An Experiment Study on the Cognitive Schema of Trajectory in Dynamic Visualization

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Abstract. In theory, when the novel has a high-matching degree with the cognitive structure, the cognitive process maintains an equilibrium status, the assimilation process of cognitive schema generates at this time. And the new information may expand the existing cognitive structure in amount and strengthen the schema. However, if the novel has a low-matching degree with the existing cognitive structure, the cognitive process appears unbalance accompanied by the accommodation process. In big data era, the visual features of the movement of objects (trajectory) has become an important element in dynamic visualization. In the display space, the movement pattern corresponds to the movement schema in cognitive schema. Based on this, we designed an experiment to verify the theoretical reasoning of cognitive schemas of trajectory in dynamic visualization. The results showed that the cognitive schemas of trajectory in dynamic visualization could build up by iterative learning in a short time. And the cognitive schema had a certain degree of inclusiveness. The difference degree between the novel and the inherent information was the main factor of the effect of the cognitive schemas. But we didn't found the obvious distinction between the assimilation process and the accommodation process of cognitive schemas in the experiment. We also found the different dynamic trajectories associated with the effect of cognitive schemas to a certain degree. This research opened up a new perspective of cognitive schemas for the study of dynamic visualization.

Keywords: Dynamic visualization · Cognitive schemas · Assimilation Accommodation cognitive load

1 Introduction

1.1 Schema

People have a natural tendency mode, we used to look for recognizable and meaningful mode of the complex pattern. This is an inherent need to find the law of things [1]. When cognitive subject facing with an unknown thing, he/she tends to look for a thinking or action mode in the pre-existing knowledge which matching the new thing. In the field of psychology, it calls the process of mode matching and also the

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mechanism of cognitive schema. The schema is similar to what's usually known as "concept", it describes the knowledge that organized in some way or in parts, and these frameworks should be filled with concrete contents. When the information input from outside, the brain automatically retrieves available cognitive schemas and generates the assimilation or accommodation process according with the matching degree of novelty and the cognitive schema [2].

Cognitive schema involves the whole process including information acquisition, understanding, memory, reasoning, judgement and problem solving. Cognitive schemas are stored in long-term memory in which including episodic memory and automatic skills, and integrated with the visual system to recognize thousands of glyphs and visual objects. Besides the external environment, the factors which influent the cognitive schema are including the experience, motivation, interests and emotions of the cognitive individual. Therefore, the cognitive schema performs difference between individuals.

As shown in Fig. 1, when the novel has a high-matching degree with the cognitive structure, the cognitive process maintains an equilibrium status, the assimilation effect generates at this time. The new information may expand the existing cognitive structure in amount and strengthen the schema. However, if the novel has a low-matching degree with the existing cognitive structure, the cognitive process appears unbalance accompanied by the accommodation process [3]. Through learning, the nature of the cognitive structure has been changed and the new schema generated to make the cognitive process to a new balance state.

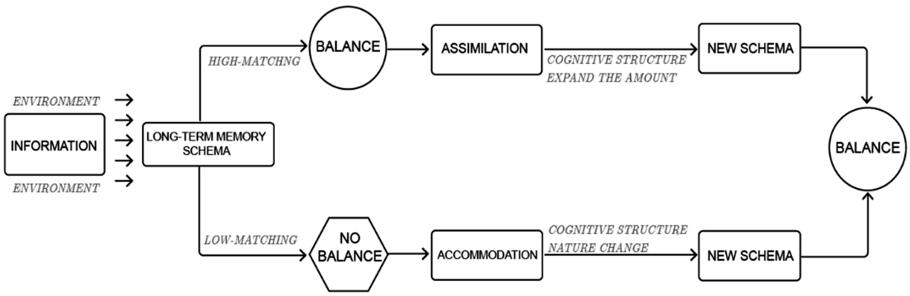

Fig. 1. Cognitive schema mechanism of assimilation and accommodation

To verify the semantic relevance of various semantic schemas, Smith et al. proposed feature comparison model in 1974. They believed the more same features between the concepts, the more connected in semantics. A feature comparison model was employed to further classify features. The essential feature of things was named defining features, and the nonessential but descriptive features was named characteristic feature [4]. In recent years, the studies on the correlation between population characteristics and cognitive schemas started to appear. Jind et al. focused on the changing patterns of psychological cognitive schemas of detached families [5]. Klibert et al. explored the difference cognitive schemas in patients with perishism and generalized anxiety disorder [6]. And Alvidrez et al. found that the schematic representation of ethnic minorities among young college students varied according to their social class [7].

