The Importance of Design in Learning from Diagrams

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Abstract. Diagrams are useful for learning because of their perceptual features. They guide learners in searching and relating information. However, research into learning with diagrams has shown that diagrams are not always effective. In this study, we investigated whether learners followed the perceptual features of diagrams by using eye-tracking as a method, and if so, whether this influenced what they remembered from its content. First results showed that most learners studied the diagram based on the content and not on the design. The way the participants studied the diagram did not seem to influence post-test scores.

Keywords: representations; diagrams; secondary notation; eye-tracking.

Introduction

Many scholars have argued that diagrams are good for learning. Visualizing information in diagrams can facilitate comprehension and communication, because diagrams clarify relationships, illustrate structure of the material, and can make thinking visible. In practice however, results into effects of diagrams have been equivocal. We argue that the less successful results are due to bad diagram design. Implied in the theoretical benefits is that diagrams support learning because of their *perceptual features*, i.e. textual, spatial, and graphical elements that improve reading. So far, learning scientists have researched diagrams for learning, but have largely ignored design characteristics of diagrams that may help or hinder learning. In our study, we have systematically varied the design of a diagram without changing its content, to examine how perceptual cues influence learning.

It is important to note that the diagrams we are talking about in our studies are representations that combine text with a two-dimensional lay-out, sometimes called node-and link diagrams. Node-and-link diagrams are very abstract compared to other representations such as drawings. The text is the core of the diagram, but perceptual cues can facilitate reading compared to reading a linear text. Newbern, Dansereau, and Patterson (1997), for example, found that learning material was better recalled when presented in a knowledge map than in a textual format.

From studies in perception we learn that diagram processing consists of (at least) two stages: a fast pre-attentive stage and a slow attentive stage (Treisman & Gelade, 1980). In the pre-attentive stage, elementary features such as colors, arrows, and boxes are detected. This stage may provide initial cues about the important components in the diagram. In the attentive stage, attention is directed towards these components and the diagram is parsed and textual elements are processed.

From research in the field of (visual) metaphor and cognition we know that people tend to see abstract things in terms of concrete experiences, such as important is large, and mentally close is spatially close. When boxes are placed close together in space, they indicate proximity on another value, such as meaning or ownership. Wiegmann, Dansereau, McCagg, Rewey, and Pitre (1992) asked students to recall information from knowledge maps, and found that spatial configurations obeying principles of good shape or Gestalt were more effective than maps that do not follow these principles. They did not check *how* learners processed these maps, however.

Eye-tracking data can give us information on how learners process a diagram. Following the eye-mind assumption (Just & Carpenter, 1980), what people look at is what they are processing. Eye-tracking could thus inform us about what part of the diagram is attended to, and in what order the diagram is read. Is the design only important in the first, pre-attentive stage, or does it guide learners through the whole learning-session? Perhaps a learner's prior knowledge of the content of a diagram is more powerful for studying it than its perceptual features. And if learners follow perceptual cues, does this influence what they remember from the diagram?

Although eye-tracking data gives direct information on how learners process a diagram, it does not give an answer to the question why learners processed the diagram the way they did. That is why in the current study we combined eye-tracking with asking participants why they processed the diagram the way they did.

In summary, we assessed (1) whether perceptual cues in a diagram indeed guide students' reading behavior, and (2) whether the way students read a diagram influences what they remember from its content.

Materials

Four versions of a diagram were created. Content of the diagram was the same, but the layout of the diagrams was different. The diagram showed the development of babies in the first four months in four developmental categories, i.e. physical, cognitive, emotional, and language development. Arrows and boxes made the orientation of the diagram to be either from left to right or from top to bottom, and the development categories were on the left while the months were on top, or the other way around (see Figure 1).

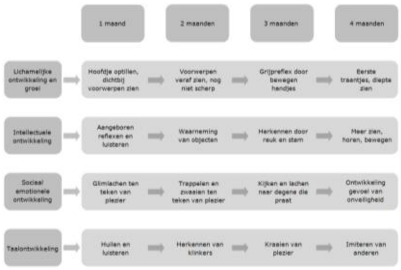

Figure 1. Example of one of the lay-outs; orientation on categories from left to right

Participants and measures

Eighty-two students from the University of Twente were randomly assigned to one of the diagrams and asked to study this diagram on a computer screen for five minutes. Their eye-movements were recorded. A post-test containing 12 questions was administered to test how much participants remembered from the content of the diagram. Five of the questions, 1 open answer and 4 multiple choice, required an orientation on months, and another 5 questions, 1 open answer and 4 multiple choice, required an orientation on developmental categories. Question 11 showed all four diagrams and asked the participants to indicate which one they had studied. Question 12 asked the participants to draw *how* they had studied this diagram. Finally, we asked them to explain *why* they had studied the diagram the way they indicated.

Results and discussion

We are currently in the process of analyzing results and will only report first results here. Final results will be presented at the meeting.

Most participants (78 out of 82) 'knew' which diagram they had used for learning; they indicated the correct diagram when all four diagrams were shown. Table 1 displays *how* participants followed the arrows in their diagram, based on their own account of how they (started to) read the diagram. A chi square test showed that the percentage participants that followed the arrows was over 30 percent points lower in the diagrams in which arrows followed months than in the diagrams in which arrows followed categories, $\chi^2(3) = 12.26$, $p < .05$. The preference for reading months from left to right (62%) instead of from top to bottom (35%) is not significant, $\chi^2(1) = 2.97$ $p = .09$.

Table 1. Number and percentage of participants who followed the perceptual cues per condition.

Followed perceptual cues?	**Yes**	**No**
	N **(%)**	***N*** **(%)**
Months from left to right	13 (61.9)	8 (38.1)
Categories from top to bottom	16 (80.0)	4 (20.0)
Categories from left to right	17 (81.0)	4 (19.0)
Months from top to bottom	7 (35.0)	13 (65.0)

A one-way ANOVA on the 10 questions did not show differences between participants that studied the different diagrams, $F(3, 81) = 1.18$, $p = .31$. Also, when split for questions that focus on months and questions that focus on categories no differences were found, $F(1,81) = 1.00$, $p = .37$ and $F < 1$ respectively. That is to say that the design of the diagram did not influence the performance on the post-test. When using participants' own account of how they studied the diagram, there were no differences between participants that stated studying the diagrams based on development categories ($N = 54$, $M = 7.36$, $SD = 2.82$) and participants studying the diagrams based on months ($N = 27$, $M = 7.27$, $SD = 3.31$), $F < 1$ (one participant indicated having used a random pattern). In addition, no differences were found between the groups for questions oriented on development categories, $F < 1$, and for questions oriented on months, $F < 1$.

Self-reports showed that for most participants the content and not the design of the diagram influenced the way they studied the diagram. An orientation on development categories was reported more often than an orientation based on months. Eye-tracking data will reveal if this was true. It could be the case that participants who indicated they had knowledge on the topic of child development diverged from the perceptual salience of the diagram to study the diagram in the way they thought 'most logical'. We have yet to analyze this based on the eye-tracking data.

As Winn (1993) pointed out, it would be very interesting to know to what extent perceptual processes can compensate for lack of prior knowledge of content. Our future studies will aim to answer this question.

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