Hierarchical Conceptual Rotation of Mental Knowledge Representation*

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Abstract

In this paper, we proposed a novel hierarchical conceptual rotation theory to explain the knowledge representation of mental. We maintain the perception and the procedure of similarity-matching is motivated by a hierarchical manner. Two key roles are hierarchical representation of knowledge and conceptual rotation. The former is composed of four different levels, with the perception procedure goes further, the degree of abstraction goes deeper. Besides, the latter consists of three stages, they are the manipulations of visual mental imagery. Experiment is specially designed to prove the widely accepted phenomenon of hierarchical structure also exists in the process of mental imagery.

Further, the discover of hierarchical mental imagery may help a lot to the further study of the procedure of learning and perception of we human. What's more, as this structure shows highly similarity with the procedure of human cognition, the proposed novel framework of the manipulation of perception may help to build more human-alike and dynamic artificial intelligence systems.

1. Introduction

The sense data is not maintained in its raw form, but is well organized into a mental representation, which can help reflect that whether it has been encountered previously. However, knowledge is a totally different form of memory that it is not activated by sensory stimulation [1]. For example, when someone form a mental image of a dog, in its absence, or recall the sound quality of their voice, you are referencing a knowledge representation of this dog that is an interpreted form of sense data. You do not obtain an image or a sound in memory literally. Instead, information enables your mind to reconstruct it and recall it.

The mental representation of knowledge can only be sidelong studied. Up to now, there are no method which can represent the hidden patterns of knowledge in our brain directly. We are limited to asking subjects to describe their knowledge representations and accepting the inaccuracies of self-reporting. It's widely acknowledged that there are two kinds of knowledge structures, which are declarative knowledge (the ability to state facts) and procedural knowledge (the ability to do things, based on implicit understanding) respectively. Both are leveraged in the learning process. For example, understanding how to drive a car is different from knowing how a car is driven. However, each of them can be transferred from the other.

Mental imagery refer to the mental representation of things that are not in sensory perception currently [2]. All the notions of a person's sound, the shape of his face, or his scent in the absence of that person, is a mental image.

Most research into this area focuses on visual stimuli, which is the ability to describe or draw in visual terms an object that is not visible in the present environment [2, 3, 4, 5, 6, 7, 8]. Imagery is often used to solve problems and answer questions - to build something requires us first to imagine what it should be when the task is completed, and to solve any problem means imagining the future state in which the problem has been solved. This requires projecting our imaginations into a future state that does not yet exist, but which we wish to effect.

There is no realistic way to assess the extent to which mental images are maintained. By an extreme theories, all images of everything we ever sense, whether we are conscious of sensing it are not, are stored in granular detail and with perfect fidelity in our memory. More realistically, however, it is doubtful that even my current estimations that the human brain has such infinite storage capacity, and while it can hold am amazing amount, it is not infinite in its fidelity, scope, or duration.

However, real progress has been made in the pursue for a better understanding of imagery through inventive research

*This research paper is delicated to be the final project of "Social Psychology". This paper is undertook with the help of Professor Tingting Han, Research Assistant Yufang Han, Professor Nanning Zheng, my girlfriend Jiale Zhang et al.

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techniques and clear-cut results. Currently there is debate over the question of whether visual imagery is really visual or is governed by general-purpose cognitive processes (as contrasted with specific visual processes). The visual argument holds that mental imagery involves the same representations used in vision, so that we can "see" an actual tree, specific types of neural processing and representations are activated. When we "image" a tree, the same or highly similar processes and representations are activated. The other side of this argument is that the representations used in imagery are not the representations used in real perception. This argument holds that "thinking in picutres" basically involves knowledge best expressed in terms of traditional (i.e., propositional or associative) representations of knowledge.

