The influence of perceptual cues on how learners study a diagram

Christina Seier

University of Twente, Enschede

Supervisor:

Dr. Jan van der Meij

Dr. Hans van der Meij

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Abstract: Diagrams are essential in education. Therefore it is useful to know how students perceive diagrams and learn from them. An important aspect in learning from diagrams is design, including perceptual cues, that may improve realizing relationships within the topic (Suthers, 2003), which leads to better recall and comprehension (Zinar, 1990). The objective of the current experiment was to investigate whether perceptual cues influence students study behavior and impact of their study behavior on recall. Participants studied one of two versions of a node-link diagram, only differing in the added perceptual cues: arrows pointing from left to right in one, and from top to bottom in the other condition. Participants received a recall-test and were interviewed on how they studied the diagram. The recall-test contained two sorts of questions: one half of the questions required orientation on the characteristics in the top header, thus top-down, the other half required orientation on the personality disorders which were in the left header, thus left-right. The general results revealed that with regard to study behavior students don't seem to be influenced by arrows, but have a tendency to study from left to right. Recall for information that was organized in the left-right order is better. Still, it remained unclear what this preference for left-right order is due to. It may be the organization of the material or someother variable, for example normal reading order. The self-reports showed that many participants chose their study behavior according to the content and not according to the perceptual cues.

Key terms: diagrams, perceptual cues, eye-tracking

INTRODUCTION

Diagrams are used in various situations of our daily life. While reading a newspaper or a magazine, doing homework, trying to set up your new shelf, finding a TV program or browsing the internet for the latest sports results – you find types of diagrams and charts everywhere.

The massive use of diagrams can also be seen in today's lectures at school or university. Flip through an average textbook in science or any other field of education you are interested in and you will come across many diagrams in many distinct forms. Therefore diagrams have been the subject of research much recently (van Amelsvoort, 2008) and in the preceding decades (Winn, 1982; Hahn, 1999).

Diagrams are graphics that are used to illustrate meaning while using less words than a text would require to explain the same (see, Larkin & Simon, 1987). This can come in handy in education because - due to the minimum of text - diagrams in most cases are fast to be comprehended which saves time for the learner. Moreover, relationships within the to-be-learned topic are visualized (Suthers, 2003) which facilitates learning from diagrams by helping to understand the topic as a whole. This leads to better comprehension and better recall (Zinar, 1990).

The multivariate use of diagrams may also be because they come along in a great variety of forms and characters (Moxley, 1983). For example, there are different graph-based diagrams such as tree diagrams and flowcharts or different chart-based diagrams like histograms and pie charts (Moore & McCabe, 2005).

One special kind of diagram is the matrix. Kauffmann & Kiewra (2009) found out that "a matrix display boosts facts and relationship learning more than a standard text, a signaled text, an extracted text, or an outline" (p.701). Thus, a matrix seems best to make learning as easy and effective as possible. Kauffmann & Kiewra refer to localization as a reason for this: they argue that a matrix "localizes related information better than other displays" (p.701).

In this study is examined if a matrix can be made even more effective by adding perceptual cues to it. Adding perceptual cues to a matrix makes it similar to a so-called node-link diagram. The only difference between a matrix and a node-link diagram is namely that in a node-link diagram relations between the boxes are indicated by perceptual cues like arrows or connecting lines (Keller, Eckert, & Clarkson, 2006).

The content in a node-link diagram is mostly mediated through text. Main ideas or concepts of the topic are written down in short, "catchy" statements and are localized according to a reasonable order (Kauffmann & Kiewra, 2009). Perceptual cues may serve as facilitation for reading and understanding the diagram and may also add extra information about the relations within the described concept.

In general, perceptual cues, sometimes referred to as secondary notation, are defined as all cues in the diagram besides text, for example arrows, colors or spatiality (Ware, 2004). In principle, perceptual cues can also be auditory or sensual, for example adding sounds to the study material. The purpose of perceptual cues is to facilitate processing, understanding, and learning the content. This can be realized by making relationships visible with the help of the cues.

Woodman, Vecera, and Luck (2003) found that if objects are grouped together with the help of perceptual cues, students tend to store these objects together what can be seen in their recall performance. They recall more objects of a specific group as ungrouped objects. The question is how grouping objects together must be done. In our node-link diagram the grouping will be by arrows that connect groups of nodes.

