Metacognitive Monitoring of Rule-Based Category Learning Tasks

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Abstract

The aim of the study was to investigate the dynamics of metacognitive monitoring during learning category structures defined by logical rules of different levels of complexity: conjunctive, conjunctive-disjunctive or complex rule. Feeling-of-warmth judgments were used repeatedly during learning to assess participants' subjective feelings about how close they are to the acquisition of the appropriate rule. After each judgment, participants were asked to describe logical rules underlying category structures. As expected, the results showed that feeling-of-warmth judgments generally follow classification accuracy through the course of learning. Rule description accuracy shows a similar pattern and is also congruent with classification accuracy through the course of learning. Contrary to expectations, there were no differences between different levels of category structure complexity on any of the tested measures.

Keywords: category learning; category structure complexity; feeling-of-warmth judgments.

Introduction

Shepard, Hovland and Jenkins (1961) in their seminal research showed that the ease of learning rule-based two-choice category structures, that can be constructed with stimuli composed of three binary stimulus dimensions, depends on the complexity of the underlying logical rule. Regarding the number of dimensions that need to be taken into account to correctly classify individual stimuli, tasks based on a simple unidimensional logical rule are the easiest to learn (type I), while tasks based on a two-dimensional conjunctive rule are more difficult to learn (type II). Tasks based on a three-dimensional conjunctive-disjunctive rule that can be formulated as a single-dimension-with-exception rule (types III, IV and V) reflect the next level of complexity, while tasks based on a more complex three-dimensional rule are the most difficult to learn (type VI). This ordering was a reference point for evaluating formal accounts of category learning (e.g. Estes, 1994; Feldman, 2000; Nosofsky, Gluck, Palmeri, McKinley, & Glauthier, 1994). However, recent studies observed that there is no type II advantage (Kurtz, Levering, Stanton, Romero, & Morris, 2013: Lafond, Lacouture, & Mineau, 2007; Lewandowsky, 2007; Love & Markman, 2003), which suggests that the original ordering should be revised (Kurtz et al., 2013).

An important question that arises from these results is how is the complexity of category structures reflected in metacognitive monitoring of the category learning process. Specifically, how is the complexity of category structures reflected in the subjective feelings related to the improvement of learning category structures. In order to examine participants' subjective feelings about how close they are to the acquisition of the rule underlying category structures at different stages of the learning process, feeling-of-warmth judgments (Metcalfe, 1986; Metcalfe & Wiebe, 1987) were used repeatedly during the course of learning. It was expected that feeling-of-warmth judgments will gradually increase following the increase in classification accuracy during the course of learning. Learning of rule-based category structures involves explicit processes of rule formation and hypothesis testing and activates the explicit or declarative category learning system which results in gradual mastering of rule-based category structures (Ashby & Maddox, 2005; 2010).

The aim of the study was to investigate how feeling-of-warmth judgments are related to categorization performance during the acquisition of category structures of different complexities (tasks type II, IV and VI).

Method

Participants

Sixty-five undergraduate psychology students from the Faculty of Humanities and Social Sciences in Rijeka, Croatia, participated in the experiment in exchange for course credits. They were randomly assigned to each of the three conditions (task types II, IV and VI). All participants were tested individually.

Materials

The participants learned rule-based two-choice category structures, labeled as category learning tasks type II, IV and VI by Shepard et al. (1961). The stimuli were pictures depicting three positions on which either of the two thematically related drawings of objects (candle–light bulb, violin–trumpet, and bolt–nut) could appear as values. Each of the two categories within a single category learning task included four stimuli.

Feeling-of-warmth judgments were used to assess participants' subjective feelings about how close they are to the acquisition of the rule underlying category learning tasks. Participants had to indicate how close they believed they were to the acquisition of the rule underlying the category structure repeatedly during the course of learning. Judgments were given on a seven-point scale ranging from 1 (meaning *'not close at all to the appropriate classification rule'*) to 7 (meaning *'completely confident about the appropriate classification rule'*).

Procedure

The stimulus presentation and data collection were performed by E-prime 2.0 software running on a personal computer. Stimuli were presented on a computer screen using unlimited (response-terminated) exposure duration. Each of the eight pictorial stimuli was presented once during each block in a randomized order. Subjects were instructed to determine whether the presented stimulus belongs to category A or B by pressing appropriate keys on the computer keyboard. If they were not sure how to classify the stimulus, they were instructed to guess about its category membership. Each response was followed by feedback on classification accuracy. After each block of eight trials, participants were asked to give a feeling-of-warmth judgment on a scale ranging from 1 to 7. Following the feeling-of-warmth judgment, participants were asked to write the underlying rule or to describe features characterizing categories A and B on a paper form. Learning continued until 20 consecutive blocks were reached.