Current theories about mental imagery are focused on three central hypotheses, they are dual-coding theory, conceptual propositional theory and functional equivalency theory, respectively. All of them can explain the visual mental imagery in some degree. Dual coding theory holds that there are two codes and two storage systems (one imaginal, the other verbal). But it's not very reasonable as we do not need to match the visual object with those stored in our brain. The conceptual propositional theory holds that both visual and verbal information are represented in the form of abstract propositions about objects and their relationships. However, it can not explain the manipulation of imagery. Further, the functional equivalency theory proposed that imagery and perception employ similar processes, which means the procedure of perception is also the process of mental imagery. The theory is widely acknowledged. Nevertheless, previous researches care more about the physical representation and mental rotation. In this paper, we proposed a novel hierarchical conceptual rotation theory, which maintains that knowledge representation of mental is the rotation and fusion of hierarchical concepts with different level of abstract. This theory is more reasonable and more human-like.

2. Related Work

2.1. Dual-Code Theory

Dual-code theory [9, 10] suggests that when forming symbolic representation, subjects use a combination of visual and verbal elements. Visual data is considered to be analogue code, a form of representation that preserves the main features of whatever is being represented - in essence, an analogue code is a sketchy outline or stick-figure representation containing only as much detail as necessary to have a sense of the thing we have perceived.

Verbal date, meanwhile is a symbolic code. That is, our conception of a principle such as "fairness" has a the most basic possible definition, and the various details by which we assess whether a given arrangement is "fair" are filigree that are closely related to, but not contained within, the basic definition of the principle.

One key difference that has been supported by research is that verbal data is most often recalled, and most accurately recalled, in a linear fashion: the words we have heard are in the order in which they were heard. Meanwhile, order seems to be entirely arbitrary for cataloging visual data: an image is perceived as a unit, all at once, and the order of sequence of images is arbitrary in terms of recollection.

Neuroscience further supports this theorem, demonstrating that the different parts of the brain that are active when images or words are perceived are also active when they are recalled.

It's also been observed [11] that perceptual data from the environment commingles with and interferes with recollection of knowledge stored in memory, which can be readily observed in everyday life when a person who is recalling a phrase from memory is disrupted by words that are spoken in the present environment, but the level of interference is less evident when a visual stimulus is presented during verbal recollection or vice-versa.

2.2. Conceptual-Propositional Theory

The propositional theory provides an alternative to the dual-code theory, which maintains that the way in which the mind handles sensory data is more abstract than words and images [12, 13]. These are merely the ways in which mental representations are expressed. In long-term memory, we store the concepts of things rather than the sensory data of actual things. Theoretical analyse shows that our brain can not remember all the physical shapes of all objects around, the extraction and manipulation of high-level features may be beneficial to the store of object in mind. There are multiple ways to describe things and the relationship between them for different people.

By this theory, it is our understanding of the relationship that shapes our knowledge, hence this relationship is more significant that the qualities of the things we describe. [1] describes four kinds of relationships, they are inclusion/exclusion (target objects), actions (behaviors), attributes (own characteristics) and spatial position (geometrical location) respectively.

The arbitrary and sometimes incorrect choice of proposition can be witnessed in the way that things are conceptualized. Consider that a hexagram may be perceived ass a single unit, or seen as two overlapping triangles, or six triangles radiating from a hexagon, or three pairs of parallel lines, or as a religious symbol.

The creation of propositions, like perception itself, is also influence by gestalt. We recognize certain defining features of an object or class of objects, but at the same time recognize that a real-world object has many additional qual-

Table 1. Comparison among theory mainstream theories on explain the knowledge representation of knowledge.

Theory	Key Point	Problem
Dualing-Coding Theory	Two codes and storage systems	Limited storage capacity
Conceptual-Propositional Theory	Concepts instead of objects in mental	Hard to explain the manipulation of imagery
Functional-Equivalency Theory	Mental imagery is similar to perception	No persuasive usage of knowledge

ities that are not considered to be defining characteristics. We more readily process both sensation and concept on the broadest level. A capital "E" is recognizes as such quickly, and it is only with some thinking that we consider that the shape might be a capital "F" superimposed on a capital "L."

It's also to be noted that the mind comes to expect further ambiguity once ambiguity has been witnessed. Shown a sequence of ambiguous drawings, a subject's interpretation becomes more deliberated before he noticed the ambiguity. Up to that point, he is not expecting ambiguity, but afterwards he begins to look for ambiguity in the rest.

