

# The Image of Images as an Aid to Improve Learning

## An Eye-tracking Experiment Studying the Effect of Contrasts in Computer-based Learning Material

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Abstract: This study addresses differences in the design of computer-based learning materials—text with or without pictures—and the aim is to show in what way these differences affect learning outcomes. In total, 46 young adults participated: 19 with dyslexia and 27 controls. Approximately half of each group received the condition *text only*, and half received the text and an integrated picture. The learning material was presented on computer screens, and the participants' viewing patterns were registered by eye-tracking. The respondents answered text-based and picture-based questions, as well as oral questions, during the experiment. The assumptions about learning are based on variation theory and on the importance of contrasts in discerning important aspects of the learning material. The results show that whether material of the same content (surrealism) is presented in text only (without explicit contrasts embedded in the text) or in text and picture form (which offers a contrast) affects learning outcomes, particularly for the participants with dyslexia, who showed a fourfold increase from pre-test to post-test (from .10 to .40).

## 1 INTRODUCTION

There is an assumption that pictures in learning material support learning, and pictures are frequently used in computer-based learning material. But what happens when learners meet both text and pictures at the same time, as in information graphics? Holsanova et al. (2009) have shown that *how* pictures are integrated with a text is vital for an average reader. When text and pictures are closely integrated, it seems that more of the text is read. Holsanova et al. (2009) measured the number of integrative saccades—that is, “transitions between semantically related pieces of verbal and pictorial information” (Holsanova et al., 2009, p.8)—and thereby found that the quantity of integrative saccades was reduced when the text was separated from the pictures. Furthermore, when pictures and text are serially arranged (as in a classic comic strip) instead of radially arranged (with a large picture in the middle and small pictures and text like satellites arranged around it), the reader tends to read more and for a longer time, and integrative saccades were

almost twice as common. One possible explanation for the longer reading time spent on the serially arranged pictures and text was, according to Holsanova et al. (2009), that the pictures and the text were arranged in the direction in which people in Western society read, from left to right. Another is that the text was arranged in a helpful way: it started with general knowledge and built on it with more and more facts. It seems obvious that the way the pictures are exposed, as well as what kind of pictures they are and what they contain, is of importance in terms of where viewers look and for how long. But in what way this contributes to a deeper understanding of the written text has not yet been clarified.

The results presented in this paper originate from a study investigating the way computer-based learning materials with and without pictures affect learning. This was tested in two different groups of subjects, namely, young adults with and without dyslexia. Based on the findings in the main study, further analysis was conducted to describe in what way *contrasts* in the learning material seem to influence the learning outcome more than the

presence or absence of *pictures* in the computer-based learning material does. The aim of the paper is to study how contrasts either within text only or between text and picture affect young adults' abilities to discern and learn from computer-based learning material presented in an experiment about art genres. The study is based on variation theory, and a multi-method approach (Yin, 2006) has been used to measure both the participants' viewing by using eye-tracking and their expressed knowledge by using multiple-choice questions and oral questions during the experiment.

## 2 THEORETICAL FRAMEWORK

In this paper we take the learning theory approach of variation theory (Holmqvist, Gustavsson and Wernberg, 2008; Holmqvist, 2011; Marton and Booth, 1997; Pang and Ling, 2010; Runesson, 1999) to study which factors are necessary for learning under the two different conditions *text only* versus *text plus picture* in two different groups of participants, young adults with and without dyslexia.

Variation theory supports dual coding theory (DCT; Clark and Paivio, 1991) by assuming that processing printed words and images requires the simultaneous discernment of a part-whole relationship in the object of learning (Svensson, 1976; Gibson and Pick, 2000; Gärdenfors and Johansson, 2005). It also assumes that variety should be designed so as not to overload learners' memory systems (Holmqvist, 2004). Information via the two senses of hearing and seeing does not overload the system as it activates two different working memories (sounds and images), while dual information delivered to one sensory memory can cause an overload (Mayer 2005; 2009). Informed by these studies, our main study (Holmqvist Olander, Nyström, Wennås Brante, manuscript) used only printed words and images—that is, only visual memory—to examine the effect of the part-whole relationship on learning through printed words and images.

### 2.1 Variation Theory

Variation theory holds that learning takes place through contrast (to make it possible for the learner to separate an aspect from the object), generalization, and fusion. For example, in art genres, which we used in this study, one feature of surrealism is that the paintings are not depictions of reality. Contrasting a surrealistic painting with a pop

art painting achieves a contrast regarding the specific aspect of whether the work is reality-based. Through the contrast, it becomes possible to separate this feature from the painting as such. This aspect can be generalized to other art genres, such as impressionism, and it becomes possible for the learner to decide that *Sunrise* by Claude Monet does not belong to the genre of surrealism because the painting does depict reality, even if the expression of it is a bit hazy. Such contrasts can be offered to the learner in various ways; in our case, we chose to present the contrasts either in text or in a combination of pictures and text so as to study whether and how the different types of material facilitate or complicate learning.

