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Insight in Rats

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Synonyms

Aha moment; Deep understanding; Eureka effect; Reasoning

Definition

Insight is a spontaneous, continuous, and direct way of solving a problem, also called Eureka effect or Aha moment. In rats, it is defined as spontaneous interconnection of behaviors to reach a goal and has also been related to the concept of causal reasoning.

Introduction

Köhler was one of the first authors who proposed the spontaneous way of solving problems as opposite to a gradual or trial-and-error solution. He tested in apes the use of roundabout methods to achieve a goal in different tasks, also called "Umweg" or "detour" problems, and he came up with the German word "Einsicht" to define the process of spontaneously solving them. The word was translated in English as insight in *The Mentality of Apes* (Köhler 1925).

At the beginning of the twentieth century, investigations were carried out on the spontaneous resolution of problems in rats, called insight. However, the definition of insight has been controversial since the word *Einsicht* was translated; the most cited and standard definition until now (Foerder et al. 2011) is Thorpe's (1956) "sudden production of new adaptive responses not arrived at by trial [error] behavior. . .or the solution of a problem by the sudden adaptive reorganization of experience" (p. 100).

Helson (1927) was the first publication in rats with the term "insight in the white rat." The principal objective of his study was to measure rats' visual perception learning and to determine if the rat's response was conditioned to the element connected with the goal or if there was a structural and functional learning of the specific problem situation, so the elements in the situation could change while the response was maintained. Helson related this experiment in rats with Köhler's experiments of insight in apes defining insight as an "ability to respond to a part in the light of the whole, a modification of activities to meet the exigencies of a situation in a manner we may call sensible, or the transposition of the general properties from one situation to another" (p. 380).

In Helson (1927), four rats were exposed to different intensity stimuli: gray color scheme and

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degrees of illumination. Rats were placed in a room with two compartments both with food, each light intensity was randomly assigned. In the first five series, Rat 1 and Rat 2 received food in the brighter gray color or light (60-watt vs. 15-watt) compartment, and Rat 3 and Rat 4 received food in the darker one (60-watt vs. 15-watt light). If the rat entered the wrong side, the plate with food was removed out of its reach. In the last four series, the values of intensity of the stimuli changed; for example, for Rat 1 and Rat 2, the brighter light was of 150-watt, and for Rat 3 and Rat 4, the darker light was of 1-*candle-power* (cp) light.

Helson (1927) concluded that there was insight in the rats' behavior because they followed structure-function principles and not connections between identical elements. "Rats responded to and retained the structure, neglecting the absolute element as such; for example, although Rat 1 and Rat 2 had been choosing the 60-watt light in the first five series of experiments, when presented with the 15-watt light, they chose the brighter and neglected the 60-watt light as they had previously been neglecting the 2-cp light" (pp. 383). Rats learned to follow the brighter light in opposition to the specific stimuli conditioned, the 60-watt light. This learning rule imply that rats adapted better to dynamic but consistent environments, through a cognitive-like reasoning approach.

Testing Rats' Insight in Mazes

Tolman and Honzik (1930) published the second article of insight in rats in which they conducted three experiments with different mazes. They defined insight as "a material, inner relation of two things to each other" that can be seen in the response as sudden changes in response. The authors hypothesize that some learning occurs in the absence of observable changes in performance, and it does not manifest until the reward is introduced, when the response appears in an insightful way.

The first experiment consisted of a replica of Hsiao's (1929) experiment, but this time with more subjects. They used the same labyrinth to test rats' insight. Rats had to infer that, if a common section was closed, none of the paths led to food access, so the only alternative was to take a third path to get the food. They trained rats to run through the paths and develop a strong preference for Path 1, a less strong preference for Path 2, and a weak or no preference for Path 3. They found that 4 of the 10 rats tested avoided Path 2 after returning out of Path 1 in the first group and 1 of 11 rats in the second group. Therefore, they concluded that the results were not sufficient to prove insight in rats, and they conducted a second experiment in which the maze was modified to require a larger movement between Paths 2 and 3. It was found that 5 of 11 rats avoided Path 2 on the first run, but they argue that these results were not clear to conclude that subjects chose pathways based on the most efficient way to reach the goal and not on the strength of the pathway's habit.