Not everyone in the field considers the propositional theory to hold, and there is some indication that the responses of participants may be more to do with perception than memory, but there is evidence to support the theory as well as contradict it.

2.3. Functional Equivalence Theory

The functional equivalence hypothesis holds that, which visual imagery is not identical to perception, it is treated as functionally equivalent [14, 15, 16]. That is to say that the mention of the word elephant conjures a mental image of an elephant that does not correspond to the sense data we have taken from any specific real-world elephant but the mental image we have is handled in the same way as a sense memory. Five distinct principles have been derived [17], they illustrated that our mental images and concepts are very similar to physical objects and percepts in terms of their properties and behaviors.

Mental rotations of objects are effected by the imagination: when we perceive a two-dimensional image, or even a three-dimensional object from a single angle, the mind is able to conceive what the appearance of the object would be if it were viewed from a different angle [14].

An often-repeated experiment is a visual test that presents the subject with a two-dimensional image of an object, and asks him to indicate whether a second image is or is not the same shape that has been rotated.

The response time is directly correlated to the degree to which an object had been rotated (i.e., less than two seconds if the object had been rotated less than 40 degrees, but more than four when the object was rotated 140 degrees or more) and this is regardless of whether the subject's response was correct or incorrect.

Response time, as well as accuracy, was also impacted according to the complexity and familiarity of the shape. For example, people can quickly and accurately respond when the object is a letter or numeral that has been rotated, as well as when the object is geometrically simple, such as a cube or a box shape.

It is also noted that the practice effect became evident in these experiments: that is, the speed and accuracy of responses were better on later puzzles than on the initial ones as their minds settled into the task of performing mental rotation.

The difference between individual participants' response times is proposed to be linked to their intelligence, though this quickly degenerates into a tautology (they are considered to be more intelligent because they are faster and more accurate at the task).

Some preliminary research indicates a neurological link between mental rotation and the visual and motor cortexes within the brain [18, 19, 20]. In essence, reinforcing the notion that the parts of the brain that are used for performing tasks and interpreting sense data are likewise engaged when the exercise is purely imaginary.

While this indicates the same mechanisms may be used, the question remains as to whether the same processes are used - there is some indirect evidence that suggests that it is so, but not sufficient to sway consensus distinctly to one or the other conclusion. The physical rotation of objects including image scaling, image scanning and image rotation. The comparison among those theories can be found at Table 1.

3. Hierarchical Conceptual Rotation

In this section, we will talk about our proposed theory, named as hierarchical conceptual rotation. It consists of two parts, the hierarchical representation of knowledge, the conceptual rotation, respectively. The frameworks of our proposed theory is shown at Fig 1. The sensory apparatuses percept the visual data and feed it into the module of hierarchical representation of knowledge. This module will first regard it in the physical level, then manipulates the knowledge and delivers to the module of conceptual rotation. It will conduct concept-level image scaling, image scanning, and image rotation in order. After this, it will output two confidence score, which represents whether the imagery procedure needs to dive into deep level in hierarchical module, whether there are high enough confidence to identify the object, respectively. If the latter confidence is higher than the threshold, the system will output the identified result and get the manipulated answer. Otherwise, it