Arrows automatically guide our visual attention to the location they are pointing at (Hommel, Pratt, Colzato, & Godijn, 2001). In diagrams arrows may be used to indicate how to read the diagram and how the nodes of it may be connected, thus to provide the learner with hints about relations or probabilities within a topic (Howard & Matheson, 2005).

Heiser and Tversky (2006) did a study on comprehending and producing mechanical diagrams. They offered people diagrams on the function of different mechanical things, for example a bicycle pump with or without arrows and led people describe these diagrams. They found, that participants who studied a diagram with arrows significantly used more functional units in their description. This indicates that arrows guide the learners' attention when reading and interpreting a diagram. Heiser & Tversky explained the functions of arrows as follows:

> Arrows can express many relations, among them pointing or connecting, sequence, change over time, path, or manner of movement or forces, and more (e.g., Horn, 1998; Tversky et al., 2000). In the case of maps, arrows indicate the direction of the route, the sequence of actions required to reach the destination. In the case of diagrams of complex systems, arrows can be used to indicate temporal sequence, the order of the operation of the components to accomplish the overall goal of the system. (p.582-583)

This shows how important arrows are in a node-link diagram. It may be that students tend to study in a certain way if there are arrows indicating an order or a temporal sequence.

As described earlier an important feature of a node-link diagram is text. Text is read consciously and perceptual cues are perceived by our perceptual system almost effortlessly (Ware, 2004). But does “perceiving” the cues also mean “using” the cues for studying? Studies on this found that the design of a diagram may affect our study behavior (Davenport, Yaron, Klahr, & Koedinger, 2008). In addition, Winn (1993) found that besides perceptual cues, prior knowledge of the topic may influence the study behavior by guiding the learner through the diagram in another way as the perceptual cues prescribe. Another example of what may influence the study behavior is the normal reading order. In all Western societies the reading order for written texts is from left to right. This could cause learners to have a preference for studying a diagram in this way, too.

We made use of a node-link diagram with information on the topic of personality disorders. The diagram has a top header, presenting four different kinds of personality disorder-characteristics (self-concept, emotion, behavior, and attitude), a left header with four different personality disorders (antisocial, dependent, schizoid, and narcissistic) and the body, containing 16 information pieces. We made two versions of the diagram. These were the same in content but differed in the perceptual cues. The first version contained arrows pointing from left to right, the second version contained arrows pointing from top to bottom. See figure 1a and 1b for the two versions of the diagram.

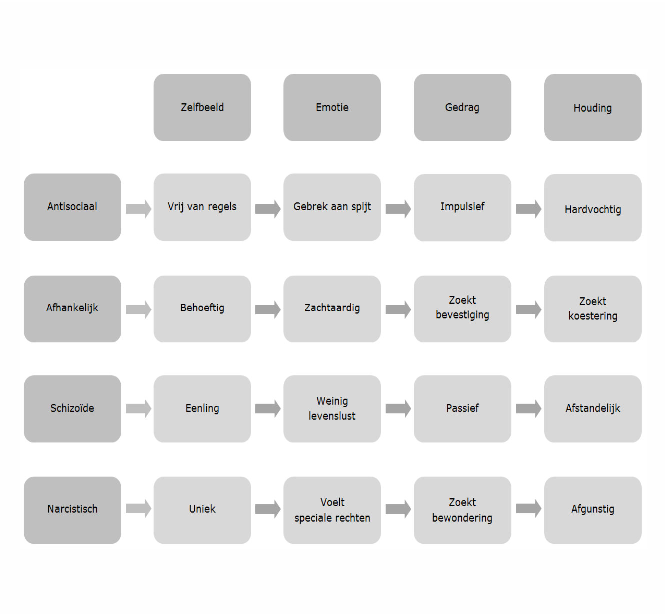

figure 1a: The diagram as used in the left-right condition.