In the third experiment, Tolman and Honzik (1930) built an elevated maze with similar characteristics: three different paths to reach the final box. They scored the number of dead-end arms rats entered, considered as errors, during each trip from start to goal box. They created three groups: reinforcement, not reinforcement, and delayed reinforcement. The reinforcement group was always rewarded with food when rats reached the end of the maze, and the number of errors decreased dramatically as a function of the number of trips they made. Rats in the not reinforcement group were just taken out of the maze when they reached the end of it, committing more mistakes, and rats in the delayed reinforcement group were taken out of the maze for the first 10 days, but rewarded at the end of it on the eleventh and subsequent trials. In this group, the number of errors made dramatically decreased on the twelfth and subsequent trials, even more than the reinforced group. The authors explained that rats in the delayed reinforcement group developed a "cognitive map" of the maze during exploration and that such mental representation guided the behavior in the rewarded sessions – evidence that learning can occur without performance. The insight run was given on the fourteenth day, and they found that, in the first run, 14 of 15 rats in

Group A and 7 of 10 in Group B avoided Path 2, taking Path 3 immediately, in spite of the strong preference and habit for Path 2 acquired during the training period. They concluded that rats can show insight behavior when they can see the situation as a whole in an elevated maze.

Replications of Tolman and Honzik's third study with rats (Caldwell and Jones 1954; Gilhousen 1931) obtained similar results. Notwithstanding, the authors questioned the term insight as an explanation of the data, due to the lack of operationalization of the concept, so the interpretation of the solutions is ambiguous. For example, Caldwell and Jones (1954) explained that if insight is defined as one-trial learning which is subsequently maintained, then this definition was not applicable in their replication, because the subjects did change their performance in subsequent trials. They suggested a redefinition of the concept that encompasses this non-maintained performance; otherwise, it could be explained in terms of associative learning.

Gilhousen (1931) highlighted factors to account for the emergence of insight. He tested insight in rats with an elevated open maze, a solution to the problem required suddenly to oppose previous habit and preference. Rats were trained to go through a jumping path to avoid going through a running block path to a food box. The hypothesis was that the more jumps rats must do, the harder that path will be, so they will choose the running path instead of the jumping-habitual path. In the test, Gilhousen moved the paths closer, so the rat had the opportunity to avoid most of the jumps, running to where it was blocked through the running path and then taking a single jump to get to the food through the jumping path. However, all rats continued choosing the jumping path in the test.

Gilhousen suggested that factors such as the type of behaviors requested to solve the problem, the dimensions of the maze, or the amount of previous training affect the emergence of insight. Running and jumping constitute separate abilities, which hinders the sudden change from one behavior to another. An unbiased test would require more similar behaviors. It would be relevant to study the effects of varying the dimensions of the maze, as it would require different abilities to jump. It could be expected that the longer the rats were required to jump, the more effort would be involved, so the rat would prefer the other path. In addition, the amount of previous training given can be important because the more training is given, the stronger the habit will be, and therefore, the appearance of a sudden change of behavior will be reduced.

Fortuitous Observations of Insight in Rats

Hamilton and Ballachey (1934), in an experiment on social behavior in rats, observed one of the rats solving their task in a different and insightful way. Rats had to climb over a barrier to access a tin of food in an open area. They usually did not eat it there but took a piece of food from the tin and returned across the barrier to eat it in a smaller enclosed space. One of them seized the tin and dragged it to the barrier and jumped to the top of the barrier, so the food tin was temporarily out of her visual field, and then "slowly leaned forward and down, grasped the tin again with her teeth, pulled the tin to the top of the barrier and dropped it on the inside" (p. 260). The authors considered this behavior an example of insight because the rat did it in a spontaneous and goal-directed way.