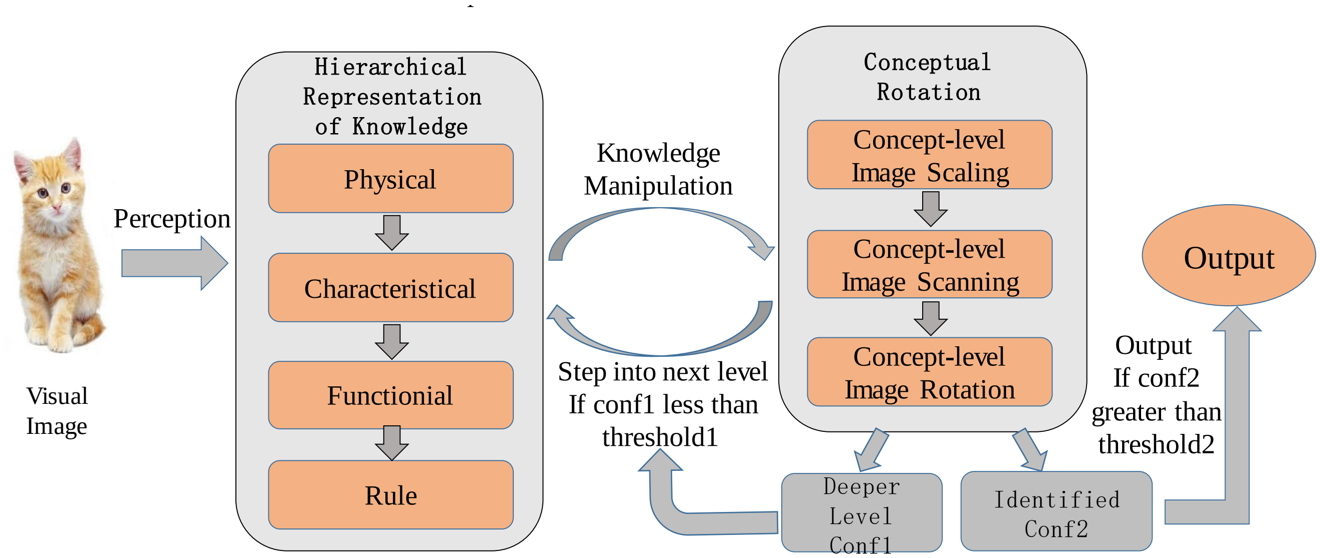

Figure 1. Framework of Hierarchical Conceptual Rotation. The sensory apparatuses percept the visual data and feed it into the module of hierarchical representation of knowledge. This module will first regard it in the physical level, then manipulates the knowledge and delivers to the module of conceptual rotation. It will conduct concept-level image scaling, image scanning, and image rotation in order. After this, it will output two confidence score, which represents whether the imagery procedure needs to dive into deep level in hierarchical module, whether there are high enough confidence to identify the object, respectively. If the latter confidence is higher than the threshold, the system will output the identified result and get the manipulated answer. Otherwise, it will measure the former confidence. If the confidence is less than another threshold, the hierarchical representation of knowledge module will step into the next level, which will be characteristic, functional, rule in order. Meanwhile, the system will conduct the same operations like the physical level does. If it fail to identify the visual image, it will report not found.

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3.1. Hierarchical representation of knowledge

Children and adults make rich causal inferences about the physical and social world, even in novel situations where they cannot rely on prior knowledge of causal mechanisms. The phenomenon of hierarchical perception in psychology has been widely discovered [21, 22, 23, 24, 25]. They proposed the perception procedure is composed of different stages. For every stage, there are special tasks with various difficulties that needs to be handled.

Typically, [26] propose that this capacity is supported in part by constraints provided by event structurethe cognitive organization of experience into discrete events that are hierarchically organized. These event-structured causal inferences are guided by a level-matching principle, with events conceptualized at one level of an event hierarchy causally matched to other events at that same level, and a boundary-blocking principle, with events causally matched to other events that are parts of the same superordinate event. These principles are used to constrain inferences about plausible causal candidates in unfamiliar situations, both in diagnosing causes and predicting effects. The results could not be explained by construal level or similarity-matching, and were robust across a variety of physical and social causal systems. Taken together, their experiments demonstrate a novel way in which non-causal information we extract from the environment can help to constrain inferences about causal structure.

The illustration of hierarchical representation of knowledge can be found at Fig 2. It consists of four different level, which are physical level,characteristic level, functional level and rule level. It goes moreand more abstract with the level steps into the deeper stage. Thephysical level represents the distinguished patterns of visual im-age, which means the mental imagery is only about the physical-patterns of objects such as global shape and color information.The characteristic level domenstrates the saliency area of ob-jects, which is also the attention-central parts. Besides, the func-tioinal level is more abstract, which shows the basic linguistic pat-terns of visual image. The deepest level is the rule-level, whichrepresents the high-order rule-based concepts, which can be cate-gorized as a whole

