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Investigating Insight as Sudden Learning

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Abstract:

Gestalt psychologists proposed two distinct learning mechanisms. Associative learning occurs gradually through the repeated co-occurrence of external stimuli or memories. Insight learning occurs suddenly when people discover new relationships within their prior knowledge as a result of reasoning or problem solving processes that re-organize or restructure that knowledge. While there has been a considerable amount of research on the type of problem solving processes described by the Gestalt psychologists, less has focused on the learning that results from these processes. This paper begins with a historical review of the Gestalt theory of insight learning. Next, the core assumptions of Gestalt insight learning theory are empirically tested with a study that investigated the relationships among problem difficulty, impasse, initial problem representations, and re-solution effects. Finally, Gestalt insight learning theory is discussed in relation to modern information processing theories of comprehension and memory formation.

Keywords:

insight, learning, impasse, problem solving

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Introduction

What is Insight?

The term *insight* has been used in many different ways in the problem solving literature. A search of APA PsycNET using the keywords "insight and problem solving" yielded a range of recent definitions. Topolinski and Reber (2010) defined *insight* as an "experience during or subsequent to problem-solving attempts, in which problem-related content comes to mind with sudden ease and provides a feeling of pleasure, the belief that the solution is true, and confidence in this belief" (pg. 401-2). In this definition, insight is a set of metacognitive feelings of ease, pleasure, accuracy, and confidence that can accompany memory retrieval during problem solving. Ollinger, Jones, and Knoblich (2008) defined insight as a description of a particular type of problem solving sequence that happens "when a problem cannot be solved using conventional stepwise methods and the problem solver suddenly realizes (the "aha!" experience) that the solution involves unconventional methods (the problem solver realizes that the problem needs restructuring)" (pg. 208). Gilhooly and Fioratou (2009) defined insight as a type of problem situation where "within the typically derived initial problem representation, the goal cannot be reached and a restructured goal representation is required for solution." They contrasted this with non-insight situations where "the goal can be reached by search within the initial representation" (pg. 356). Finally, Luo and Niki (2003) defined insight as "the reorientation of one's thinking, including breaking of the unwarranted 'fixation' and forming of novel, task-related associations among the old nodes of concepts or cognitive skills" (pg. 316).

Based on these definitions one can see common themes underlying the concept of "insight" such as suddenness, restructuring/reorientation, and difficulty/fixation. In these examples, the term insight is used in very different ways. In one definition, insight is a psychological experience or phenomenon. In the next, it is a particular problem solving sequence. In the next, it is a type of problem situation. And, in the last example, insight is defined as a problem solving process. The difficulty in pinning down a definition of insight is not surprising, because the Gestalt psychologists and later researchers often used this term in multiple ways (Chronicle, MacGregor, & Ormerod, 2004; Dominowski, 1981; Köhler, 1959; Weisberg, 1996). To get to the root of the concept of insight, it is useful to bring up the historical context in which it was first used (Ellen, 1982; Hergenhahn, 2009; Hergenhahn & Olson, 2005).

The History of the Gestalt Concept of Insight

In the early 20th century, psychology was emerging from its roots in philosophy to become an empirically based and experimental science. Empiricist philosophies from the 19th century were playing a key role in shaping the new science. Empiricist philosophers, such as J. Mill (J.S. Mill, 1869/1967) and Bain (1855/1977) had proposed that all memory phenomena are the result of the passive association of co-occurring sensations or ideas, and all behavioral phenomena were due to the association of overt behaviors and resulting feelings of pleasure or pain (hedonism). Bain's original conception allowed for learning that was not just based on co-occurrence (contiguity) of environmental stimuli through the *law of constructive association*. Bain proposed that ideas or memories that had been previously acquired from the environment through passive association could themselves be associated with each other through co-occurrence of recall, thereby creating "new combinations or aggregates different from any that have been presented to it in the course of experience" (1855/1977, pg. 571 cited in Hergenhahn, 2009). It was this law of association that Bain used to explain creativity. Despite allowing for this potential creative process, Bain's theory still proposed that gradual and passive association through contiguity and reinforcement is the basic mechanism for all learning. The learning process he described began with a need in the organism (e.g. hunger or danger). In the face of this need, organisms would begin to produce random behaviors. If one of those behaviors ended up co-occurring with the satisfaction of the need, then an association would be formed. Over repeated re-exposures this bond would strengthen until the organism would begin displaying the adaptive behavior immediately and consistently when that need arose.

Hergenhahn (2009) pointed out that in the late 19th century Bain's books that presented this empiricist viewpoint, *The Senses and the Intellect* (1885) and *Emotions and the Will* (1859), had become the standard textbooks for university psychology courses in both the United States and Europe. Titchener's (1899) *A Primer of Psychology* went a step further to propose that all psychological phenomena could be explained based on elemental components of *sensations* (sensory input), *images* (neurological traces of sensation), and *affections* (emotions), and that all learning consisted of the building of associations between these psychological elements via the frequency of their co-occurrence. In the early 20th century, this associationist approach to psychology culminated in Watson's (1913/1994) Behaviorist perspective where even Titchener's psychological elements were abandoned in favor of connections between environmental stimuli and overt behavioral responses.

It is in response to these ever stricter associationist theories of learning that the Gestalt concept of insight was developed. Köhler (1959) recounted the sense of discontent with associationist theories that accompanied the Gestalt movement in his presidential address to the American Psychological Association. In this address, he discussed the "prison" of "psychology as taught at the universities when we [the Gestalt psychologists] still were students" (pg. 728, bracketed clarification of "we" added):

> *At the time, we had been shocked by the thesis that all psychological facts (not only those in perception) consist of unrelated inert atoms and that almost the only factors which combine these atoms and thus introduce action are associations formed under the influence of mere contiguity. What had disturbed us was the utter*

> *senselessness of this picture, and the implication that human life, apparently so colorful and so intensely dynamic, is actually a frightful bore (p. 728).*

In this address, Köhler admitted that the concepts the Gestalt psychologists developed in their early work were often vague and misleading, and cited insight as an example of such a concept. He went on to attempt to clarify the concept of insight:

> *What is insight? In its strict sense, the term refers to the fact that, when we are aware of a relation, of any relation, this relation is not experienced as a fact by itself, but rather as something that follows from the characteristics of the objects under consideration (p. 729).*

In other words, associationist theories attempted to explain all learning as the result of gradual and passive association of repeatedly co-occurring external stimuli or the sensations they produce. However, the Gestalt psychologists proposed that, in order to fully explain learning and behavior, theories needed to address internally-generated relationships between memories or ideas that are formed based on meaningful conceptual and functional characteristics.

This point of view was articulated by Koffka (1935/1963) as the difference between the *geographical environment* and the *behavioral environment*. The *geographical environment* is a description of the physical elements (e.g. surrounding objects) and properties (e.g. color, weight, position) of the situation in which an organism is behaving or learning. The *behavioral environment* is the organism's subjective interpretation of the current environment based on the aspects of the environment it is attending to or ignoring, its current goals or motivations, its knowledge of the properties of the objects in environment, and its prior experience with the functions or uses of the objects.

