchers explained this by the fact that past experience is transferred to the present problem-solving strategy. This result demonstrates in another way that analogical insight allows for the recategorization of the problems. In the case of the dot-to-dot pattern with the same shape training sets, the insight brought to the subjects by past experience was not to categorize the 9-dots problems into categories beyond the dot-to-dot pattern (or beyond the square), but simply to categorize the training and actual problems as connected problems of the same shape. Thus, the insight expected by the researcher, which led to recategorization, did not occur during problem solving. Based on the same logic, in the case of the dot-to-dot pattern with the different shape training sets, subjects could neither recategorize the 9-dots problem into a beyond dot-to-dot pattern nor recategorize it into the same shape pattern as in the past experience, so the problem-solving ability decreased.

In a more recently conducted set of experiments, scholars have similarly demonstrated that the lack of a priori experience is one of the major factors in making the insight problem more difficult (Kershaw & Ohlsson, 2004). We can observe that a priori experience is necessary for resolving insights, and there are studies that show that it is also necessary for correct categorization (Bornstein & Mash, 2010). Therefore, we can demonstrate that there may be a connection between solving insight problems and categorization.

Changing Categorization and the "Small-World" Model

Schilling's "small-world" model and theory (2005) have similar logic to the categorization thesis. She argues that insight emerges with atypical associations in problem solving, which create representational shortcuts in the recombination and the search of problems. In her article, the recombination of problems means that the cognitive agents make a connection between two closely related ideas in order to find a solution. This connection may be unexpected, which is what insight brings to the "AHA!". And in the categorization thesis, recategorization behaves like recombination. In fact, the recategorization brought by an analogy insight is also the rapid abstraction and combination of two seemingly unrelated problems, so as to categorize the problems that cannot be distinguished at first sight into the correct category and obtain relevant information.

Several of the experimental examples used by Schilling (2005) can likewise be explained by categorization. For example, the apes were given a hoe and food was placed out of their reach. The apes were more likely to learn to use the hoe to reach the food if the researchers let them play with the stick and discovered how it functioned. Schilling's (2005) theory suggests that apes discovered the functional similarities between hoes and sticks, created associations and recombined them, and learned to solve the problem of obtaining food. And the categorization thesis could explain that apes gained analogical insight in using sticks and solved the problem by dividing the hoe and the food problem into a category which was used to reach the food. Other examples can also be explained using similar logic. Thus, the small-world model and categorization thesis can be viewed as different interpretations of the same set of logics, and both are valuable.

Connections to Other Theories

The categorization thesis can also fit in well with other theories. Firstly, most of the problems that are difficult to be solved belong to ill-defined problems. Ill-defined problems may have several drawbacks, such as unclear definitions of the initial state or goal state, or unclear potential pathways. However, the recategorization can transform the ill-defined problem into a well-defined problem. For example, in the MC problem, it is challenging for participants to identify all potential pathways to solve the problem. Also, they don’t know whether the answer to the problem is possible or impossible, so the goal state is also not clear. But after mastering the details of parity, participants narrowed down their pathway of actions and realized that the goal state is to prove the parity of the board. At this point, the MC problem becomes well-defined.

Second, some scholars argue that experts who are proficient in a particular field may have a more difficult time solving insight problems in that field because they are bound by their fixed experiences (Schilling, 2005). This is consistent with the characteristics of categorization. As mentioned above, categorization includes many different levels. Experts usually have a very detailed knowledge of their field, so they may tend to focus on the subordinate level rather than the superordinate level when categorizing problems. Thus, despite having accurate and detailed knowledge, it is more difficult for experts to see similarities between some categories, and make it more difficult to gain analogical insight.

Analogical insight and categorization theory can likewise be supported by physiological findings. It has been shown that, based on fMRI and EEG, sudden insights emerge when the resolver sees previously unseen connections (Bowden et al., 2005). This "connection" is likely to represent the occurrence of association, which is evidence for the existence of analogical insight. Both the small-world model and categorization thesis explain the process by which such associations occur, which is by relating features of other problems or things to the problem at hand. Recategorization, then, is likely to occur when dealing with insight problems.

Categorization theory can also explain the difference between insightful and non-insightful questions. As demonstrated in the 9-dots problem, training improves the ability of cognitive agents to solve insight problems and reduces reaction time (Weisberg & Alba, 1981). Automation may occur if a lot of training is repeated (Schilling, 2005). This automated phenomenon in fact transforms insight questions into non-insight questions specific to individuals, such as students who can automatically relate water and marbles to the characteristics of decimals and integers after a few years of math classes.

Conclusion and Discussion

Overall, the thesis suggests that the insight mechanism may be related to the cognitive agent's categorization of the problem. In the case of non-insight problems, the cognitive agent's categorization of the problem based on previous experience is usually fast and correct. However, for insight problems, the categorization of the problem may be vague or misleading. Therefore, the intuitive categorization is likely to be wrong, making it difficult for the cognitive agent to obtain information relevant to problem-solving. Thus, in previous experiments, miscategorization caused many participants to search in domains that did not contain the correct answer, resulting in a solution that could not be found even if exhausted. At this point, the solution will emerge if participants realize that they are miscategorizing the problem and put it back into the correct category by analogy. This unconscious act of making analogies and correctly categorizing them may explain the generation of insight.

It is noteworthy that each cognitive agent may have different methods and strategies for categorizing problems, and this feature is very similar to the logic by which people categorize objects. Experts in a particular problem category are more likely to focus on the subordinate level rather than the superordinate level when categorizing problems. This is because they have too much knowledge about their familiar categorization, making it harder to detect errors in their superordinate level of categorization. It is also more difficult for them to gain analogical insight and change their problem categorization. On the other hand, if cognitive agents lack knowledge of the correct category to which the problem belongs, they cannot recategorize the problem and obtain more valid information through the new categorization.

As mentioned above, the MC problem, the 9-dots problem, the small-world theory, and other theories are consistent with the categorization theory. Thus, we can tentatively conclude that the thesis that analogical insight allows cognitive agents to recategorize problems has more information about the problem and being able to solve them is potentially correct. The establishment of the categorization theory means we can transfer theories about object categorization to the study of insight to further explore the human cognitive system. This knowledge transfer can help us better understand how cognitive agents approach problems. In addition, potential benefits may arise from the study of the insight principle. For example, it has been suggested that the realization of innovation may involve transforming unknown relations into always relations (Kheirandish & Mousavi, 2018), which is similar to the theory of recategorization. If the categorization theory proves to be correct, then we may be able to improve people's learning and innovation abilities by understanding problem categorization. If the understanding of insight is applied to computer science, we may be able to improve existing algorithms. In linguistics, the word-based hints used in the previous experiments may help expose more findings on how people process words semantically.

However, more research on this theory can still be conducted in the future. For example, experiments could be conducted to demonstrate whether this recategorization exists, or more physiological studies could be conducted to explain the insight phenomenon. Possible experiments and studies include self-report and brain activity studies. For example, in subsequent experiments, researchers could ask participants to describe or record their thought processes before and after the "AHA moment" to analyze whether they are involved in categorizing the problem. We can also compare the brain regions that are active during insight problem solving with those that are active during object categorization to determine if the same brain structures are involved. If we can show that there is a process overlap between categorization and insight, then the categorization theory is likely to be valid.