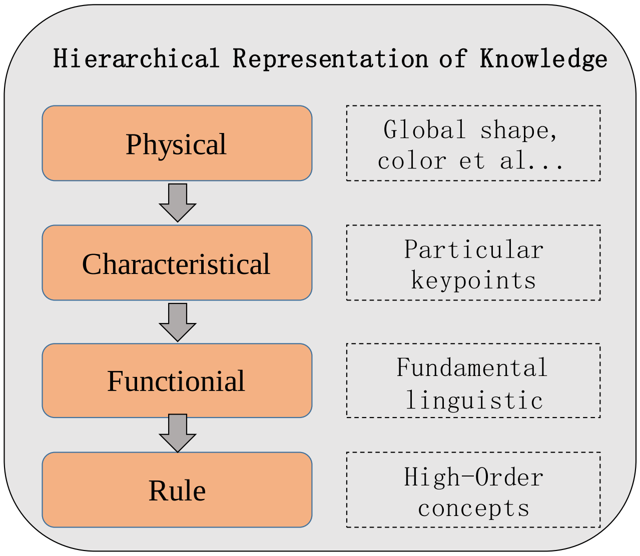

Figure 2. The illustration of hierarchical representation of knowledge. It consists of four different level, which are physical level, characteristic level, functional level and rule level. It goes more and more abstract with the level steps into the deeper stage. The physical level represents the distinguished patterns of visual image, which means the mental imagery is only about the physical patterns of objects such as global shape and color information. The characteristic level domenstrates the saliency area of objects, which is also the attention-central parts. Besides, the functioinal level is more abstract, which shows the basic linguistic patterns of visual image. The deepest level is the rule-level, which represents the high-order rule-based concepts, which can be categorized as a whole.

3.2. Conceptual rotation

We will introduce the second part of our mental imagery framework, which named as conceptual rotation. It consists of three stages, which are concept-level image scaling, concept-level image scanning and concept-level rotation, the architecture is fully illustrated in Fig 3. We will talk about the different stages in the following.

3.2.1 Image Scaling

Aside of the shape, color, and texture of objects we perceive, there is also the matter of their size. In general, we have a predilection of larger objects: when describing an environment, we relate the larger objects first, consider them to be of greater importance. We perceive larger objects to be closer to ourselves, and give them greater attention.

While size is fairly easy to assess when objects are perceived in relation to one another, it is more difficult to assess how we perceive an object to be in itself. There is the definite sense that things ought to be of a certain size, and that a given object I unusually large or small compared to our

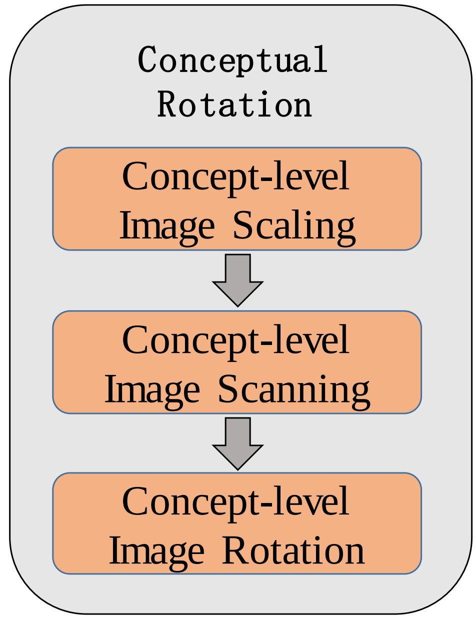

Figure 3. The illustration of conceptual rotation. It consists three procedures, which are concept-level image scaling, concept-level image scanning and concept-level image rotation, respectively.

mental representation of it.

The details of a given object (how large an elephant's ears should be) are fairly easy to observe because the parts are seen in relation to the whole. We can immediately recognize its ears are 10% larger than they ought to be, but do not have the same facility in recognizing whether the entire object is slightly disproportionate - shown a mouse and a rabbit in the same picture, we do not immediately notice (or notice at all) that the mouse is 10% larger or rabbit is 10% smaller than it ought to be - but if the mouse's head is 10% larger than it ought to be, it seems immediately peculiar, provided we have an existing mental representation of both.