Therefore, associationist theories proposed psychological processes that work on the sensations produced by the geographical environment (i.e. seeing the co-occurrence in the external environment, or sight), whereas Gestalt theories proposed psychological processes that work on the internal memory representations of the environment that organisms form through perception, comprehension and the application of prior experience (i.e. insight). In this notion of the concept of insight, any psychological process or behavior that is based on an organism's subjective internal mental representation of a situation, and not simply the objective co-occurrence of environmental stimuli, would be an insight phenomenon.

The difference between these two approaches can be illustrated by contrasting the problem solving behaviors of animals as described by Thorndike (1911) and Köhler (1925/1956). In Thorndike's experiments on animal problem solving, he put cats in a "puzzle box" which contained various levers and switches, one of which would release the cat from the box (a desirable outcome). The cats' problem solving behaviors began with random movements until one happened to interact with the release device. When put in the same situation for a second time, the cats again behaved randomly until interacting with the release device by chance. Slowly, over multiple trials, the cats' behaviors became less random and more focused on the area of the release device. Eventually, the cats would begin to go directly to the release device when put into the puzzle box. In this type of problem solving behavior, solutions were discovered slowly through trial and error, and new information was acquired incrementally as the release device became associated with a desirable outcome over time.

Köhler (1925/1956) described a very different problem solving pattern in apes that were put in the situation of having food placed out of their reach. He described a solution pattern where first the apes would try previously used problem solving strategies to reach the food, such as attempting to climb to it on the cage or poke at it with a stick. When these procedures failed, they would stop all overt problem solving behaviors for a period of time. Finally, in some cases, they would quickly perform a distinct set of actions to retrieve the food, such as stacking up crates and climbing on top of them. Unlike Thorndike's cats, when the apes were put in the same situation again, they did not engage in random behaviors or overt trial-and-error problem solving. Instead, the apes would often quickly enact the same final solution they discovered in the previous trial.

The pattern of behavior exhibited by Thorndike's cats fits perfectly with the associationist theories of learning. The cats gradually and incrementally learned the relationship between pressing the release lever and opening the door through repeated exposure to the co-occurrence of the two environmental events. However, the *initial attempt* --> *failure* -->*solution* -->*one-trial learning* pattern observed by Köhler could not be explained by proposing that the apes gradually formed new associations through the overt manipulation of environmental stimuli or repeated co-occurrence of recalled prior experiences. Instead, Köhler explained this pattern by proposing that when the initial attempts at solving the problem based on previously learned strategies failed, the apes abandoned behavioral trial-and-error strategies in which they attempted to search for the solution in the geographical environment, and began cognitive trial-and-error strategies where they mentally searched for new functional relationships among different prior experiences. This cognitive trial-and-error process, or reasoning, led to the discovery of new relationships that restructured the apes' behavioral environment.

Köhler's results suggested that learning attained through manipulations of the internal behavioral environment (cognitive trial-and-error/restructuring) was qualitatively different than learning attained through associative processes working on objects in the external geographical environment (frequency of co-occurrence of external events/contiguity). In order to highlight these differences, Gestalt psychologists referred to the learning processes involving internal cognitive processes as *insight learning*, to be contrasted with gradual learning by association.

Other Gestalt psychologists attempted to investigate insight learning (restructuring) in humans by adapting Köhler's problem solving methodology (Duncker, 1945/1972; Maier, 1931; Wertheimer, 1954/1959). In order to do this, they attempted to create laboratory situations that would be likely to lead to the initial *attempt* --> *failure* --> *solution* pattern observed in Köhler's apes. For example, Duncker (1945/1972) created problem situations where participants needed to use a familiar object (e.g., cork, pliers, pendulum, paperclip, etc.) in a different manner than usual. In one condition, he first had solvers use the object in its normal fashion, and then attempt to solve the target problem. In the control condition, he had participants attempt the target problem without pre-utilization. The idea behind this manipulation was that utilizing the familiar object in its usual manner would structure the solver's behavioral environment around the familiar functions of the object, thereby making the use of the object for other functions less likely. He found that the pre-utilization of the common object negatively affected solution rates and led to more failed attempts during solving. Hence, problem difficulty via *functional fixedness* or *fixation* became another phenomenon that was consistent with the Gestalt view that the structure of the behavioral environment was more important in determining the difficulty of a problem than the objective external geographical environment. Furthermore, fixation or functional fixedness was thought to set the stage for insight learning processes since restructuring through cognitive trial and error can be used to overcome these difficulties.

In summary, the Gestalt concept of insight was primarily intended to contrast learning processes that function on an organism's behavioral environment (such as restructuring a mental representation through cognitive trial-and-error) against those that are a function of frequency of co-occurrence in an organism's geographical environment (such as association by contingency through behavioral trial-and-error). Insightful learning processes were proposed to be qualitatively different than associative learning processes in that they did not require gradual and incremental attainment of new knowledge through overt trial-and-error. Instead, insightful learning processes result in sudden, one-trial learning. Furthermore, fixation or functional fixedness is a phenomenon that can lead to impasse, and can set the stage for insight learning processes. However, insightful learning is possible in any situation where the initial application of previously learned solving routines fails, and a solver begins cognitive trial-and-error processes that can restructure the information in the behavioral environment.

Investigations of Insight Learning

Against this background it is interesting to note that very little modern research has been conducted to investigate the core concept of sudden *insight learning*, which was actually the primary phenomenon of interest to the Gestalt psychologists. In order to investigate learning of any kind, a basic condition that needs to be met is that behavior must be sampled at multiple time points, with evidence for learning coming from changes in behavior over time. While studies employing single problem solving attempts can investigate solution processes (as most studies of insight have done), only studies looking at problem solving across multiple solution attempts can speak to whether insight learning has occurred.

In one of the few modern studies that has attempted to directly investigate insight learning, Dominowski and Buyer (2000) showed that people's re-solution times on a set of classic insight problems were significantly faster than solution times for people who failed to initially solve the problems and were shown the answers. This study showed that information attained from the successful solution of insight problems did lead to better memory for solutions than that attained from being shown the solution. However, Dominowski and Buyer (2001) did not contrast these findings with problems that required the application of previously learned routines to complete the test of the Gestalt view of insight learning. There are many reasons why one may expect faster solution times on a second problem solving attempt and only some may reflect insight learning. Other alternatives include effects of re-exposure such as reducing the effort needed to re-read the problem, reduced time in formulating a solution strategy, or excluding branches of the search space that were previously found to be ineffective (Ash, Wiley, & Cushen, 2009).

