SIMILARITY-BASED AND EXPLANATION-BASED LEARNING OF EXPLANATORY AND NONEXPLANATORY INFORMATION

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ABSTRACT

We suggest that human learners employ both similarity-based learning (SBL) and explanation-based learning (EBL) procedures and that the successful use of these procedures is determined by the characteristics of the information to be learned. In a domain without underlying causal structure, multiple examples can lead to successful SBL, but not to successful EBL. In a domain with underlying causal structure, the use of appropriate background knowledge can lead to successful EBL, but not to SBL. A series of experiments was carried out in which a common initial passage was followed with a variety of different types of information (a second similar instance, a second contrasting instance, frequency data, or explanations). EBL occurred only when subjects had sufficient background knowledge and when the information to be learned could be causally structured. SBL occurred when there were multiple examples, even in domains without causal structure.

INTRODUCTION

Studies on concept formation and schema acquisition in Psychology have typically assumed that multiple examples are required for knowledge acquisition. These studies assume that knowledge acquisition is based on similarity-based learning (SBL), in which learners look for communalities and differences among examples and generalize the communalities and variabilize the differences (Anderson, Kline, & Beasley, 1979; Hayes-Roth & Hayes-Roth, 1977).

On the other hand, recent machine learning models of explanation-based learning (EBL), require only a single example for schema acquisition because the systems can analyze the causal structure of an example and generalize the explanation part of the example (Mooney & DeJong, 1985; Mitchell, Keller, & Kedar-Cabelli, 1986). Ahn, Mooney, DeJong, and Brewer (1987) presented psychological evidence that people can acquire a schema from a single example if they have sufficient domain knowledge or if the schema to be acquired has a causal structure. Ahn, Mooney, Brewer, and DeJong (submitted) also showed that EBL fails when people do not have sufficient domain knowledge or when the structure of a schema cannot be causally connected. These studies focus on EBL and do not show how this type of learning mechanism is related to SBL.

Recently, several researchers in the area of machine learning have attempted to integrate SBL and EBL (Danyluk, 1987; Kodratoff & Tecuci, 1987; Lebowitz, 1983, 1986; Pazzani, 1985; Pazzani, Dyer, & Flowers, 1986). These models make use of SBL or EBL in somewhat different ways. For example, Lebowitz's IPP looks for communalities of examples first and then tries to explain the communalities. Similarly, Pazzani's UNIMEM uses correlation first, since explanation is an expensive process. On the other hand, Pazzani et al.'s OCCAM uses prior causal theories in preference to correlational data.

In the present study, we outline a psychological theory of knowledge acquisition that uses both similarity-based learning and explanation-based learning procedures and carry out learning experiments designed to explore this hybrid approach.

EXAMPLE

The example used for this experiment was a description of a potlatch ceremony. This ceremony occurred among Indian groups of Northwestern North America; during the ceremony the host chief gave away valuables in order to improve his status. The following passage is a specific instance which includes the background knowledge necessary to understand the potlatch ceremony. The required background knowledge is given in brackets.

Guetela is a Kwakiutl chief and a descendent of Mamaleleqala. On July 13th, 1745, Chief Guetela invited four chiefs: Chief Namqic, a descendent of Dentalayo, Chief Qomoyue, a descendent of Mamaleleqala, Chief Laokoatx, a descendent of Wina, and Chief Tsamas, a descendent of Wina.

[The purpose of this ceremony was to increase Chief Guetela's status with respect to Chief Qomoyue who had the same ancestor. Both chiefs claimed the same family title because they both were descendents of Mamaleleqala. So Chief Qomoyue was entitled to compete with Chief Guetela for the status conferred by possessing the family title.]

[To be witness to the ceremony, chief Nemqic, Chief Laokoatx, and Chief Tsamas were also invited. These chiefs were invited because they were members of the same "moiety" as Chief Guetela's wife. Moieties are twofold divisions of a tribal group. Every individual is assigned to one of two moieties at birth, on the basis of the affilation of his or her mother. This means that Chief Guetela and his children were in opposite moieties.]

Before the ceremony, Chief Guetela and his tribe prepared for the ceremony by collecting as many blankets and canoes as they could afford. [Blankets and canoes were highly valued in this society. Chief Guetela wanted to give away these items because the more valuables Chief Guetela gave away during the ceremony, the higher his status became.] They also prepared smoked salmon and berries. Chief Guetela put on his best blue shirt with a raven on it. Dancers for the ceremony took raven and eagle masks from a copper box.