Another example is Ewer (1971), who conducted different tests in free-living rats to investigate performance when food was placed out of their reach. A task consisted of vertically pulling a string with a nut attached, and the rats took no more than two trials to find out how to pull the string up and reach the nut. Ewer concluded that, although the rats did not solve the tests on the first attempt, they did not show learning by trial and error, but by trial and success, because "once a success was achieved, even if this was more or less by chance, they were extremely quick to learn what to do" (p. 164).

The definition of insight proposed by Ewer (1971) created confusion in the area and is one of the problems that still persist. The behavior described by Ewer (1971) may not be strictly insight because the solution, the first response, appeared after several attempts; however, maintenance was sudden and quickly obtained, so this may be an example of faster learning but not truly insight. Nonetheless, the description may fit what most people think of as insight. The problem becomes then of interpretation; how fast should the response be to be considered as insight? Could the solution in the second attempt be considered as insight, or is the experience with the first trial sufficient to consider the solution as a result of trial-error learning? These questions are still in need of resolution.

Hebb's Theory of Insight

Hebb proposed one of the earliest theoretical analyses of insight in *The Organization of Behavior* (1949). Hebb manipulated rats' experience before exposing them to novel problems. He found that faster learning abilities and insightful solutions were more common in laboratory rats that freely explored his home and were manipulated as pets than in rats housed in standard laboratory conditions. Also, he explained that there is a permanent effect of early experience on problem-solving, so animals exposed to specific environments can have the requisite experiences, which can be interconnected to solve new problems presented in adulthood.

In Hebb's theory, the insight is an organized set of responses to a new situation that arises from the reorganization and integration of experiences that have been learned given specific consequences, but such new organization has not been learned. Hebb emphasized the necessity of experience in the emergence of insight, just as Maier (1935) pointed out in rats.

Hebb (1949) considered that insight continually affects learning, because it complements it, and, thus, the distinction between learning and insight must be a matter of degree. He concluded that insight is not a separate phenomenon from learning because it is part of the same processes. He claimed that Köhler's chimpanzees could have been using both associative learning and causal reasoning to solve problems. There is no need to limit insight to situations when there is a fast solution of the problem, but also delayed solutions can be conformed in a similar way, for example, after a confusion period that could take a time or even several trials. This approach is consistent with Ewer's (1971) definition of insight.

Insight: Is It a Synonym of Reasoning in Rats?

Extensive research with *detour* or *Umweg* problems was conducted by Maier (1935) with rats. The problems were situations where the subjects have to overcome an obstacle, so they had to use a roundabout method to achieve a goal. He postulated that, when solving a problem, two distinct abilities interact: (1) to integrate contiguous experiences as described by the laws of association, which he identified as learning, and (2) to bring together spontaneously elements of past experience without having them previously associated by contiguity, which he designated as reasoning. Therefore, for Maier, the phenomenon described by Köhler as insight was termed "reasoning." He was the first to claim that spontaneous integration of different experiences was insight learning.

One of the mazes that Maier built to assess reasoning in rats (1929) consisted of placing rats on a table with a ladder that gave access to the ground. The table was divided by a grating that prevented rats from entering the other part of the table. Experience I involved the rats walking freely through the place. In Experience II, a second table was positioned with an elevated pathway connecting the inaccessible location of the first table. The second table had three ring stand ladders that connected it to the ground. At this stage, the animals climbed from the ground to the new table and crossed the bridge from the new table to the inaccessible area of the first table. The test consisted of placing the animals at the first table and presenting food in the inaccessible area of the first table. Animals should recombine Experiences I and II to solve the problem. Maier analyzed the number of correct responses, time scores, and the directness of the run and concluded that experienced rats were able to recombine them, but rats without Experience I or II failed to solve this task.