Ash and Wiley (2008) also provided some evidence supporting the Gestalt notion of insight learning. This study used a hindsight bias paradigm to assess the initial representation of problems in memory. To do this, participants read a set of insight and arithmetic word problems without attempting to solve them. The insight problems were arrangement puzzles composed of objects like pennies or matchsticks, while the arithmetic problems contained a similar number of distinct numerical expressions. For each problem, participants rated how important they felt each component of the problem would be toward reaching the solution. For the purposes of the present topic, the component importance judgments can be interpreted as measures of the appropriateness of solvers' initial problem representations. Those with more appropriate problem representations should rate the components that must be used in solving the problem as more important and components that are not critical for solution as less important. After making their initial judgments, participants attempted to solve each of the problems. A week later, participants were brought back to the laboratory and asked to remember their original component importance ratings.

In this study, only correctly solved insight puzzles produced a hindsight bias. That is, participants who had correctly solved the insight puzzles were unable to access their memory for their initial judgments. No bias was seen on the second session component importance ratings for incorrectly solved insight puzzles, or either correctly or incorrectly solved arithmetic word problems. In a second experiment, all participants were given step-by-step instructions on how to solve the problems after they completed their initial solution attempts. The results of this study showed the exact same pattern as Experiment 1. Providing people with the solutions for insight puzzles that they failed to solve themselves did not lead to any changes in memory for importance ratings. Only those who successfully solved the insight puzzles had higher component importance scores in their second session memory ratings. In summary, Ash and Wiley (2008) found evidence that people who correctly solved insight problems acquired a more appropriate problem representation, and retained that more appropriate representation a week later without incremental practice or instructions asking them to attempt to remember their solutions. However, no evidence for attainment or retention of a more appropriate problem representation was observed when participants failed to solve the insight problems and were shown the answers. Therefore, these results can be interpreted as evidence of the one-trial insight learning process proposed by the Gestalt psychologists.

Because Ash and Wiley (2008) directly tested insight problems against arithmetic problems that required the application of previously learned routines, these results go a step further than the Dominowski and Buyer (2001) re-solution results. However, these results still do not provide conclusive evidence for the Gestalt view of insight learning. In particular, this study fails to take into account a key aspect of the Gestalt perspective on insight; that it is the interaction between the current problem situation and a solver's initial internal representation of the situation that sets the stage for insight learning. In other words, there is no such thing as an "insight problem," and one cannot assume that any puzzle will always be solved via the attempt-impasse-solution pattern. Classic insight problems are laboratory stimuli that have been designed by researchers to be highly likely to lead to solvers adopting inappropriate initial solution strategies (Ash, Wiley, & Cushen, 2009) and to lead to fixation or impasse. However, despite their design, there is no guarantee that solvers will actually experience impasse during solution (see Cranford & Moss, 2012). For example, Fleck and Weisberg (2004) collected detailed verbal protocols while participants attempted to solve Duncker's candle box problem and found that, while impasse was highly related to problem difficulty, most participants solved this problem without reaching impasse. According to Gestalt theory, impasse, or initial failure, plays a central role in insight learning. It is only in situations where solvers need to abandon their original solution strategy that they will begin the cognitive trial-and-error processes that can lead to the restructuring or re-organization of prior knowledge. Therefore, in order to make strong conclusions about whether evidence exists for insight learning as a distinct form of learning, one needs to assess whether solvers actually experience and overcome impasse during their solution processes, and not simply assume that all puzzle problems can only be solved via restructuring.

Overview of the present study

The present study combined the methodologies of previous studies by using component importance ratings as a measure of solvers' initial problem representations (Ash & Wiley, 2008), re-solution times on a second problem solving attempt to assess learning (Dominowski & Buyer, 2000), and verbal protocols to assess the occurrence of impasse (Fleck & Weisberg, 2004) in order to empirically investigate the central aspects of Gestalt insight learning theory. The object arrangement puzzles and arithmetic problems from Ash and Wiley (2008) were used in order to directly test for learning differences between problems solved by restructuring vs. routine solving procedures.

The first issues addressed in this research were necessary to set the stage for testing the Gestalt view of Insight Learning. For the puzzle problems to serve as valid laboratory models of the Gestalt insight learning sequence; 1) they should be more likely to lead to impasses than the routine arithmetic problems and 2) people should be able to overcome these impasses and solve the puzzle problems on their own (i.e. without specific hints or direction by the experimenter). If these puzzle problems do not lead to impasses, then they are unlikely to invoke the solving processes that can lead to insight learning. Furthermore, if solvers are unable to overcome these impasses, then, while the puzzle problems may be good laboratory models for studying problem difficulty (i.e. fixation, impasse or failure), they are not appropriate stimuli for studying insight learning. The next issue addressed by this research was the role of solvers' initial problem representations on impasse and problem difficulty. Gestalt theory predicts that for puzzle problems, inappropriate initial representations should be related to problem difficulty (i.e. impasse and failure). However, since the arithmetic problems should be solved by the application of previously learned solution routines, their difficulty should stem from other factors than the solvers' initial representations. Finally, this research addressed whether learning would vary as a function of problem type, impasse and solution success. Decreases in re-solution times were used as our measure of learning. Gestalt insight learning theory specifically predicts greater decreases in re-solution times for the puzzle problems solved after impasse than for puzzles solved without impasse, or arithmetic problems solved through the application of previously learned solution routines.

Method

Participants

Fifty-two introductory psychology students from the University of Illinois at Chicago psychology department participated to fulfill a class requirement. Data from five participants were lost due to malfunctioning recording equipment.

Materials & Apparatus

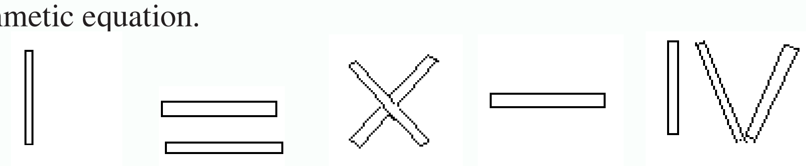
Puzzle Problems

The four object arrangement problems used in this experiment were the same as those reported in Ash and Wiley (2008; Appendix). An example problem is shown in Figure 1. These problems were selected from previous research on insightful problem solving. Problems were selected that contained discrete elements that could be rated separately to assess solvers' initial representations of the problems. These puzzle problems have been classified as insight problems in previous work because they are likely to evoke initial representations that are not conducive to solution, and they are unlikely to be solved via the direct application of previously learned strategies or routines.

Example Puzzle Problem

Below is a picture of an equation in which the roman numerals are constructed using matchsticks. Notice that the both sides of the equation are not mathematically equal. Describe how you could make the both sides equal by moving only one matchstick.

The rules are that: A) only one stick is to be moved; B) a stick cannot be discarded, that is, it can only be moved from one position in the equation to another; C) a slanted stick cannot be interpreted as a vertical matchstick; D) the result must be a correct arithmetic equation.



Example Arithmetic Problem

Solve for **Y**.

Find the exact number that the variable Y equals by using only the necessary equations from the set of equations below.

3**Z** * 3 = 27	2**C** - 9 = **Z**	**P** – **C** = 2 **D**
5**Z** –11 = **M**	2 **X** = 56 + **A**	8**M** – **C** = **Y**
3**Y** + 14 = **X**		

Figure 1. Example Puzzle and Arithmetic Problems from Ash and Wiley (2008).