1.2 Cognitive Schema in Dynamic Visualization

However, there were few researches on the cognitive schemas of dynamic visualization. Cognitive schema plays a key role in the process of dynamic visualization. In the era of big data, dynamic representations are now more common due to the increasing scale and dimensions of the information. The dynamic visualization with temporal attribute could guide individual's perception by the features of visual presentation. In the GUI visualization, the data information migrates in visual features according to the temporal dimension. These visual representations are mainly composed of the primitives in spatial structure and visual coding [8, 9]. Thus, the visual features of the movement of objects (trajectory) has become an important element in dynamic visualization. In the display space, trajectory of the nodes can be represented the transition and migration of the data. The movement pattern corresponds to the movement schema in cognitive schema. Combined with the precious empirical structure, it could help us grasp the complex action patterns quickly by mapping the understanding of action schema in low-level to the action information need to learn [10].

Cognitive schema is a black box for us, so we want to understand the mechanism of assimilation and accommodation matching process of cognitive schema to achieve the goal of visual cognition. In theory, assimilation is produced by unilateral access of knowledge which cost less cognitive effort, while accommodation is integrating the relevant schemas to a new knowledge structure which need more cognitive effort for its more complex and varied in structure. Therefore, the experiment attempted to complete a new schema through the pattern implantation of motorial structure.

2 Experiment

2.1 Experimental Design

Specifically, assimilation is a pattern matching process that directly converts the acquired information into the knowledge system of the brain. Then judge the similarity between the acquired knowledge and the knowledge in long-term memory by comparing the definitional and descriptive characteristics of the model. If in high similarity, the novel information could be integrated in the knowledge structure in the form of cognitive schema. Based on this, the design idea of the experiment was to establish a cognitive structure within a short time through the implantable schemas, i.e. experimental materials learning process and then provided the dynamic visual stimulus with feature comparison. The subject would make the decision when compared the similarity between the implantable patterns and the matching stimulus as shown in Fig. 2(a).

Correspondingly, when in low similarity, the subject could not incorporate the novel information into their own knowledge structure in the form of cognitive schema, the subjects should adjust their knowledge structure to a new schema as to conform to the descriptive characteristics of the acquired knowledge. This pattern matching process is accommodation. In the experiment, the changing amplitude was quantitative controlled, and the accommodation effect would be more obvious when differences increased, as shown in Fig. 2(b).

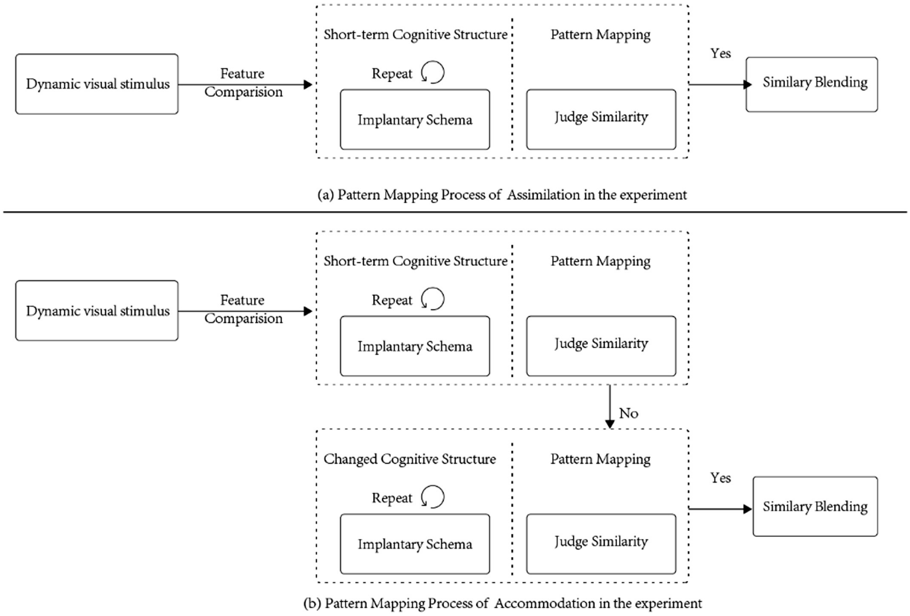

Fig. 2. Pattern mapping process of assimilation and accommodation in the experiments

2.2 Subjects and Materials

The experimental paradigm evolved from the Corsiblocks span task [4], an experimental paradigm that tests visual-spatial cognitive ability. The experimental focused on the cognitive schema of trajectory. As shown in the experimental process in Fig. 3, after displaying the introduction that described the experimental steps and operation