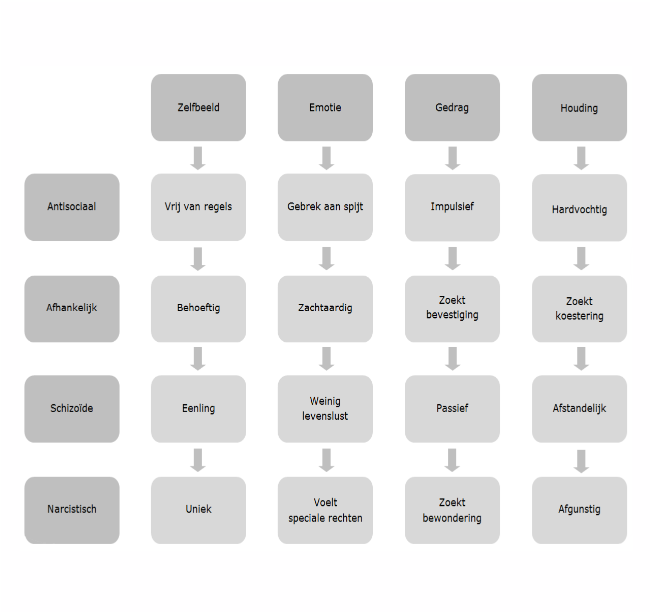

figure 1b: The diagram as used in the top-down condition.

Due to this design it was possible for students to choose between studying the content from left to right and studying from top to bottom. Arrows were added to guide the students' study behavior in one of the two described directions. We made the assumption that the arrows guide the reading and study behavior of the students with regard to direction of reading and studying the diagram, because arrows are commonly assumed to signal movement and direction (see, Heiser & Tversky, 2006).

This led to our research questions. First: Do perceptual cues (in this case: arrows) in a diagram influence how students study the diagram? Thus, we needed to know if the reading process was different in one of the two conditions. We assumed that perceptual cues, like arrows, will influence the reading order because the literature suggests they are influential on how students study a diagram. As a site effect we assumed that students will read the headers first. The headers were colored in a deeper shade of grey than the body of the diagram. Surber & Schroeder (2006) let students read short texts with or without headings. They found that recall was significantly better when students read the headings first. This was especially true for students with prior domain knowledge. We assumed that students are used to this and therefore will read the headers in our diagram before they concentrate on the body. Second: Does reading order influence recall? We presumed that participants who read the diagram from the left to the right, will be better on questions concerning personality disorders (arranged from left to right within the diagram) and participants reading the diagram from top to bottom will reach better results on questions concerning specific characteristics of the personality disorders (arranged from top to bottom within the diagram). To test our hypothesis on this question we compared the study performance of the students in the two conditions.

To answer these questions, we needed a method to measure what the students look at while studying and to extract a sequence in their looking- and therefore studying-behavior. A good possibility to control for participants eye-movements and fixations while studying is an eye-tracker (Grant, 2003; Salvucci & Goldberg, 2000). This instrument consists of one or two cameras that are adjusted according to the position of the participant's eyes and then record where the participant looks. What is measured are the fixations during eye-movement. A fixation is the time the eye looks at one point relatively stable. The other kind of eye-movement is called saccade and describes the time when the eye moves rapidly over a text without reading and fixating anything. It is assumed that learners process a text when they fixate it with their eyes (Just & Carpenter, 1980). Thus, eye-tracking makes it possible for us to get to know learners' behavior while studying material. It does not get us to know why they study it in the certain way. As we wanted to know if readers are influenced by the offered arrows or something else, (e.g. normal reading order as an argument to study each diagram from left to right despite any perceptual cues) we added the interview part and asked the participants why they studied in the way they did.

METHOD

Participants

The participants were 42 first- or second-year students of the University of Twente, Enschede in the Netherlands, with ages ranging from 18 to 26 with a mean age of 20.84 years. 10 of the participants were male and 28 were female. The students received course credits or money for their participation.

The eye-tracking data of four participants were not analyzable due to technical error and therefore excluded from the dataset. This left 38 participants. The participants were randomly assigned to one of two conditions. 19 participants were in the left-right condition and 19 were in the top-down condition.

We asked the participants to indicate on a scale up to ten points, what they thought their prior knowledge of personality disorders was. They indicated an average of 3.65 points with a standard deviation of 1.86 points.

Design

We used a between-subjects design. The independent variable was orientation of arrows and the two dependent variables were reading process and study performance.