Arithmetic Problems

The four arithmetic problems were the same as those reported in Ash and Wiley (2008). An example problem is shown in Figure 1. These problems were novel problems that could be solved by the direct application of previously learned strategies or routines. The problems were designed to complement the puzzle problems, by having some components that were useful in solving the problems and other components that were not necessary for the solution.

Component Importance Judgments

This measurement asked participants to rate each component or element of each problem according to "how important it is in finding the solution to the problem." Each of the components of the problems was labeled with a letter at the top of the page. For the example puzzle problem shown in Figure 1, participants were asked to rate five components, I, =, X, +, and IV. For the example arithmetic problem, participants were asked to rate each equation. Underneath the problem was a set of 7.3 cm lines anchored with "very unimportant" on the left side and "very important" on the right side. Participants indicated their judgments by making a mark across the line with a pen or pencil.

Protocol Directions and Training

Participants were asked to talk aloud about what they were doing while attempting to solve each problem. The exact directions were as follows:

> *Your task for this portion of the study is to solve a series of problems. You will be given 4 minutes to solve each problem. I will tell you when to begin each problem. So that we understand what you are doing while you solve each problem you will be asked to talk aloud while solving the problem. Be sure to keep talking through the problem solving process. If you are reading the problem, please do so aloud. If you write anything on the paper while solving please verbalize what you are writing. If you stop talking during the session I will remind you to keep talking. If you reach a final answer before the entire 4 minutes has passed, please inform me and tell me your final answer. You will not be given any feedback as to how close you are to solution or the accuracy of your solution. If time runs out while you are solving a problem please stop immediately and wait for my signal to begin the next problem. Remember it is very important that you keep talking aloud while solving the problem. Do you have any questions?*

Before solving the main set of target problems, participants completed two practice problems in order to become familiar with the think aloud instructions. One problem was a long division problem that asked participants to divide a four-digit number by a two-digit number. The second was a set of three anagrams in which the participants were asked to rearrange scrambled letter strings to form common English nouns. Video and audio of all protocols was recorded with a mini-8 Sony video camera.

Procedure

Participants completed the study individually. The study consisted of two one-hour sessions exactly one week apart. Participants were seated at a 4 feet by 3 feet desk with a camera mounted on a tripod approximately 2 feet to their right and three feet above the desk to record progress on written materials. On the desk there was an 8.5 by 11 inch rectangle on which the camera was focused. The participants were asked keep the materials over the rectangle at all times. The experimenter sat 4 feet to the right of the participant throughout the experiment.

Participants began by completing a rating packet that included the Component Importance Judgment task for each of the eight problems. In total, participants were asked to make 105 ratings about the eight problems. Participants were randomly assigned to receive the problems in one of eight counterbalanced orders that were created with the constraints that every other problem was either a puzzle or arithmetic problem and that each problem was the first and last problem in one of the orders. This order stayed constant for each participant across all materials. The directions for the rating packet stressed that participants were not to begin solving the problems and that we were interested in their initial impressions of the problems. Participants were given a maximum of 15 minutes to complete the entire rating booklet. This time limit was determined via pilot testing, which showed that participants required up to 1 minute to read each problem and up to 4 seconds to make each rating. All participants finished the rating booklets under this time limit.

Next, participants received the think-aloud instructions and completed the two practice problems. They were given 4 minutes to complete each practice problem. During and after each of the practice problems, participants were given feedback about their think-aloud performance. Comments were constrained to think-aloud performance and no feedback was ever given on problem solving performance. After the practice problems, participants attempted to solve each of the target problems in the same order as the rating packet. Participants were given 4 minutes to solve each problem. While solving the target problems the experimenter reminded subjects to talk under only three conditions. The first was if the participant had failed to make any utterance (including utterances such as um, uh, ah) for more than 10 seconds. The second condition was if hand motions or writing on the page were not accompanied by verbalizations. The third was if verbalizations were too quiet to be picked up by the recording equipment. Feedback on solution progress was only given if participants gave "impossible" or "unsolvable" as their final answer. On these occasions, participants were reminded that all problems had solutions and told how much solving time remained. The participants were instructed to circle their final answer and inform the experimenter when they reached their final answer. Upon attempting all the problems, participants were asked not to discuss the details of any of the problems they saw or their solutions with anyone else in the Subject Pool and reminded to return for the second session one week later. Participants were given no feedback about the correctness of their solutions and were not informed of the purpose of the second session.

Participants returned to the laboratory exactly one week later. During the second session, participants were reminded of the protocol instructions and asked solve each of the problems. All solving procedures were identical to session one.

Data Coding

Initial Problem Representation Scores

The importance ratings for each of the problem components were recorded by measuring the distance of each mark from the left side of the line in centimeters. Ratings for components used in solving the problems were averaged, and ratings for components not used in solving the problem were reverse coded and averaged. Next, these two subscores were averaged to form one overall score for each problem. Higher scores on this measure denoted a more appropriate initial representation of the problem (i.e. higher importance ratings on components useful for solution and lower ratings on components not useful for solution).

Impasse

The videos were coded for impasse by two independent coders, one of whom was unfamiliar with the purpose or predictions of the study. Impasse has been defined as "a state of mind that is accompanied by a subjective feeling of not knowing what to do and a cessation of overt problem-solving behavior" (Knoblich et al. 1999). This was taken literally for the operational definition of impasse used in coding the protocols. Durations of silence in the face of reminders to speak, utterances related to impasse (being lost, stuck, etc.), and lack of overt problem solving behavior (e.g., not writing, or not pointing to the problem) were taken as signs of impasse. Inter-rater reliability results from the independent coders' binary (impasse, no impasse) judgments on the 47 participants revealed that impasse coding was reliable, *Kappa* = .92, $p < .001$.

Solution Success

Solutions were coded using the paper and pencil solution packets. The solution was coded as successful if the participant produced the intended answer for each problem and circled the final answer. If it was unclear from the problem packet, then the video was consulted to determine if the correct final answer was reached. All incorrect solutions and problems that were not finished by the end of the 4 minutes were coded as unsuccessful.

Solution Times

Solution times were recorded based on the video data. The time was recorded as the point at which the participant indicated to the experimenter that they had reached a final answer. The time taken by the participants to explain the final answer was not included in their solving times.

Analysis Strategy

As discussed previously, it cannot be assumed that all puzzle problems will lead to impasse. Instead, impasse and restructuring are the result of an interaction between the solver and the problem situation. Thus, to capture this interaction, all data were analyzed at the level of observation. With 47 participants solving eight problems, this resulted in 376 observations (half from puzzle problems and half from arithmetic). In this design, solvers with differential impasse and solution rates may contribute different numbers of observations to different cells (including no observations). Therefore, a linear mixed-model analysis of variance approach was used to analyze these data where problem type was entered as a fixed independent variable, impasse and solution success were entered as fixed factor covariates, and participant was entered as random factor. Essentially, this analysis allows for any individual differences between participants to be removed from the omnibus and follow-up comparisons where possible, without requiring observations for every participant in every combination of the independent and quasi-independent variables as would be required by a repeated-measures analysis. Restricted Maximum Likelihood Estimation was used to compute mean and variance parameter estimates in all analyses. For the Initial Problem Representation Scores, the inclusion of the random participant factor prevented the models from converging. Therefore, these analyses were conducted without the random participant factor using a between groups analysis of variance at the level of the problem observation.