Results and discussion

In order to examine changes in classification accuracy, rule description accuracy and feeling-of-warmth judgments during the acquisition of category structures, the course of learning was divided into four learning stages. The analyses were performed for two groups of participants: learners (who have successfully master the task), and non-learners (who have not master the task).

We performed three three-way ANOVAs with classification accuracy, rule description accuracy and feeling-of-warmth judgments as dependent variables, task type and performance group as between-subject factors and learning stage as a repeated measure factor.

Classification accuracy. For classification accuracy, the results showed significant main effects of performance group ($F_{1,59}$ =77.15, MSE = 0.029, p = 0.000) and learning stage ($F_{3,177}$ =85.88, MSE = 0.009, p = 0.000), significant two-way interactions of performance group and task type ($F_{2,59}$ = 3.70, MSE = 0.029, p= 0.031), and performance group and learning stage ($F_{3,177}$=43.47, MSE= 0.009, p = 0.000). A significant three-way interaction of task type, performance group and learning stage ($F_{6,177}$ = 2.64, MSE = 0.009, p = 0.018) was also obtained. Pairwise comparisons showed that classification accuracy increases through learning stages for participants who mastered task types II and VI, while an increase in classification accuracy for participants who mastered task type IV is observed starting from the second learning stage. Expected differences with respect to task type were not observed. However, the delayed increase in classification accuracy observed for task type IV relative to task types II and VI might suggest a greater complexity of task type IV. The results are in accordance with studies showing no type II advantage (Kurtz et al., 2013: Lafond et al., 2007; Lewandowsky, 2007; Love & Markman, 2003) when presented stimuli are composed of drawings which are therefore difficult to verbalize and make category learning harder. Equal classification accuracy on task types II and VI probably indicates that participants use the strategy of simple memorizing single stimuli instead of mastering the underlying rule when faced with the task which is extremely difficult to be described in terms of logical rule (task type VI). The use of memorization strategy can improve classification performance on task type VI and make it comparable to task type II which is mastered by discovering the appropriate logical rule (Nosofsky & Palmeri, 1996). Delayed acquisition of task type IV compared to the two other task types may be due to the deceptive simplicity of the underlying single-dimension-with-exception rule where the exception impedes category learning in the initial learning stages.

When comparing two performance groups, classification accuracy is higher for learners compared to non-learners starting from the third learning stage for task types II and IV, and starting from the second learning stage for task type VI. Results are shown in figure 1(a).

Rule description accuracy. Rule description accuracy was determined by assigning the value 1 to each stimulus which could be correctly classified based on the rule description given by the participant and the value 0 to each stimulus which could not be properly classified based on the same rule description. The number of stimuli that could be correctly classified was divided by the total number of presented stimuli per block to express rule description accuracy as a proportion.

For rule description accuracy, the results showed significant main effects of performance group ($F_{1,59}$ =37.98, MSE= 0.192, p = 0.000) and learning stage ($F_{3,177}$ = 43.14, MSE= 0.025, p = 0.000), and a significant two-way interaction of performance group and learning stage ($F_{3,177}$ = 26.83, MSE = 0.025, p = 0.000). Pairwise comparisons showed that rule description accuracy increases through learning stages for learners, while it remains low for non-learners. When comparing two performance groups, rule description accuracy is higher for learners starting from the third learning stage. Again, expected differences with respect to task type were not observed. Generally, rule description accuracy is in line with classification accuracy through the course of learning. Similar patterns observed for classification and rule description accuracy show that it is possible to verbalize what is learned in different learning stages or to monitor the ongoing rule-based category learning process (Ashby & Maddox, 2005; 2010). Results are shown in figure 1(b).

Feeling-of-warmth judgments. A similar pattern to the ones described above was observed for feeling-of-warmth judgments. The results showed significant main effects of performance group ($F_{1,59}$ = 26.20, MSE = 5.944, p = 0.000) and learning stage ($F_{3,177}$ = 61.15, MSE = 1.030, p = 0.000), and a significant two-way interaction of performance group and learning stage ($F_{3,177}$ = 40.22, MSE = 1.030, p = 0.000).