Diagrams

The diagram to study was a 4x4 node-link diagram on the topic of personality disorders, containing two nominal scales. One scale, called the top header, contained characteristics of personality disorders: self-concept, emotion, behavior, and attitude. The other scale, called the left header, contained the names of the personality disorders: antisocial, dependent, schizoid, and narcissistic.

See figure 1a and figure 1b (p.6) for the two versions of the diagram.

The diagrams were presented on a 17” computer-screen.

Eye-tracker

To record the eye movements of the participants we used an eye-tracker. It scans the position of the eyes with a frequency of 60 samples per second.

The computer programs used in connection with the eye-tracker were Facelab 4.5 for adjusting the cameras and Gazetracker 7 for storage and analysis of the eye-movements and gazes. The cameras were Plea-cameras.

The diagram consisted of 24 cells, each containing one piece of information. For analysis of the eye-tracking data, look zones were defined. Each cell formed a look zone, which were numbered as shown in figure 2.

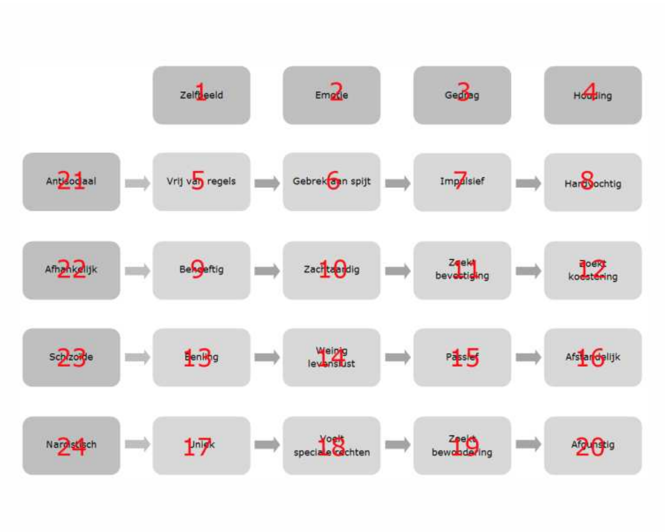

figure 2: The diagram with the defined and numbered look zones.

We took looking within a 30 pixel diameter for a duration of minimal 100 ms as a fixation.

Cumulative fixation duration (all fixations in a look zone added) and average fixation duration was calculated for each look zone.

One of the research questions was if participants were influenced by the arrows in studying the diagram. This would be true if we could find certain sequences in reading order. To answer this question we made use of a model created by van Amelsvoort et al. (in preparation) to analyze if participants studied the diagram in a certain way, thus read the diagram in sequences that relate to a certain study behavior, for example studying from left to right or from top to bottom. The model is called EMS-model (Eye Movement Sequence-model). The EMS-model tries to find a sequence based on the look zones in the diagram body from left to right (e.g., 5, 6, 7) and top-down (e.g., 5, 9, 13). As long as the time spent in look zones belonging to the sequence are larger than the time spent in look zones not fitting the sequence, the sequence is intact. When the time spent in look zones not fitting the sequence becomes too long, the sequence is terminated and the EMS-model looks for a new sequence. For the analysis of eye movement patterns in the current study, minimally three subsequent row or column look zones had to be present to count as a sequence. In the EMS-model we had to take into account that participants sometimes temporarily deviate from a strict order. For example, when studying the body cells, they temporarily look at the headers to integrate the information (see Peebles and Cheng, 2001). The sequence < 5, 6, 7, 8 > counts as a strict left-to-right sequence in the same row. However, should the sequence < 5, 6, 2, 7 > (where 2 is a header cell) also count as a left-to-right sequence? We argue that this depends on the duration participants fixate in the look zones, and we included fixation time in a look zone as a variable in our eye movement sequence extraction model.

The algorithm basically has to decide whether, given a current sequence, the next look zone fixation is added to this sequence or not. We denote the score of the current sequence after i fixations as S_i and the duration of the ith look zone fixation in the current sequence as d_i. The empty sequence has $S_0 = 0.0$. There are now two cases:

1. The next fixation is compatible with the current sequence (e.g., current is < 5, 6 > and next is < 7 >). In this case the score is updated with: $S_{i+1} = \max(S_i, d_{i+1})$.
2. The next fixation deviates from the current sequence (e.g., current is < 5, 6 > and next is 2. In this case the score is updated with: $S_{i+1} = S_i - C * d_{i+1}$. Here C is a constant. If S_{i+1} becomes negative the sequence terminates.