In contrast, Wolfe and Spragg (1934) did not replicate Maier's results (1929) using three adaptations of Maier's apparatus with both elevated and enclosed pathways. They found that rats' performance was not superior to chance, so rats were apparently unable to combine two segments of behavior successfully. In a fourth variation, the behavior of Maier's rats was replicated, but Wolfe and Spragg criticized the amount of training that rats needed to get it. They concluded that success in the task cannot be called reasoning because the training procedure would have introduced learning (i.e., association by contiguity) and solutions were achieved in "a manner entirely consistent with ordinary learning principles" (p. 469). Maier (1935) argued that the amount of training does not mean that they learn to recombine more easily because the route to food cannot be learned, since it is different each day. They increased their exploration but not their ability to find which path leads to food, because the training does not determine which path leads to food on a test.

Other possible methodological variables that Maier emphasized as important when recombining experiences are the training procedure and the differences in the apparatus. Wolfe and Spragg did not carry out a general exploration period on the days of the tests and changed the position of the food box and starting point in the maze. If the pathways to be selected were near the starting point, rats easily chose a pathway without a possible appearance of a confusion period, committing mistakes. Instead, when the starting point was next to the food, which was behind a wire obstruction, rats attempted to reach it first without success, and during this confusion period, they can "reason" which path to take to reach the food.

Shepard (1933) also used the term reason in rats and defined it as adaptive reactions that are "a combination, in advance of the reaction, of factors from separate experiences, and where such separate experiences involve essential contradictory or differing elements that must be functionally recognized" (p. 149). He exposed rats to enclosed mazes with food boxes with different start points, alleys, sections, and shortcuts. One maze consisted of long *cul-de-sacs* and a subsequent correct path to food. After letting the rats thoroughly explore it, a shortcut was opened in one of the dead ends. In the first trial, it passed the blind as usual but paused when it came to the new opening, explored the area, and went through it to the food box. Then, the rats were removed and placed at the start point again. Most of the rats turned at the appropriate junction and took this former blind alley to go directly to the food. Shepard suggests that rats reasoned because they spontaneously took the shortest path to the food.

More recently, comparative psychologists have been interested in causal reasoning and other cognitive processes mediating problem-solving behavior. Some studies with rats found evidence of causal reasoning using instrumental and Pavlovian procedures (Blaisdell et al. 2006; Polack et al. 2013). However, in these cases, causal reasoning is not defined as a spontaneous combination of experiences but as rats' inferences about their actions and other events in the future, a trait that is implicit in the insight phenomena (Shettleworth 2012). Some other researchers prefer to just describe the behavior as "spontaneous or innovative problem-solving," because the insight concept may have hypothetical cognitive mechanisms underlying further implications, as planning actions (Taylor et al. 2012).

Insight as Spontaneous Interconnection of Behaviors in Rats

A classic test to study insight in animals was developed by Epstein et al. (1984): the box-displacement task. This test is an adaptation of Kohler's experiment with chimpanzees in which a banana was suspended in the ceiling and the subject had to stack boxes to reach it. In Epstein et al.'s (1984) experiment with pigeons, the banana was replaced by a plastic banana, and every time it was pecked by the pigeon, food was given. In the test, the pigeon had to move a box under the plastic banana to reach it. Pigeons were able to solve the task in a direct, smooth, and continuous way, after specific training of three prerequisite behaviors: to push a box, to climb onto a box, and to peck a banana. Epstein et al. considered these solutions evidence of insight in pigeons and proposed the "generativity theory" (Epstein 1990) to better characterize the phenomena as "spontaneous interconnection of separate repertoires of behavior" (p. 117). For more information, see *Insight in Pigeons* ("▶ Insight in Pigeons" by Longán and Buriticá, this volume).