Results and Discussion

Solution Success and Impasse

Participants were 2.77 times more likely to come to impasse on the Puzzle problems than on the Arithmetic problems (puzzles $M = 61\%$ vs. arithmetic $M = 22\%$; $t(46) = 7.55$, $p < .001$)[1]. Table 1 shows the pattern of impasse and solution success by problem. These data show that the pattern of higher impasse rates on the Puzzle problems was fairly consistent across problems. Separate 2 (arithmetic vs. puzzle) x 2 (impasse vs. no impasse)

[1] This analysis was reported in Ash & Wiley (2008) Note 1 (p. 835) as a manipulation check for our insight vs. incremental problem manipulation. We are reporting it here for the reader's convenience. All other analyses and results in this paper are original and have not been reported in any other publication.

chi-square tests were conducted for all possible pairwise sets of Arithmetic and Puzzle problems. These analyses showed that the only cases where the Puzzles did not lead to significantly more impasses was when the Glasses problem was compared to the Solve for Y ($\chi^2 = 2.36$, $p = .125$) or Food problems ($\chi^2 = 2.36$, $p = .125$). On all other comparisons, the puzzles were more likely to lead to impasse ($\chi^2 = 13.95$ to 29.10, *ps* < .001). The parenthesized numbers in the successful solution column of Table 1 show the rates at which participants were able to solve problems after coming to an impasse. For the Arithmetic problems, the Solve for Y problem had the lowest post-impasse solution rate. For the Puzzle problems, the Glasses problem had the lowest solution rate. However, these results show that overcoming impasses to find the correct solution is fairly common in both problem sets. In fact, on two of the puzzles, Triangle and Match XV, the majority of solutions came after solvers experienced an impasse.

Table 1
F requency of impasse and solution rates (solved after impasse shown in parentheses) as a function of problem (N=47).

			Impasse	Solved (After Impasse)
Arithmetic	Solve for Y	Count	12	16 (1)
		%	25.5%	34.0% (6.3%)
	ATM	Count	8	11 (3)
		%	17.0%	23.4% (27.3%)
	Distance	Count	10	25 (7)
		%	21.3%	53.2% (28.0%)
	Food	Count	12	25 (8)
		%	25.5%	53.2% (32.0%)
Puzzle	Triangle	Count	34	16 (11)
		%	72.3%	34.0% (68.8%)
	Glasses	Count	19	13 (3)
		%	40.4%	27.7% (23.1%)
	Match III	Count	30	16 (7)
		%	63.8%	34.0% (43.8%)
	Match XV	Count	32	13 (8)
		%	68.1%	27.7% (61.5%)

Another important aspect of this descriptive analysis is the observation that both the Arithmetic and Puzzle problems were solved with and without impasse. This allows for the analysis of all effects as a function of problem type, solution success and solution process (i.e. whether or not solvers reached impasse). The Gestalt position would propose that solution after impasse should be more likely on problems showing evidence of inappropriate initial problem representations. Furthermore, the Gestalt position would propose that the type of new information generated through the application of previously learned solving routines should be qualitatively different than the new information emerging from solving puzzle problems following impasse.

Initial Problem Representations

In order to investigate the relationship between solvers' initial problem representations and their later solution process, we analyzed component importance judgments as a function of problem type and solution type (Successful with No Impasse, Successful with Impasse, and Unsuccessful). These results are displayed in Figure 2. On these scores, higher values represent more appropriate initial problem representations. The analysis revealed a main effect of solution type, $F(1, 370) = 11.36$, $p < .001$, and a main effect of problem type, $F(1, 370) = 16.46$, $p < .001$. These effects were subsumed in a significant solution type X problem type interaction, $F(1, 370) = 3.47$, $p = .032$.

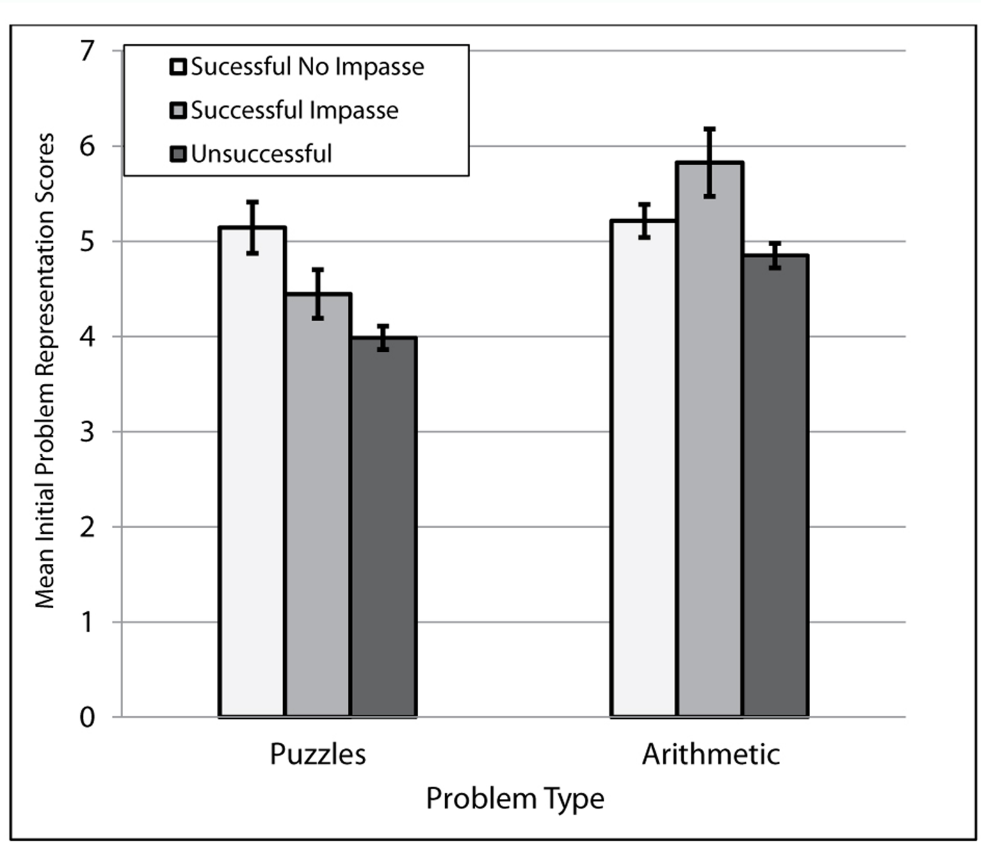


Figure 2. Mean Initial Problem Representation scores as a function of problem type and solution type. Higher scores mean more appropriate Initial Problem Representations. Error bars = estimated standard error of the mean.