The algorithm is illustrated using the following example.

I	1	2	3	4	5
look zone	5	6	2	7	3
duration (d_i)	0.4	0.5	0.1	0.5	0.3
score (S_i)	0.4	0.5	0.3	0.5	-0.1

0. Each empty sequence has $S_0 = 0.0$.
1. Look zone 5 is a body cell, so it can start a sequence < 5 >, $S_1 = \max(S_0, d_1) = 0.4$.
2. Adding 6 results in < 5, 6 >. A sequence is initiated when two subsequent look zone fixations are adjacent left-to-right (in the same row) or top-to-bottom (in the same column). < 5, 6 > fits these criteria. The score is updated to $S_2 = \max(S_1, d_2) = 0.5$.
3. Look zone 2 is not in the left-to-right row of the current sequence. If C equals 2.0 then the score is updated as follows $S_3 = S_2 - (C * d_3) = 0.3$.
4. Look zone 7 is in the correct left-to-right row: $S_4 = \max(S_3, d_4) = 0.5$.
5. Look zone 3 is not in the row: $S_5 = S_4 - (C * d_5) = -0.1$. The score is now negative and we reject adding 3. The complete sequence is then < 5, 6, 2, 7 >.

The constant C is a factor which determines how quickly a sequence is broken if a fixation is not in the correct row or column. For C equals 2.0 it means that the fixation duration outside the sequence can be at most half (1/C) of the longest fixation duration inside the sequence.

Tests

Demographic questionnaire

Prior to studying the diagrams, participants were presented with a paper-and-pencil demographic questionnaire, which contained some general questions about personal background, such as age and gender, and about previous knowledge on the topic of personality disorders.

Participants indicated how much prior knowledge on the topic of personality disorders they thought to have on a scale ranging from 1 to 10. We analyzed if there was a difference in post-test performance between participants who indicated to have much prior knowledge (>5) and participants who indicated to have less prior knowledge (<5). 11 participants indicated to have much prior knowledge (>5), while 28 participants indicated to have low prior knowledge (<5). The post-test scores revealed no difference between the two groups. Therefore we decide to apply the following analyses to the whole group of participants.

Post-test

Right after the study time had passed, participants received a paper-and-pencil posttest, which was a recall test that did not ask for any comprehension of the topic. Besides measuring how much participants could recall, we made an attempt to measure if they had followed the arrows while studying by designing the post-test in the following way: the test consisted of 12 questions, containing open-answer questions like “Describe in note form the characteristics of a dependent personality” and multiple-choice closed questions like “Into which category of characteristics falls ‘feeling to have special rights’?” with the answer possibilities “self-perception”, “emotions”, “behavior” and “attitude”. One open answer and four multiple choice questions required the participant to orientate on the characteristics in the top header, another open question and another four closed multiple choice questions required orientation on the personality disorders in the left header.

The two open-answer questions were scored in the following way: for each correct answer in the correct place, participants received 1 point. For each correct answer in the wrong place they received 0,5 point, similarly they received 0,5 point for an incomplete answer in the right place and for an incomplete answer in the wrong place 0,25 point. Thus, in total participants could reach a maximum of 4 points for each open-answer question. The multiple-choice questions were scored with 1 point for each correct answer. In total up to 16 points could be achieved. The sum of the points achieved in open-answer and multiple-choice questions was calculated, the so called overall score. We further calculated the scores for all questions and all personality-related questions and all characteristic-related questions separately. By comparing the personality-related score with the characteristic-related score in relation to the condition participants were in, we were able to find out if the condition had influence on the study outcomes, for example if a participant in the left-right condition attained better score on personality-related questions than on characteristic-related question. This is what we would expect according to our hypotheses.

In question 11 the participants were shown both versions of the diagram and were asked to mark the one they had studied. Finally, to answer question 12 the participants had to draw how they studied the diagram.

There was no time limit for completing the posttest.

Interview

After completing the post-test, participants were asked the following question: “Can you explain how you studied the diagram and why you did it this way?”. Their answers were recorded, transcribed and analyzed for indications of reasons why participants chose to study the diagram in a certain way.