Leonardi et al. (2011), based on Epstein's theory, reported four experiments using the box-displacement task to obtain evidence of insight in rats. In rats, the displacement-box task is like Epstein et al.'s (1984), but instead of pecking the banana plastic, rats had to pull a chain with a ring attached to a bar that activated a water dispenser. Rats were trained to do three prerequisite behaviors: to push a cube directionally toward a point of light that was changing position, to climb onto the cube, and to pull the chain (Leonardi et al. 2011). Nevertheless, rats did not show insight in this task, except one, which solved the task in a sudden, direct, and continuous way, but required more than one test and additional training of prerequisite behaviors.

Leonardi et al. (2011) suggested that rats' negative results could be due to the importance of visual cues to solve this task. The albino rat appears to have consistently impaired visual acuity, and this high-effort visual task is demanding for rats. So, in comparison with chimpanzees and pigeons, this task could be more difficult for this specie and strain. Likewise, the authors noted other procedural variables that could be affecting the ability to spontaneously solve problems: if the learning criteria of the prerequisite behaviors are strict, as well as if rats are trained in the same order in which the resolutions are expected, insight resolutions are more probable to appear during test.

Based on Maier's study, Neves-Filho et al. (2015) showed insight in rats in a new problem situation called "the dig and climb test." The task was to place a rat in a cage where food was visible but unreachable. The cage was divided into two parts by a transparent acrylic barrier. On the left side, the ground was full of sawdust. On the right side, there were ladders that gave access to the platform with food. The transparent barrier had a hole, covered by sawdust, connecting both sides of the cage. So, the rats in the right side had to dig in the sawdust until they found the hole, cross it to get to the other side of the cage, and to climb the ladders to access the food. The behaviors that expected to be spontaneously recombined were (1) to dig in the sawdust and (2) to climb a ladder.

All rats had a pretest session to establish if they were able to solve the task just by exploration, without any training of the prerequisite behaviors, but none of the six rats tested solved the problem in the pretest. Then, Neves-Filho et al. created three groups of two rats each. The full group learned the two prerequisite repertoires, while the other two groups lacked training of one of the two repertoires; one was called digging group, and the other one climbing group. Once all rats reached a learning criterion of the behaviors, they exposed them to the problem. In the test, only the full group solved the task in an "insightful" way. They described the resolution as "the two subjects crossed the hole as soon as they found it, and immediately climbed the two ladders" (p. 8), one in 83 s and the another in 135 s. The performance was like Epstein et al. (1984) behavior in pigeons, that is, in a continuous, fluid, and direct way, although Neves-Filho et al. recognized that "insight is not a clear operational term to describe problem-solving behaviors" (p. 11). For example, there are no specific time criteria to define a solution as insight or trial and error.

Neves-Filho et al. (2015) also did a post-training of the lacking behavior to the climbing and digging groups and a post-test in the same task. In this case, one out of the four subjects solved the task but with pauses between crossing to the other side of the chamber and climbing the ladder. To explain this difference, Neves-Filho et al. suggested that the type of training affected the sudden solution of the problem. In the case of the full group, the training was concurrent; that is, one behavior was trained just after the other; while in the case of the climbing and digging groups, the behaviors were trained at different times, independently or sequentially. As just concurrent training showed spontaneous solving of the task, the authors point out that it facilitates insight rather than an independent training of the behaviors.

Further, Neves-Filho et al. (2016) examined the differences in rats' insight in the dig-climb task using different types of training and orders in the sequence trained. Surprisingly, subjects of all experimental conditions solved the final task (n = 5), and two did it by insight. One subject of the group with both behaviors trained at the same time (concurrent), and another trained first with one and then the other (sequential). Therefore, they conclude that order of training did not increase the emergence of insight. However, they did find that the rats trained concurrently solved the problem in a shorter time than the sequentially trained ones – data that provides some evidence that the type of training can affect the spontaneity in resolution. They argue that the use of a less strict behavior learning criteria than Neves-Filho et al. (2015) could have negatively affected the emergency of insight, so more research is needed to confirm these hypotheses.