Follow-up analyses on Puzzle problems revealed a significant simple effect of solution type, $F(1, 370) = 8.07$, $p < .001$. Initial Problem Representation Scores on Puzzle problems that were correctly solved after impasse were not significantly different than those for unsuccessfully solved problems, $F(1, 370) = 2.63$, $p=.11$. However, the Initial Problem Representation Scores were significantly higher for Puzzle problems correctly solved without impasse when compared to the problems solved with impasse and unsolved problems, $F(1, 370) = 9.25$, $p = .003$. These results suggest that on the puzzle problems, less appropriate initial problem representations were related to problem difficulty which resulted in a higher incidence of impasses and more failures to solve.

Follow-up analyses on Arithmetic problems revealed a significant simple effect of solution type, $F(1, 370) = 4.05$, $p = .018$. However, the pattern on the Arithmetic problems was quite different than that observed on the Puzzle problems. In this analysis, Arithmetic problems solved with impasse showed evidence of higher Initial Problem Representation Scores when compared to the other solution types, $F(1, 370) = 4.57$, $p = .033$, and there was no significant difference between mean Initial Problem Representation Scores on Arithmetic problems that were correctly solved without impasse and those that participants failed to solve, $F(1, 370) = 2.83$, $p = .093$.

This result suggests that people who had more appropriate initial representations were more likely to come to impasse before solving the Arithmetic problems. However, this result is difficult to interpret because of the low rates of impasse on the Arithmetic problems. The most important result from the Arithmetic problems is that the accuracy of participants' initial problem representations was not predictive of success or failure on these problems.

These results suggest that the Puzzle problems were likely to be initially inappropriately represented and that these inappropriate initial representations were related to problem difficulty. These results also support the Gestalt view that when problems require the application of previously used routines, solvers are likely to form an appropriate representation of the problem and impasse is not likely to occur. Therefore, the results of the impasse and initial problem representation analyses provide evidence that the puzzle problems selected for this study are internally valid laboratory models for investigating the Gestalt theory of insight learning, because these problems were likely to lead to impasse, solvers were able to overcome these impasses and solve the problems, and less appropriate initial representations of the problem were associated with problem difficulty and impasse.

First and Second Session Solution Times

Our critical measure for testing the Gestalt theory of insight learning was changes in solution times between a first and second attempt. Re-solution rates for prior solvers were generally high and similar across both types of problems (Arithmetic 73% to 94%; Puzzles

87% to 100%). The estimated mean solution times on both first and second problem solving attempts are shown in Figure 3 as a function of problem type, impasse, and initial-attempt solution success. Results of the mixed models analysis revealed significant main effects of solving session, $F(1, 233.66) = 58.35$, $p < .001$, impasse, $F(1, 249.80) = 18.19$, $p < .001$, problem type, $F(1, 261.92) = 135.24$, $p < .001$, and a session X impasse interaction, $F(1, 34.47) = 18.19$, $p < .001$. These effects were subsumed within a significant session X problem type X impasse interaction, $F(1, 223.66) = 21.41$, $p < .001$.

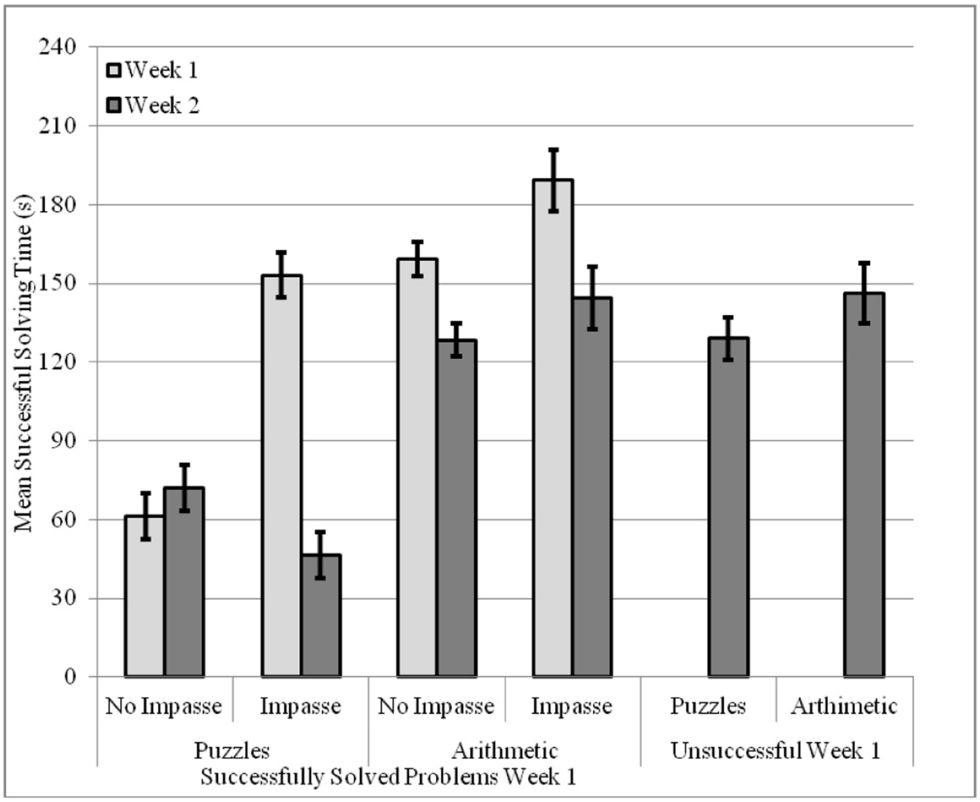


Figure 3. Estimated mean successful solution times as a function of Week 1 success, impasse and problem type. Error bars = standard error of the mean.

On Puzzle problems, there was a significant session X impasse interaction, $F(1, 82.55) = 48.39$, $p < .001$. Follow-up analyses revealed no significant difference between Week 1 solution times and Week 2 re-solution times on problems solved without impasse, $F(1, 82.55) = 0.86$, $p = .357$, as shown in the first pair of bars in Figure 2. However, there was a large difference between Week 1 solution times and Week 2 re-solution times for problems solved with an impasse, $F(1, 82.55) = 79.42$, $p < .001$, as shown in the second pair of bars.

On Arithmetic problems (third and fourth pairs of bars), there was no evidence of an interaction between session and impasse, $F(1, 112.27) = 1.03$, $p = .313$. There was a simple main effect of session showing faster Week 2 solving times (Week 1: $M = 172.06$ s vs. Week 2: *M* = 134.22 s), *F*(1, 112.28) = 30.29, $p < .001$. There was also a simple main effect of impasse with faster solving times on Arithmetic problems solved without impasse (No Impasse: *M* = 144.07 s vs. Impasse: *M* = 162.21 s), *F*(1, 147.25) = 3.96, *p* = .048.

These results show qualitatively different re-solution patterns for Puzzle problems and Arithmetic problems. On Puzzle problems, those who solved without impasse on their first attempt did so very quickly and solved just as quickly on the second attempt. However, for those who experienced an impasse, solving times were much slower on the initial attempt and re-solution times were as fast as they were for solvers who did not reach impasse.