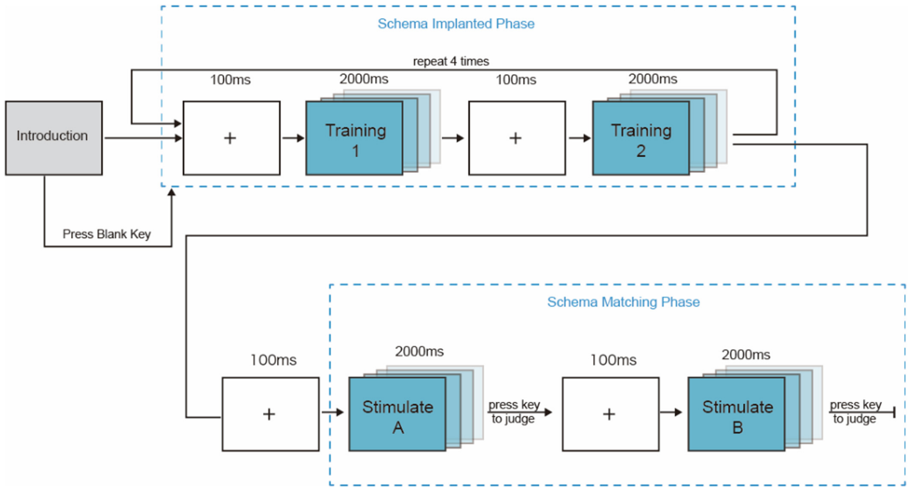

Fig. 3. An experimental trial of the procedure of cognitive schema of trajectory

methods, the screen showed the cognitive schema implantation phase in each trial in which two training materials (Fig. 4) were presented repeatedly. The material 1 corresponded the letter F, while the material 2 corresponded the letter J. After displaying alternations for 5 times, the stimulus material A and B that similar to the material 1 and 2 were displayed in the cognitive schema matching phase. The subjects were asked to judge the attributable of the stimulus materials and press F or J at the first time. And 20

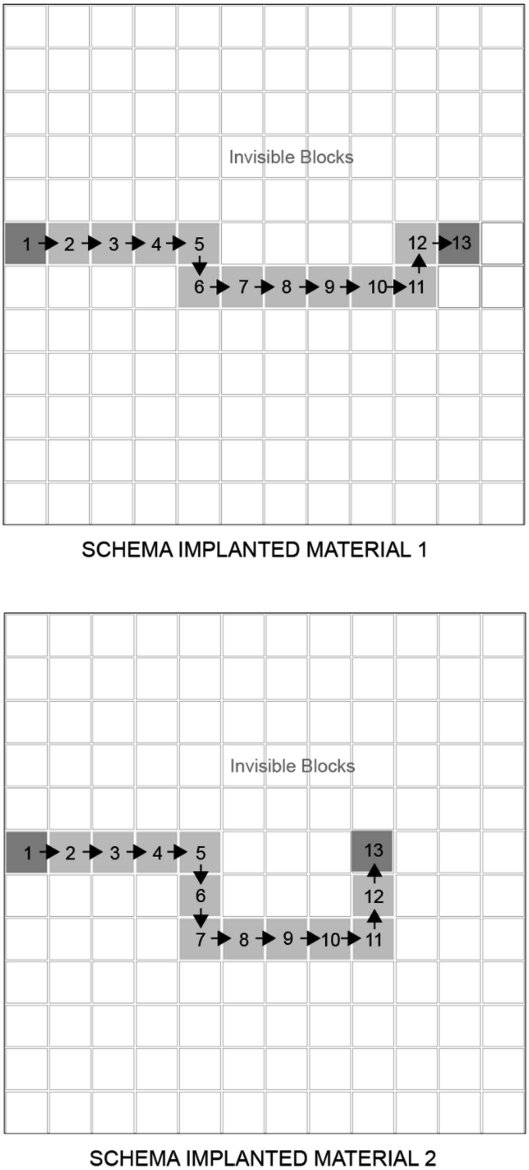

Fig. 4. The diagram of cognitive schema trajectory implanted training materials in the experiment

graduate students (5 female) participated in each group. All subjects had normal or corrected-to-normal vision. The Tobii X2-300 compact non-contact eye tracker was employed to collect the eye movements' and performance data.