Pairwise comparisons showed that feeling-of-warmth judgments increase through learning stages for learners, while they remain low for non-learners. When comparing two performance groups, feeling-of-warmth judgments are higher for learners starting from the third learning stage. Generally, the results showed that feeling-of-warmth judgments are in line with categorization performance during the acquisition of category learning task types II, IV and VI. Thereby, feeling-of-warmth judgments gradually increase through the course of learning for participants who successfully mastered the task.

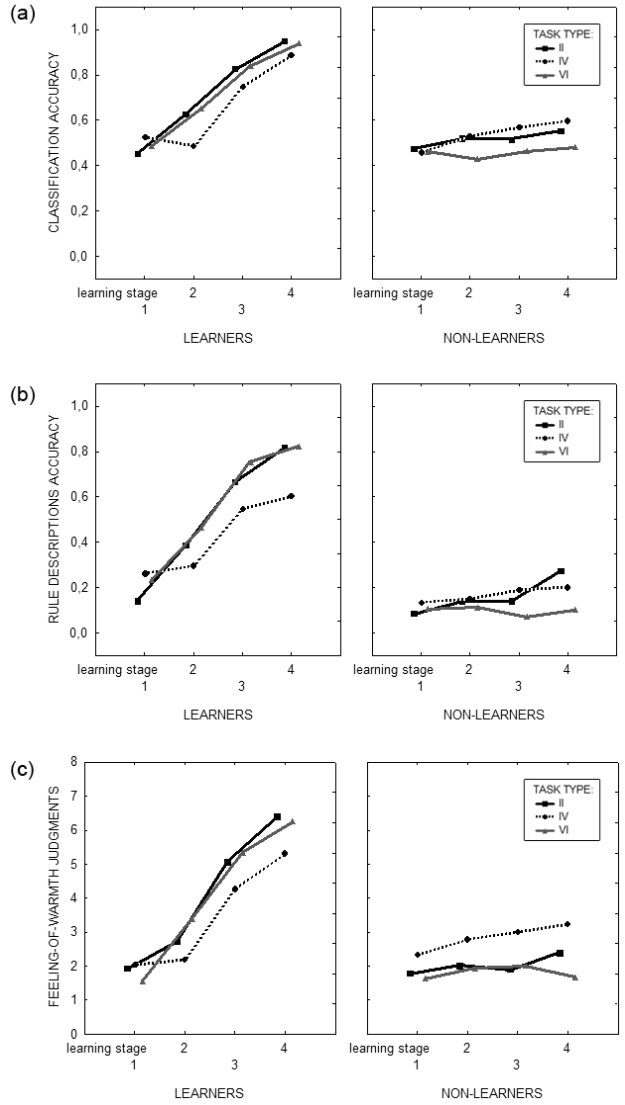

Figure 1. (a) Classification accuracy, (b) Rule description accuracy and (c) Feeling-of-warmth judgments with respect to two performance groups, three task types and four learning stages.

This is consistent with previous research conducted in the domain of problem solving showing incremental patterns of feeling-of-warmth judgments during the course of solving algebra and non-insight problems whose solutions are reached gradually (Metcalfe, 1986; Metcalfe, & Wiebe, 1987). These findings suggest that metacognitive monitoring of the course of learning rule-based category structures is efficient to some extent.

Furthermore, the results showed that the two-way interaction of task type and performance group on feeling-of-warmth judgments approached significance ($F_{2,59} = 2.63$, MSE = 5.944, $p = 0.080$). Pairwise comparisons showed that participants who mastered task types II and VI gave higher feeling-of-warmth judgments compared to participants who have not master those tasks. On the other hand, this difference is not observed for two performance groups exposed to learning task type IV. This result also points to the greater complexity of task type IV since, on average, participants who successfully mastered task type IV had difficulties to discriminate whether the acquired underlying rule is appropriate. Results are shown in figure 1(c).

Conclusion

We observed similar patterns in the dynamics of classification accuracy, rule description accuracy and feeling-of-warmth judgments through the course of learning rule-based category structures. This suggests that learning which activates the explicit or declarative system can be metacognitively monitored (Ashby & Maddox, 2005; 2010).

Contrary to expectations, lack of differences between tasks of different complexities supports previous findings that the original ordering of category structure complexity (Shepard et al., 1961) should be revised (Kurtz et al., 2013: Lafond et al., 2007; Lewandowsky, 2007).

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