On Arithmetic problems, impasse generally slowed both initial solving and re-solution times, and re-solution times were generally faster than initial solving times. This pattern of results suggests that the new information acquired in overcoming impasse on the puzzle problems was being remembered in a qualitatively different fashion than the new information acquired by applying previously learned problem solving routines.

Next, we investigated whether the differences between initial and re-solution times were really a function of prior solution or if they were just due to re-exposing participants to the same problems. For the re-exposure analysis, we used data from participants who failed to solve during the first session, but were able to solve during the second session. The Week 2 solution rates for prior unsuccessful solvers ranged from 29% to 59.5% on the Arithmetic problems and 8.8% to 22.6% on the Puzzle problem. Week 2 solution times were analyzed as a function of Week 1 solution type (Successful with No Impasse, Successful with Impasse, and Unsuccessful) and problem type (see Figure 3, dark bars) using a mixed models analysis. Results revealed main effects for problem type, *F*(1, 166.99) = 73.49, $p < .001$, and solution type, *F*(1, 176.71) = 13.55, $p < .001$, which were subsumed within a significant problem type X solution type interaction, *F*(1, 173.51) = 8.63, $p < .001$. Follow-up analyses on Puzzle problems revealed a simple effect of solution type, *F*(1, 171.84) = 18.09, $p < .001$. Session 2 solution times on problems that participants previously failed to solve were significantly slower than those for problems solved without impasse, *F*(1, 169.68) = 20.57, $p < .001$, or with impasse, *F*(1, 170.31) = 34.87, $p < .001$, on the first attempt. However, on Arithmetic problems there was no simple effect of initial solution type on Week 2 solution times, *F*(1, 178.51) = 1.67, *p* = .192.

In other words, the re-solution effects observed on the puzzle problems solved with impasse were not simply due to re-exposure to the problems. Therefore, the faster solving times on problems previously solved with impasse were truly "re-solution" effects, in that they depended on whether or not the problems were actually solved by the participants. However, the faster Week 2 solution times for Arithmetic problems were not necessarily "re-solution" effects, because problems that were not correctly solved during the first session had the same decreased solution times on the second attempt as those that were solved during the first session. This suggests that the second session time savings on Arithmetic problems was largely due to factors that were unrelated to participants discovering the correct answer to the problem or the solution process by which they found that answer.

In summary, the ultimate goal for this research was to explore whether evidence could be found for the Gestalt theory of insight learning. We found that puzzle problems that were solved after coming to an impasse showed the re-solution patterns that were predicted in the Gestalt psychologists' theory of insight learning. These results also showed that overcoming an impasse during routine problem solving does not lead to the same learning as overcoming an impasse associated with an inappropriate problem representation, and that the reduction in solution time between initial and second attempts on routine problems is more likely due to re-exposure to the problems and does not depend the success or failure of the participants' initial attempts.

Conclusions

The results of this investigation offer empirical support for several of the major assumptions of the Gestalt theory of insight learning. First, it was demonstrated that the puzzle problems were more likely to lead to impasse than the arithmetic problems. However, it is also important to note that not all solvers experienced impasse on all of the puzzle problems. Thus, these results replicate Fleck and Weisberg (2004) by showing not all solvers come to impasse before solving classic insight problems. Furthermore, they highlight the importance of taking a process-oriented approach to studying insight phenomenon instead of a problem-oriented approach (Ash, Cushen, & Wiley, 2009; Ellen, 1982; Fleck & Weisberg, 2004).

Second, people were regularly able to overcome impasse and go on to solve the puzzle problems. For the purposes of studying insight learning, it is important to have problems that people can solve without hints or experimenter interventions. Hints and training interventions are useful methods for studying fixation and other sources of problem difficulty (Ash, Cushen, & Wiley, 2009). However, according to Gestalt insight learning theory, there is a need to differentiate between new information obtained from the external environment, and new information resulting from internal problem solving processes. Exposure to external hints and training interventions should lead to gradual associative learning, while only situations where solvers overcome impasse through internal restructuring or re-organizational processes should lead to sudden insight learning (Cushen & Wiley, 2012; Ellen, 1982).

Third, inappropriate problem representations were found to be related to difficulty on the puzzle problems but not related to problem difficulty on the arithmetic problems requiring the routine application of previously learned solution strategies. Those who more appropriately represented the puzzle problems from the outset showed less likelihood of coming to impasse, and very fast initial solving times. In essence, this suggests these situations were not problems, in that the solution was readily attainable without any major obstacle. However, in situations where solvers inappropriately represented the puzzles, these were difficult problems that led to impasse and failure. This can be contrasted with the Arithmetic problems where difficulty was not related to solvers' initial problem representations and solvers showed faster solving times during the second session regardless of whether or not they had previously solved the problem. This result is important because it supports the Gestalt notion that the structure of the *behavioral environment*, or internal problem representation, can be a source of difficulty in problem solving.

Fourth, and most important for the Gestalt insight learning theory, the new information discovered by overcoming impasse on the Puzzle problems was readily retained by solvers. Second session solving times on Puzzle problems that were solved after impasse were considerably faster than the first session solving times. Furthermore, second session solution times on Puzzle problems that were not previously solved were slower than previously solved problems, and similar to the first session solving times on problems where participants reached impasse. This pattern is exactly what would be predicted by the Gestalt concept of insight learning and stands in stark contrast to the learning patterns observed on the routine Arithmetic problems.

There are several limitations on the inferences that can be drawn from the current study. For example, the inclusion of the initial component importance rating procedure may have had an effect on later problem solving behaviors in the current study (Cushen & Wiley 2012). Therefore, before drawing firm conclusions about one-trial learning, these results need to be replicated on a wider variety of problem tasks and using different assessments of learning. Furthermore, these results do not speak to the processes that were involved in overcoming impasse on these puzzle problems, or whether these processes relate to the cognitive trial-and-error and restructuring processes proposed by Gestalt psychologists. However, these results do offer empirical validation of the basic assumptions of the Gestalt theory of insight learning and provide a framework by which future research into insight learning can be conducted.

Internal Representations and Sudden Learning

In the introduction, we argued that the Gestalt concept of insight was not intended to refer to specific problem solving phenomena. Instead it was a term that was intended to differentiate psychological phenomena that function at the level of an organism's internal behavioral environment from those that function on the external geographic environment. The Gestalt psychologists disputed the associationist assumption that gradual learning processes based on frequency of co-occurrence could be used to explain the acquisition of all an organism's knowledge about the relationships among external stimuli and internal ideas. Gestalt psychologists proposed that an alternative mode of learning was needed to explain the acquisition of new knowledge as a result of conceptual thinking and reasoning.