The guests arrived through the north gate of the village. Chief Namqic's shirt was orange, and Chief Laokoatx and Chief Tsamas's shirts were yellow. On these three people's shirts, an eagle was drawn. Chief Qomoyue was wearing a blue shirt with a raven printed on it. Chief Guetela's wife was wearing an

orange dress with an eagle printed on it and also a seashell necklace. [there are 4 additional paragraphs in the experimental passage]

Explanatory and Nonexplanatory Constraints and Variables

This passage was designed to contain four basic forms of information: constraints that are either explanatory or nonexplanatory and variables that are either explanatory or nonexplanatory. In a complex knowledge structure variables are slots which can be filled by different objects or agents. Constraints specify necessary properties of variables and necessary relationships between variables. Some constraints and variables have underlying explanations. For example, in the passage above, the information that the host chief's status improves after the ceremony is an example of an explanatory constraint because it provides an explanation for the purpose of the ceremony. The items given away by the host chief are examples of an explanatory variable because they play a role in the underlying causal structure, but the specific type of valuable object is not crucial. On the other hand, some constraints and variables are nonexplanatory. The information that the host chief looks at the guests before the dancing starts is a nonexplanatory constraint. There is no causal account of this action in our passage; it is simply a conventional behavior. The information that the guest chiefs arrive through the north gate is a nonexplanatory variable because it is not connected to the explanatory structure of the ceremony

ACQUISITION CONDITIONS

If an individual reads a single description of a specific instance of a potlatch ceremony that contains no explanatory information, our theory suggests that the learner will acquire little correct information from the passage since neither SBL or EBL processes will be possible. However, there are a variety of different forms of information that the learner can be given in a second passage, and our hybrid model of learning can be used to make a number of differential predictions in these cases.

SBL: Single Similar Instance

If a learner is given a second instance that is very similar to the original instance (i.e., has the same variables as the first one), then the learner should attempt to carry out SBL. With two instances of this type the learner will correctly assume that the repeated constraints are, in fact, constraints, but will incorrectly assume that the repeated variables are also constraints. For example, if the color of the host chief's clothing was actually a variable, but the same color occurred in both examples, then the learner will tend to think that this color is a requirement for a potlatch ceremony.

SBL: Single Contrasting Instance

If a learner is given a second instance that has each variable changed, then the learner should be able to carry out SBL for nonexplanatory constraints and variables. For example, if the color of the host chief's shirt was blue in the first example and it was red in the second example, the learner can infer that the color of shirts is a variable in a potlatch ceremony. For repeated constraints SBL will also succeed. For

example, if in both examples the host chief faces the guests before the dancing starts, the readers should use SBL to infer that this is a constraint in the ceremony.

SBL: Multiple Contrasting Instances

If a learner is given a series of instances that contain changed variables,then the learner should be able to use SBL to learn which aspects of the texts are variables and which are constraints. This condition is similar to the case of a single contrasting example, except that the larger number of cases should lead the learner to be more confident about the outcome.

EBL

If a piece of information is part of a causal structure and the learner is given the appropriate background knowledge, then the learner can use EBL to give an account of explanatory constraints and variables (Ahn, Mooney, DeJong, & Brewer, 1987).

METHOD

Procedure

Subjects read a first passage (i.e., the passage describing a single instance of a potlatch without any background knowledge). Then they answered all 16 yes/no questions, wrote justifications for their answers, and rated their confidence on a 5-point scale. After they finished answering all the questions, the subjects read one of the four follow-up passages and answered the yes/no questions a second time. Subjects were not allowed to change their answers for the first set of questions after they read their second passage.

Materials

The basic materials for this experiment consisted of an initial passage, four follow-up passages, and a series of yes/no questions designed to test what had been learned from the texts.

Yes/No Questions

We developed four types of yes/no questions There were questions based on the explanatory constraints and variables and on the nonexplanatory constraints and variables. One of the questions for explanatory constraints was, "After the ceremony will people think that the host chief has higher status than before?" One of the questions for explanatory variables was, "Will the wife of a host chief be happy if her husband gives away the family's drums?" One of the questions for nonexplanatory constraints was, "In this kind of ceremony, would it matter if the host chief did not look at the guests before the dancing?" One of the questions for nonexplanatory variables was, "In this kind of ceremony, is it necessary that the guest chiefs enter the village through the north gate?" There were four questions for each type, resulting in a total of 16 questions.