3.2.2 Image Scanning

Everything within our field of vision, whether an image or a real environment, is unconsciously perceived at a glance, but only as raw sense data without recognition. We recognize things by scanning, which means moving our gaze around the environment and separating out individual items for the purpose of recognizing them and testing them against memory.

We refers to a study in which subjects were shown a depiction of several objects and asked to press a button when they saw a specific object, on the assumption that the length of time it took to press the button corresponded to its order in which subjects gave attention to various items in the image.

Results suggested that when objects are depicted in a line, horizontally and vertically, subjects are naturally inclined to scan them in a given order (top to bottom, left to right) - but this is mediated by the preference for certain objects (larger instead of smaller, brighter instead of paler, etc.) such that we will start with the object that is most effective at drawing attention and scan the remainder relative to it.

3.2.3 Image Rotation

Inspired by [14], we assumed that the conceptual rotation of different representation form of knowledge can be categorized into two different aspects, which are rotation in the picture plane, rotation in depth, and rotation in the diagonal, respectively.

The physical-level rotation in the picture plane and in depth are both fully observed in [27]. However, we assume the dynamic characteristic of stored patterns in various, so we introduced a novel diagonal rotation, which means the mental imagery can process the image towards a fixed diagonal direction. Further, What makes our method different from the previous work is that we care about the rotation of different abstract level of knowledge representation. Previous work only pay attention to the physical level, but the single level of abstraction lacks of the ability of representation of variated patterns. The different level of abstraction can help to increase the model representative ability while every layer only focus on a particular abstract level of handled information.

4. Experiment Design

For the design of experiments, we will conduct from two aspects, one is to prove the hierarchical representation of knowledge with different level of abstract, the other is to validate the procedure of conceptual rotation. As the latter will influence the former through the whole procedure of mental imagery, we will first try to prove the process of conceptual rotation. Then, we will attempt to discover the hidden abstract structure of mental knowledge representation.

4.1. Verification of Sequence Conceptual Rotation

In this subsection, we will try to prove the exist of three process of conceptual rotation and the sequence order when handling information. Three sub-experiment will be conduct to verify the phenomenon of conceptual-level image scaling, conceptual-level image scanning and conceptual-level image rotation respectively. The main measurement method is the reaction time as it's widely acknowledged to judge the mental rotation [16, 14, 27]. The experiment details will be illustrated in the following. As we assume the conceptual rotation is independent with the concept level, we only experiment on the psychical level representation of knowledge, the Verification of all the three processes obey the same assumption.

4.1.1 Experiment One

This experiment is dedicated to verify the exist of image scanning while conducting conceptual rotation.

Inspired by the fact that small objects are generally sees less clearly than large objects [8]. We will have participants imagine a target animal (e.g., a rabbit) next to a small or large creature (e.g., a fly or an elephant). When the rabbit is envisioned in conjunction with the elephant, the mental image is of a small rabbit with less detail. However, when the rabbit is envisioned next to a fly, the rabbit is relatively large and its image has more detail. The assumption here is: It takes longer for participants to determine appropriateness of a certain property (e.g., ears) when the rabbit is relatively small.

To guard against the possibility that such results might derive simply from greater interest in elephants than in flies, we will test animals in the context of a gigantic fly and a tiny elephant. The assumption here is: It will take more time to evaluate the target animal when it war paired with the giant fly than with the tiny elephant.

Besides, we will conduct another experiment to enhance our theory. We will ask participants to imagine squares of four different sizes – each six times the are of the next smaller one and each identified by a color name. After the participants are able to envision the size of the square on the basis of the color, they will be given a color and animal name, such as “green bear” or “pink tiger”, and asked to summon up an image of the designed animal according to the size of the box linked with the color. After this, a possible property of the animal will be presented. **The assumption here is**: The time required to decide whether the property is a characteristic of the animal in the small boxes than for those in the larger ones.

Add some picture illustrating the experiment design.