Gestalt psychologists were particularly interested in the distinction between information created by enacting previously learned solution routines or engaging in overt trial-and-error processes, and information gained via internal reflection that involves discovering fundamentally new relationships distinct from those suggested by prior experience (Duncker, 1945/1972; Koffka, 1935/63; Köhler, 1925; Maier, 1931; Wertheimer, 1954/1959). It seemed that only this alternative approach to learning could explain creative thinking. For example, Wertheimer (1954/1959) proposed that "discovery does not merely mean that a result is reached which was not known before, that a question is somehow answered, but rather that the situation is grasped in a new and deeper fashion—whereupon the field broadens and larger possibilities come into sight. These changes of the situation as a whole imply changes in the structural meaning of part items, changes in their place, role and function, which often lead to important consequences" (pg. 169).

In other words, it was proposed that some knowledge that is gained during problem solving is the result of a fundamental restructuring or reorganization of the solver's prior knowledge or interpretation of the problem situation. From this perspective, the hallmarks of insight learning, as proposed by the Gestalt theorists, were that it was the result of reflections on internal, mental representations of a situation which resulted in new understanding that was attained immediately and not gradually.

In many ways, this emphasis on internal representation is what motivated the resurgence of interest in cognitive psychology in response to the Behaviorist theories in the late 1950s. It is also revealing that both the Gestalt psychologists and cognitive psychologists focused on research in perception, attention, memory and problem solving to challenge the dominant associationist traditions of their time. Anderson (1993) noted this connection when he wrote "Although Köhler and the other Gestalt psychologists used problem-solving tasks to demonstrate the inadequacies in the behaviorist conceptions of learning, they failed to offer an analysis of the problem-solving process… Problem solving finally was given a coherent program of analysis by Newell and Simon (1972)." Newell and Simon's (1972) research can indeed be considered a formalized model of the Gestalt concept of the behavioral environment. In fact, the Gestalt psychologists and Newell and Simon could be contrasted as two sides of the same coin. On one side, the Gestalt psychologists were deeply interested in the perceptual, learning, and memory processes involved in the construction of the behavioral environment, but they were somewhat vague on the processes involved in cognitive trial-and-error or reasoning. On the other side, Newell and Simon's (1972) model proposed very specific processes for reasoning and problem solving, but were largely agnostic about the processes that lead to the acquisition of knowledge, or the construction of the internal problem representation.

Focusing on insight learning as a process by which internal representations are formed and revised is an important message to be taken away from the current study. If one conceives of insight as a specific problem solving process that accompanies solutions on certain laboratory puzzle problems, then this effectively limits the type of research that will be conducted and the implications that can be drawn from that research. However, if one conceives of insight as a learning phenomenon in the way the Gestalt psychologists intended, then research on insight phenomena becomes more central, instead of a tangential exercise in explaining strange behavior on esoteric puzzle problems.

The concept of the behavioral environment not only relates to Newell and Simon's (1972) concept of the problem space and problem representation, it also has parallels in the types of mental representations proposed throughout cognitive psychology. For example, Kintsch (1993; van Dijk & Kintsch, 1983) has distinguished between different levels of mental representations involved in text comprehension and memory. The surface model is the mental representation of the actual words and phrases in contained in a piece of text or discourse. The situation model is a representation of the meaning that has been elaborated upon and integrated with the reader's prior knowledge.

One can clearly see the relationship between this model of text comprehension and the Gestalt concepts of the geographic and behavioral environments. Further, the tension between associationist and Gestalt theories has a correlate in the text processing literature. Kintsch (2001) developed a computational model of text comprehension that determines the relationship among the meaning of words based on their frequency of co-occurrence in usage across a large sample of texts. Therefore, this model provides a strictly associationist account of comprehension and memory for discourse. However, other researchers have proposed comprehension models that involve memory representations that are based on the causal relations between the concepts described in the discourse (Langston & Trabasso, 1999; Trabasso & van den Broek, 1985). Wolfe, Magliano, and Larsen (2005) demonstrated that these two modeling approaches explain independent variability in participants' memory for the information presented in a text and the judgments derived from that information. They explained this by proposing that the association-based model captures bottom-up comprehension processes, while the causal model captures top-down comprehension processes.

We propose that the differentiation between "bottom-up" and "top-down" is really just a modern instantiation of the Gestalt notion that qualitatively different psychological processes function at levels of the geographic and behavioral environments. We also find it compelling that the types of processes proposed at each level mirror the differentiation between associative relationships and deeper functional relationships (such as causation) that were central to the Gestalt theory of insight learning. This suggests that far from being just a problem solving phenomenon, future research into insight learning may lead to discoveries that can be applied to diverse domains of cognition.

In a second example, Anderson and colleagues (Anderson, Bothell, Byrne, Douglass, Lebiere & Qin, 2004; Anderson & Lebiere, 1998) have elaborated on Newell and Simon's (1972) original computational model of reasoning processes by integrating it with computational models of attention, perception, memory and learning processes. Their Adaptive Components of Thought – Rational (ACT-R) is designed to be a fully functioning cognitive architecture (Newell, 1990) that can be used to explain how the different components of the mind work together to produce unified cognitive behaviors and experiences (Anderson et al, 2004). For the purposes of problem solving, this model proposes three different types of memory. Declarative memory is the long-term memory store containing factual, definitional, and semantic information. In this model, memory structures are composed of nodes representing different pieces of information stored in long-term memory and associative connections between these nodes. When a piece of information enters memory either through perception or retrieval, activation spreads through these associative links and brings related information into consciousness. Procedural memory is where the processes that can be used to act on these memory representations are stored (i.e. the available operators). These processes are modeled as if/then statements combined with sets of memory and command operations. Finally, the Goal Module directs attention (or activation) to the different memory modules based on the goals of the problem solver and their current progress in solving a problem.

For the purposes of the present discussion of insight learning, the important aspect of this model is that learning in both the Declarative Memory module and the Procedural Memory module is based on associative processes that depend on co-occurrence. Therefore, ACT-R's basic learning mechanism is similar to those proposed by the empiricist philosophers. Since, ACT-R allows for the association of both co-occurring sensations and co-occurring ideas, it has processes that are similar to Bain's (1855/1977) law of constructive association which allow for new ideas to be created from new combinations of past experience. However, these creative associations, just like any other associations, need to be built up gradually over time through repeated co-occurrence.

The Gestalt theory of insight learning proposes that that new combinations of prior experience created from reasoning processes that re-organize and restructure can be learned quickly and without repetition. Furthermore, they propose that different learning mechanisms function on information presented in geographic and behavioral environments. Therefore, current ACT-R learning mechanisms would not be able to accommodate these types of processes. Developing computational models that can account for creative leaps, novel discoveries, and instances of one-trial learning still represents an interesting challenge for association-based models (Ash, Cushen & Wiley, 2009; Langley & Jones, 1988).

In closing, the main point of this paper is that the original Gestalt conception of insight was much more encompassing than just a problem solving mechanism or the generator of Aha! moments. It was a general principle that learning based on reasoning or thinking is qualitatively different than learning based on association. We hope that this review of the Gestalt concept of insight will help future researchers in clarifying the relationships and differences between different insight phenomenon, and that some find these results, at the very least, compelling enough to inspire them to include measures of representation, solution process, and learning in their future work on insight and creativity.

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