The Fig. 4 showed a diagram of the experimental materials. Since the experimental material was represented the motion trajectory, the actual experimental material was an animation with 13 frames. The animation showed the movement of a white node on a black screen (in each frame only played one white square), and the Arabic numbers in Fig. 4 indicated the plane position of the white node in each frame. In order to eliminate the effect of the primacy effect and recency effect of the working memory. The

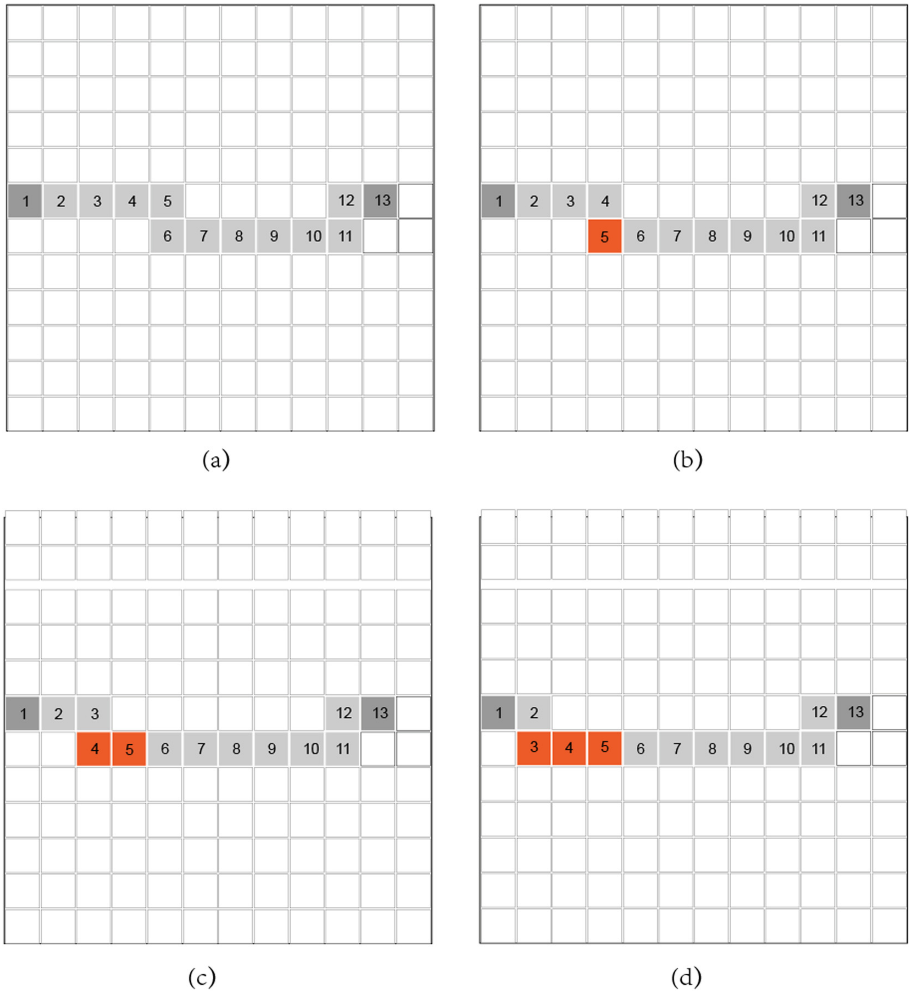

Fig. 5. The quantity change of the trajectory of the dynamic visual stimulus in the experiment. (a) Training material 1 displayed in the schema implanted phase; (b) quantify the degree of difference 1; (c) quantify the degree of difference 2; (d) quantify the degree of difference 3.

initial position and the ending position in the animation were kept uniform between the training material and the similar stimulate material. And the independent variable was the motion trajectory of the node.

In order to investigate the different effects of cognitive schema, the stimulus materials which displayed after the implantation schema was designed in quantitative changes. As shown in Fig. 5, the similar stimulus material of schema implanted material 1 provided three different magnitude changes. In the premise of consistency in the first and last position and the overall path shape (right down right up and right), the number of changed waypoints in the trajectory were 1, 2, and 3, respectively.

3 Results and Discussions

The experimental data including the correct rate, reaction time and eye-tracking were recorded during the experiments. There were two independent variables in the experiments, which were two types of experimental materials (shown in Fig. 4) and three difference degree between the target stimulus and the training materials. The two-factor interaction map with the dependent variable of mean value of reaction time of 20 subjects was shown in Fig. 6. As we seen, there was a cross trend between the two ordinates that indicated the interaction effect between the two factors to a certain degree.