4.1.2 Experiment Two

This experiment is designed to prove the exist of image scanning when handling conceptual rotation. That is, whether there is a image scanning process affected by the size and spatial properties of conceptual-level image. In order to prove our theory, we will ask participants to memorize a set of drawings and then to imagine one at a time. At one time they will be asked to “focus” on one end of the object they had imagined (e.g., if the object is a speedboat, they are asked to “look at” the rear portion). A possible property of the original picture will be named', and the participant is going to be asked to decide whether or not it is in the original. The assumption here is: Longer times

Table 2. Comparison of all the experiments. Aim item default to be "Try to prove β exists in the procedure of mental knowledge representation (mental imagery), while $\beta \in Aim$".

Item	Aim	Assumption	I.V.	D.V
Ep-01	image scaling	It takes longer for participants to determine appropriateness of a certain property when object is relatively small	the relative size among rabbit, elephant and fly	the reaction time of the ear
		The time required to decide whether the property is a characteristic of the animal in the small boxes is longer than those in the larger ones	the boxes size containing animals	the time to decide the correctness of a given property
Ep-02	image scanning	Longer time is required to make judgement about properties that involved scanning distance	the distance between the focused area and the test area	time to make judgment
Ep-03	rotation in the table-plane	There is a linear relationship between the rotation angle and identified time	rotation angle	the identified time
	rotation in depth	There is a linear relationship between the rotation angle and identified time	rotation angle	the identified time
	helix rotation	There is a linear relationship between the rotation angle and identified time	rotation angle	the identified time
Ep-04	physical layer	The physical layer functions in mental knowledge representation	focus on global information	the ability to identify and identified time
Ep-05	characteristic layer	The characteristic layer functions in mental knowledge representation, and it's layered after the physical layer	feature extraction, selection, and combination	the ability to identify and identified time
Ep-06	functional layer	The functional layer works in mental knowledge representation, and it's deeper than characteristic layer	relationship among mental imagery and real object	the ability to recall and recalled time
Ep-07	rule layer	The rule layer works in mental knowledge representation, and it's the most abstract knowledge	give several rules to obtain corresponding mental imagery	the ability to recall and the recalled time

are required to make judgement about properties that involved scanning distances. For example, those involving a scan from stern to bow took longer than those involving one from porthole to bow. Participants who are asked to keep the whole image in mind will show no differences in the time required to identify properties from different locations. It will appear that mental images can be scanned and that the time required to scan them is similar to that needed to scan real picutres.

Add some picture illustrating the experiment design.

4.1.3 Experiment Three

This experiment is aimed at verifying the phenomenon of image rotation in the process of conceptual rotation.

The experiment reported here was designed to measure the time that subjects require to determine such identity of shape as a function of the angular difference in the portrayed orientations of the two three-dimensional objects.

This angular difference was produced either by a rigid rotation of one of two identical pictures in its own picture plane or by a much more complex, nonrigid transformation, of one of the pictures, that corresponds to a (rigid) rotation of the three-dimensional object in depth.

This reaction time will be found to increase linearly with the angular difference in portrayed orientation and it is assumed to be no longer for a rotation in depth than for a rotation merely in the picture plane. These findings appear to place rather severe constraints on possible explanations of how subjects go about determining identity of shape of differently oriented objects. They are, however, consistent with an explanation suggested by the subjects themselves. Although introspective reports must be interpreted with caution, all subjects will claim that to make the required comparison they first had to imagine one object as rotated into the same orientation as the other and that they could carry out this "mental rotation" at no greater than a certain limiting rate; and since they perceived the two-dimensional pictures as objects in three-dimensional space, they could imagine the rotation around whichever axis was required with equal ease. Besides, we will also conduct the helix rotation.

4.1.4 Analysis

Experimental results are expected to demonstrate that the experiment (sum up all the result above). Besides, by comparing the relative reaction time among these three experiments, we may safely draw the conclusion that three elements in conceptual rotation (concept-level image scanning, concept-level image scanning and concept-level image rotation) are processed in order.