Procedure

After receiving a short instruction and information about the study, signing informed consent and answering the questions of the demographic questionnaire, the participants took place behind the eye-tracker, which was calibrated before the intervention started with a total time of six minutes including a study time of 5 minutes. First, participants had to look at 9 calibration dots, each appearing for 3 seconds. Than they were instructed to study the diagram that appeared for 5 minutes and afterwards the participants had to look at 9 calibration dots, that appeared for 3 seconds each, again. When the study time had passed, the participants received the paper-and-pencil recall test. After filling in the test, the short interview was conducted. Afterwards, participants received a debriefing and were offered the possibility to ask questions about the study if they were interested.

RESULTS

We began the analyses by exploring the data in a global way to obtain a general survey of the data found.

On average, 93.78% of all eye movements were tracked. 97.14% of all fixations fell into one of the look zones. The average fixation time was 249 milliseconds. For these general results, ANOVA's showed no difference between conditions. This indicates that the eye-tracker worked well and conclusions can be drawn reliably from the different conditions.

To control for possible differences in how long participants looked at the different sorts of cells, we compared the overall fixation time per cell in the body, $M = 7.26$, $SD = 1.48$, with the overall fixation time per cell in the headers, $M = 7.51$, $SD = 2.76$, by running a paired-samples t-test on the data and found no difference, $t(37) = 0.412$, $p = 0.683$.

We calculated the sequences in our participants' looking behavior with our EMS-model. To get an impression of where participants started studying the diagram, we analyzed their first sequence of fixations. We received the following results: 26 participants first looked at the header cells before they looked at the body of the diagram. This preference for the header cells was more outstanding in the left-right condition (15 participants had their first sequence in one of the headers, only four in the body) than in the top-down condition (11 participants looked in the header first, eight looked in the body). The favored header to look first was the left header, showing the names of the personality disorders. In total 19 of the 38 participants looked at the left header first.

The question which diagram they had studied was answered correctly by 33 out of the 38 participants when they were shown both diagrams idem. 18 participants reported they had read the headers first before they had started reading the body of the diagram.

1. Do perceptual cues (in this case: arrows) in a diagram influence how students study the diagram?

Time in sequence

	Condition			
	left-right		top-down	
Sequence	*M*	*SD*	*M*	*SD*
left-right	37.41	26.60	30.41	19.90
top-down	10.06	10.09	19.57	19.61

table 1: Means and standard deviations of time in sequence in the body.

Table 1 shows the means and standard deviations of time in sequence per condition in seconds to provide an overview of the data.

The time in sequence was calculated with our EMS-model. We did ANOVAs to get to know if the perceptual cues influenced how the participants studied the diagram. If they did, time in sequence had to be statistically significant longer in the direction according to the direction of the arrows. We found no main effect for condition when running an ANOVA on mean time in left-to-right body sequence, $F (1, 37) = 0.846, p = 0.364$. The average time in sequences from left to right was not significantly longer when the arrows pointed from left to right than when they pointed from top to bottom. Likewise, we did an ANOVA on mean time in top-down body sequence and found that the average time in sequences from to bottom was not influenced by the condition, either, $F (1, 37) = 3.54, p = 0.068$. The average time in sequences from top-to-bottom was not significantly longer when the arrows pointed from top to bottom than when they pointed from left to right.

Asked for their reasons to study the diagram the way they did, seven participants mentioned the arrows. Five of them were in the left-right condition and two in the top-down condition. In total, five participants mentioned they did not realize the arrows at all until they were asked to indicate which diagram they had studied. Six participants could not describe why they studied the diagram in a specific way, they said, they “don’t know”. Furthermore, most of the participants (N = 24) specifically reported first following one order, then following another (i.e. "first I studied the columns, then I studied the rows" or "first I looked at the diagram in a messy way, then I chose to study it per row").

Initial sequence pattern

It may be that participants were initially influenced by the perceptual cues and only later chose to study another way, when they were more used to the composition of the diagram and its topic. Therefore, to check if participants initially followed the arrows, we analyzed what was the direction of the first sequence participants followed in the body. In the left-right condition, 84.2% of all participants' first reading sequence was from left to right. In the top-down condition, 42.11% of all participants' first reading sequence was also top-down. For one participant the EMS-model couldn't find any sequences at all.