Using "the dig and climb test," Longán and Buriticá ("▶ Effects of Environmental Enrichment in the Insight in Rats", in preparation) studied the effects of environmental enrichment in the insight and problem-solving in rats in different types of training and order of behaviors. The experimental group (n = 8) were reared under enriched housing conditions in trios; in such conditions, the animals could develop an ample repertoire of behaviors (to move in different surfaces, social interactions, etc.) through interaction with conspecifics and different objects like an activity wheel and various materials such as wood and fabrics. A control group (n = 9) lived in trios in common housing: acrylic box with sawdust.

Longán and Buriticá established that an insight resolution must be as Epstein et al. described: continuous, fluid, and direct. The link between the two prerequisite behaviors should take a short time to be considered as insight, and other behaviors should not be performed between them. In the first exposure to the problem without any training, called pretest, one rat of the social group and three rats of the enriched group solved "the dig and climb test," one of the enriched group by insight (37 s between the two prerequisite behaviors). Then, a training of one prerequisite behavior was done, and after rats reached the same behavior learning criteria as Neves-Filho et al., rats were exposed to Test 1. One rat of the enriched group solved the task by insight (19 s) in Test 1, after the climbing behavior training. Then, rats learned both prerequisite behaviors in a sequential training, and a second test was done (Test 2). One more rat of the enriched group solved it by insight (22 s), and none of the social group subjects solved the task in Test 2. As in Neves-Filho et al. (2016), no significant differences were found in the order or type of behavior training. Instead, the enriched group was faster in reaching the climbing learning criteria than the social group. These results provide evidence that environmental enrichment facilitates insight, problem-solving, and response acquisition, supporting the hypothesis proposed by Hebb.

Finally, Dicezare (2017) designed a new insight task in rats based on Köhler (1925) in chimpanzees. It consisted of pushing a cube toward a platform and climbing on it and then onto the platform to get food. A concurrent training was carried out of two prerequisite behaviors: to push the cube toward a lit partition and to climb on the cube and on a platform. Other ways to climb on the platform were extinguished. Rats (n = 2) solved the problem in a spontaneous, direct, and continuous way. They performed the second behavior (to climb) right after finishing the first behavior (to push), with 1 second of difference. It was concluded that the procedure adopted made possible the emergence of insight in rats in a methodologically similar way to that used by Epstein et al. (1984) in pigeons.

Conclusions

The recent insight research with rats suggest that its study may not require such elaborate problems or specific species. Spontaneous problem-solving in rats has been demonstrated in several studies for a century, and it is still studied nowadays. Despite great efforts, the term "insight" remains confusing in relation to the processes that underlie it. More elaboration and specificity of the phenomenon through behavioral and time criterion are needed to provide a solid measure to evidence it and identify its mechanisms.

The literature established the importance of experience like specific training or environmental enrichment to the emergence of insight in rats. Training of prerequisite abilities may be enough for the interconnection of behaviors to occur, but there are also variables that can hinder the appearance of insight, for example, the specific difficulty of the problem task to the specie or the amount of experience related to the task (i.e., low learning criteria), while environmental enrichment can favor the acquisition of new behaviors and the emergence of insight in rats.

The theoretically contentious question is whether insightful behavior is the product of a special mechanism or process, as opposed to processes used in routine problem-solving like trial and error. The relation between higher cognitive processes such as reasoning, insight, and associative learning still remains unsolved, due to the lack of observational data to evidence it. Rather, attempts at showing such cognitive processes must first demonstrate that insight study cannot be accounted for in terms of associative learning. Some pioneering studies are already solving this question demonstrating neural correlation with the phenomenon in rats to explain sudden responses in problem-solving (Durstewitz et al. 2010).

Cross-References

▶ Goal-Directed Behavior
▶ Insight
▶ Insight in Pigeons
▶ Means-End Reasoning
▶ Problem Solving
▶ Wolfgang Kohler

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