4.2. Verification of Hierarchical Representation of Knowledge

In this subsection, we will try to prove the exist of four levels of knowledge representation of mental with different abstraction. Four experiments are specially designed to verify the four knowledge levels (physical, characteristic, functional, and rule), respectively. The analysis will show sum up the set of experiments and make a conclusion as a whole. We assume that the exist of hierarchical representation of knowledge is independent with the processes in conceptual rotation module (including concept-level image scaling, scanning and rotation). So we will just pick the image rotation as our experiment material.

4.2.1 Experiment Four

This experiment is dedicated to verify the physical level of mental knowledge representation. As the third experiment just care about the physical mental imagery concerning mental rotation, experiment four is just the same as the previous one. We will try to evaluate the reaction time.

4.2.2 Experiment Five

This experiment is designed to prove the characteristic level of mental knowledge representation. It is widely acknowledged that we human can obtain features and patterns from raw data, and this is a important foundation of machine learning and pattern recognition, which care about the diversified artificial intelligence [28]. The physical level focus on the representation of objects as a whole. Meanwhile, feature level knowledge pay attention to the saliency part of the objects and reconstruct it. We assume the mental rotation in the characteristic level really happens.

We will select several representative features from a physical object and reconstruct them without losing spatial similarity with the raw data. For example, several keypoints of a giraffe (neck, ear, eye et al). Similar to the rotation on physical level, we try to rotate the combined features and evaluate the identified reaction time.

4.2.3 Experiment Six

This experiment is aimed at verifying the functional level of mental knowledge representation. The functional level knowledge representation of mental begins to pay attention to the linguistic information of mental imagery and try to discover the relationship between then. The main task here is: If there is a relationship between A and B, we can observe A well, whether we can recall the mental imagery of B by only using the information of A.

Here we assume that there is a tight bound between toothpaste and toothbrush. We will try to present the toothpaste to the participants and test how long they will recall the toothpaste. Further, we will also handle the conceptual rotation. In this experiment, it's the rotation of toothbrush explicitly, which represent the rotation of functional-level patterns.

4.2.4 Experiment Seven

This experiment is dedicated to verify the rule level of mental knowledge representation. That means, every object obeys some implicit rules, which makes it distinguished with others. Here the question is: we give a set of rules concerning an mental imagery, whether the participant will identify it and how long they will cost.

4.2.5 Analysis

Experimental results are expected to verify that the experiment (sum up all the result above). Besides, by comparing the relative reaction time among these four experiments, we may safely draw the conclusion that four elements in the hierarchical knowledge representation module (physical level abstraction, characteristic level abstraction, functional level abstraction and rule level abstraction) are processed in order.

4.3. Discussion

Firstly, I will sum up the keypoints of those seven experiments and compared them according to the assumptions, independent variables, and dependent variables. The details can be found at Table 2.

To the best of our knowledge, our theory is the first to illustrate the hierarchical knowledge representation of mental imagery. Besides, it's also the first time to regard the internal process of imagery as the layered conceptual rotation.

However, as far as we know, how to select the proper object with layered abstraction is of vital importance. For example, the rule level representation of knowledge is hard to be visualized. This might be the prior towards our future work.

5. Conclusion and Perspectives

In order to explain the knowledge representation mechanism of mental, we proposed a novel hierarchical conceptual rotation theory in this paper. We argue that the perception and process of stimulation is motivated in a hierarchical manner. We also maintain that hierarchical representation of knowledge and conceptual rotation are two important roles in the processing of mental imagery. The former is composed of four different levels, which are physical layer, characteristic layer, functional layer and rule layer, respectively. They are going to be more and more abstract. The latter is composed of three different aspects, which are conceptual-level image scaling, image scanning and image rotation. Experiment is specially designed to proe the widely accepted phenomenon of hierarchical also exists in the process of mental imagery.

Further, the discover of hierarchical mental imagery may help a lot to the further study of the procedure of learning and perception of we human. What's more, as this structure shows highly similarity with the procedure of human cognition, the proposed novel framework of the manipulation of perception may help to build more human-alike and dynamic artificial intelligence systems. We argue that more researchers pay attention to the hierarchical structure of mental imagery and its relationship with visual perception. It may create a new era of the understanding of we human.

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