In the interview we asked the participants which sequence they think they followed initially. In the left-right condition 13 participants reported that they looked at the diagram from left to right initially. This is 68.42 % of all participants in this condition. In the top-down condition eight participants (42.11%) reported that they looked at the diagram in a top-down sequence initially. Seven of them later switched to a left-right sequence and some mentioned in the self-reports that this was the way they studied most of the time. 10 participants (52.6%) in this condition started reading from left to right initially. Only three of them later switched to reading from top to bottom. The main reason for switching the reading order in the top-down condition was that participants found it hard to study the diagram from top to bottom.

2. Does reading order influence recall?

Overall, participants answered more than half of the post-test questions correctly, with a mean of 9,14 (SD = 3,01) out of 16 points.

A paired-samples t-test showed that overall, participants more often gave right answers on the personality-related questions, $M = 4.87$, $SD = 1.58$, than on the questions focused on the characteristics, $M = 4.27$, $SD = 1.82$, $t(37) = 2.38$, $p = 0,022$.

To see if this difference may be due to differences between the two conditions we did one-way ANOVA's. These showed no differences between the conditions on questions that are personality-related, $F(1, 37) = 0.013$, $p = 0.91$, and questions that are characteristics-related, $F(1, 37) = 0.463$, $p = 0.501$. There is no difference between the two conditions.

DISCUSSION

Our study explored if learners were influenced by perceptual cues when studying a diagram. We used a node-link diagram on the topic of personality disorders with arrows as perceptual cues.

The eye-tracking data and the self-reports revealed that nearly all participants read the headers first. This attitude is consistent with the findings of Surber & Schroeder (2006), who did research on the effect of headings in texts and diagrams. They found that "in general, headings seem to improve recall of high importance information" (p. 2).

Our first research question was if arrows could influence how students studied the diagram. From our eye-tracking data we can conclude that the perceptual cues did not influence the students. Our results showed no effects for the orientation of arrows on mean time in sequence. This means, that the participants did not look longer in sequences that accord to the direction of arrows in either condition. The self-reports showed that some learners did not even notice the arrows or, if they did notice them, found them confusing.

All in all, it seemed from the self-reports and eye-tracking data that participants preferred studying from left to right. We found that participants looked longer in sequences from left to right than in sequences from top to bottom, independent of the condition they were in. The question that remains is if they did this because they chose to learn according to the personality disorders. Another possibility is that the participants did so because left to right is their normal reading order. A follow-up study will be devoted to this hypothesis. The content of the headers will change places, thus the top header will contain the personality disorders and the left header will contain the characteristics. If there is a preference for studying according to the personality disorders, study behavior then should change to learning from top to bottom.

At least in the initial phase of reading arrows seemed to play a role. Most participants started reading in the direction of the arrows. Still, it is important to notice that the number of participants who followed the arrows initially, is much smaller in the top-down condition. This points to the idea that normal reading order may influence how learners approach a diagram.

The self-reported initial sequences corresponded very well with the observed initial sequences. This indicates that learners were aware of how they looked at a diagram and studied its content.

Many participants reported that they changed their study behavior during the experiment. This may refer to the aspect that there was not a better study order. The content of the diagram can be learned in both ways equally well. It would be unwise to only make use of one of them. Therefore, we suggest that learners chose the one that seems to be easier or more logical to them and later often used the other way to control if they got it all in their head. This was also explicitly reported by some of the participants in the self-reports.

Our second research question was if reading order of the diagram influences the recall of its content. This question was assessed by the posttest. All participants performed equally well on the posttest, regardless of the direction of perceptual cues in the diagram they studied. It seems that the arrows did not influence what was recalled.

On average, participants performed better on personality disorder-related questions than on characteristic-related questions. This may be due to the effect that most participants studied the diagram in a personality disorder-related way, showing a relationship between organization and recall of the learned material.

Our results led us to the conclusion that learners actively comprehend the content of a to-be-learned diagram. Then they make a choice how to study it. This choice seems to be more influenced by the content of the diagram (especially the headers) than by perceptual cues.

From this study we can conclude that perceptual cues do not automatically influence the study behavior. We must take into account what the learner thinks is useful.

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