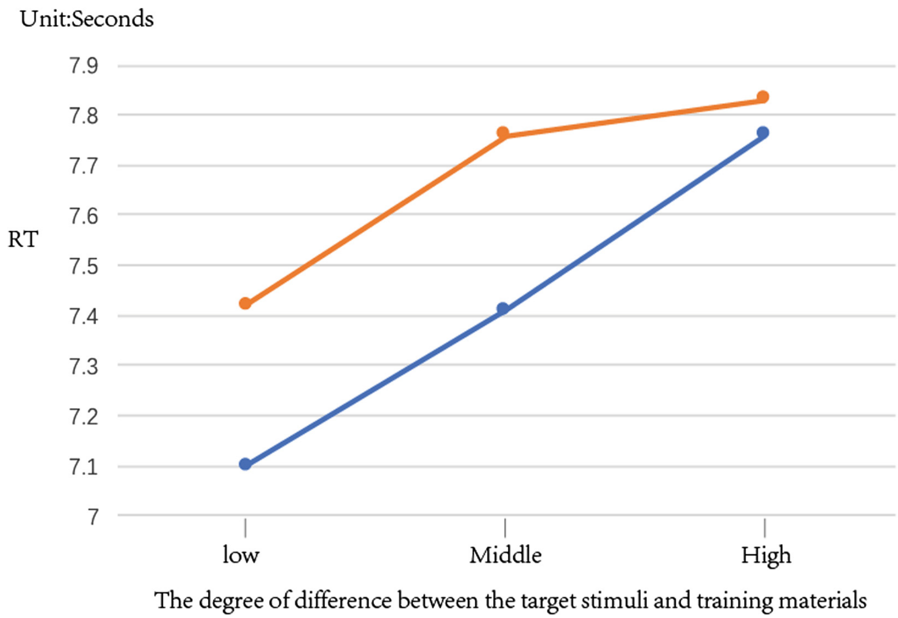

Fig. 6. The interaction map of trajectory cognitive schemata study.

This experiment could reflect the mechanism of the cognitive schema in some extent. The t-test result between two different type of experimental materials $t = -1.702$, $df = 118$, $= 0.091$, showed main effect was not remarkable. The ANOVA test of the three-difference degree between the target stimulus and the training materials showed the significant effect, $F(2,117) = 3.448$, $p = 0.035 < 0.05$. And when the trajectory difference was in low level (shown as Fig. 5(b)), there was no misjudge in distinguishing the material's attribution. When the difference degree increased, the subjects started error with the rate about 10%. The high correct rate showed that the subjects did generate the cognitive schemas of the dynamic trajectory during the experimental process.

The results of ANOVA test showed that there was a significant difference between three-difference degree in material 1, $F(2,57) = 3.659$, $p = 0.032 < 0.05$, but was no significant difference in material 2, $F(2, 57) = 0.934$, $p = 0.399 > 0.05$. In the training phase of the experiment, the cognitive schemas of dynamic trajectory were generated from the two stimulus materials and the associated letters. And the cognitive schemas determined cognitive performance in the schema mapping phase. The test results of both the interaction of two factors and different significance indicated that even experimental materials effected the change magnitude on the effects of cognitive schemas, but the main factor of performance of cognitive schemas was the similarity between the novel knowledge (schema matching phase) and the intrinsic schema (schema implanted phase).

There were multiple units of similar target materials with same difference degree in the schema matching phase. We compared the eye-tracking data of two units of the same material and difference degree with long interval. Among them, the fixation dwell time and the number of fixations were common eye-tracking indexes which could indicate the immediate cognitive load [11, 12]. The paired t-test results of the same subjects showed that there was no significant difference in the index of fixation dwell time $t = 1.141$, $df = 18$, $p = 0.269$, and also no significant difference in number of fixations $t = 1.161$, $df = 18$, $p = 0.874$. The results indicated that the subjects had no significant changes in cognitive load during the experimental process.

4 Conclusion

Theoretical reasoning and experimental analysis showed that the cognitive schemas of trajectory in dynamic visualization could build up by iterative learning in a short time. And the cognitive schema was not fixed but had a certain degree of inclusiveness. The difference degree between the novel and the inherent information was the main factor of the effect of the cognitive schemas. But we didn't found the obvious distinction between the assimilation process and the accommodation process of cognitive schemas. We also found the different dynamic trajectories associated with the effect of cognitive schemas to a certain degree. This research opened up a new perspective of cognitive schemas for the study of dynamic visualization.

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