Initial Instance Passage

On the first trial, all the subjects received a passage which described a single instance of a potlatch ceremony without any added background knowledge. This passage corresponds to the example passage given earlier with the information in brackets omitted

Follow-up Passages

Similar instance passage. In this passage both the constraints and variables in the first initial passage were kept constant. For example, the guest chiefs left the village through the south gate in both passages.

Dissimilar instance passage. In this passage the constraints from the initial passage were repeated, but the values of the variables were changed. For example, the guest chiefs left the village through the north gate in this passage, while they left through the south gate in the initial passage.

Dissimilar instance with knowledge. In this passage the constraints from the initial passage were repeated, the values of the variables were changed, and the needed background knowledge was included.

Generic information with knowledge. This passage was written in generic form so that it gave roughly the frequency information that a learner would obtain after having read a very large number of individual passages. The passage began "The American Indians who lived in the Northwest part of the country frequently carried ot an interesting ceremony." For a nonexplanatory constraint it stated that "the host chief stood up and then dancers started entertaining the people," and for a nonexplanatory variable it stated that, "The shirts were all in various colors." This passage also included the relevant background knowledge.

Design

Fifty-two undergraduate students participated in this experiment in partial fulfillment of a course requirement for introductory psychology. There were four experimental conditions with 13 subjects in each condition. The subjects in the Similar Instance Condition received the initial instance passage and then the similar instance passage. The subjects in the Dissimilar Instance Condition received the initial instance passage and then the dissimilar instance passage. The subjects in the Dissimilar with Knowledge Condition received the initial instance passage and then the dissimilar with knowledge passage. The subjects in the Generic with Knowledge Condition received the initial instance passage and then the generic information with knowledge passage.

RESULTS

Table 1 shows the average percent correct for the four different types of questions in each condition. (EC refers to explanatory constraints, EV to explanatory variables, NC to nonexplanatory constraints, and NV to nonexplanatory variables). The numbers reported are the percent correct in each condition on the first trial and on the second trial.

TABLE 1. THE PERCENT CORRECT FOR EACH CONDITION ON EACH TRIAL

Conditions	Similar Instance		Dissimilar Instance		Dissimilar with Knowledge		Generic with Knowledge	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
EC	54	54	44	54	54	77	52	87
EV	44	46	48	48	54	81	50	77
NC	77	81	75	69	73	65	88	65
NV	29	27	29	81	33	58	13	39

The data provide considerable support for our dual-process theory of learning. We predicted that the subjects in the Similar Instance Condition would not be able to use SBL or EBL successfully and the data show little learning from the second example.

We predicted that the subjects in the Dissimilar Instance Condition would not be able to apply EBL, but would show SBL for the two nonexplanatory conditions. The subjects with dissimilar instance passages showed little learning in the explanatory conditions as predicted. The subjects showed considerable learning in the nonexplanatory variable condition, but they showed no learning in the nonexplanatory constraint condition This is not in keeping with our predictions. We are not sure what is going on in this condition, but perhaps the exposure to explanatory information temporarily changes their estimates of the likelihood that a nonexplanatory constraint is a true constriant. It is also possible that the subjects may be operating under a Gricean discourse rule (Grice, 1975) which leads them to believe that if an author chooses to mention something in the text it must be important and perhaps it is a constraint.

We predicted that the Dissimilar with Knowledge Condition would lead to successful SBL and EBL. All of these predictions are supported except that the nonexplanatory constraint information once again did not show the predicted learning.

We predicted that the Generic with Knowledge Condition would also lead to successful SBL and EBL. The results support the predictions except in the nonexplanatory constraint condition.

CONCLUSION

In this paper we propose that different learning mechanisms are successful depending on whether the learner has appropriate background knowledge or not and on whether the information to be learned is explanatory or not. Our data show that background knowledge is required to carry out EBL and to learn

explanatory information. Repetition is required to carry out SBL and to learn nonexplanatory items, but does not lead to the understanding and learning of explanatory information. This finding requires the development of theories which relate learning mechanisms to the character of the information to be learned.

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