### 2.2 Variation Theory and Reading

To read is to combine signs with sounds, putting sounds together into meaningful words and interpreting them in the context in which they are found. Drawing on variation theory about how knowledge is attained (Marton and Tsui, 2004), a person who is reading needs to simultaneously experience both the parts—that is, the phonemes represented by one or more letters—and the wholeness—that is, the words in that particular text as well as the entire text itself. One example (Wennås Brante, 2010) involves the difficulties involved in differentiating *b* from *d*. If a child sees a dog, it does not matter whether the dog turns around; it remains the same dog. But the signs *c* and *l* are the parts that make up wholes as they can be used both independently and in any combination. The combinations can be *b*, *d*, *p* and *q*. The critical feature is to know the importance of the parts' directions in the combination so as to understand that the letters differ and not are the same when seen from another perspective. To make the distinction, learners must discern the parts simultaneously with their directions. If they learn only about *b*, there is a risk that a *d* or *p* will be interpreted as a *b* the first times the learners see the new letters. If they learn about *b*, *d*, *p*, and *q* at the same time, the variation needed to discern the importance of the parts' directions will be offered. Based on this example, it is easy to understand the complexity of the critical features that reading comprehension includes. Through the use of interviews and eye-tracking it is possible to ask participants what they have actually been aware of and can express about the text, at the same time as we study what they *could* have been aware of by following their eye gazes. This differs from what they have been *presented*, as we do not

know which parts of the text they seem to neglect and which parts they seem to focus on.

### 2.3 Picture Viewing

Perceived objects are affected by visual factors as contrasting or semantic factors (Henderson, 2003; Nyström and Holmqvist, 2008). This means that people use their knowledge about the world to gaze intelligently through a real-world scene (Henderson, 2003). They seem to do the same thing when looking at a picture. Yarbus (1967) showed in a famous eye-tracking study that a task influences the visual pattern. When the task was to find out relationships between people in a picture, one kind of a scan-path emerged which differed from the scan-path emerging when the task was to find out whether, for example, the people in the same picture have eaten dinner. Viewers tend to know what they are looking for and steer their fixations in that direction, according to Yarbus (1967).

Brockmole and Boot (2009) have reported that task-irrelevant aspects of visual stimuli also influence the fixation durations. This complicates the use of pictures as comprehension aids because it is hard to ensure that every picture tied to a text has only task-relevant aspects. If it does not and if the reader encounters problems comprehending the parts simultaneously with the whole in a single gaze, the pictures become just one more part to be distracted by. Furthermore, a study by Nummenmaa et al. (2006) shows that people seem to allocate attention to emotional pictures rather than to neutral ones. Even when instructed to attend to neutral pictures, fixations on the emotional ones form. This means, according to Nummenmaa et al. (2006), that orientation towards emotional stimuli is highly exogenous. One cannot, in other words, completely steer one's attention to the pictures that are perhaps most relevant or that contain the most information; one is drawn to emotional pictures. Text and picture integration can thereby be efficient or misleading, depending on which pictures are presented.

A study (Hannus and Hyönä, 1999) of 10-year-old children showed that high-ability children paid more attention to pictures in a text and could make better use of them than low-ability children did and could. Comprehension scores were also higher for high-ability children when they encountered a text with illustrations, but comprehension scores for low-ability children did not improve under the same conditions (Hannus and Hyönä, 1999).

Holsanova et al. (2009) showed that *how* pictures are integrated with a text in information graphics is

vital for an average reader. The way pictures are designed and offered, as well as what they contain, is important in terms of where a viewer looks and for how long. However, this does not tell anything about the viewer's awareness. How the viewing pattern contributes (or does not) to a deeper understanding of the written text has not yet been clarified.

A person reading a text processes it visually, phonologically, and semantically at the same time. When reading a text integrated with pictures, the person attends to the pictures, as well. What does this mean for dyslexic readers' reading comprehension?

## 3 PREVIOUS FINDINGS

The results of the main study show that there are significant differences between the two groups of participants and interesting differences between the two different conditions. The results show significant differences in both comprehension scores and visual behaviours between respondents with and without dyslexia in the two different conditions (text only or text plus picture). Respondents with dyslexia did not use strategies to gain a global overview of the information, something that the participants without dyslexia did more quickly. This trend supports the hypothesis that the participants with highest learning outcomes used global-overview strategies. Participants with dyslexia showed haphazard viewing patterns, strengthening the assumption that a global overview as a strategy promotes learning (Holmqvist Olander, Nyström & Wennås Brante, manuscript). The condition *text and picture* decreased learning for respondents with dyslexia, with one exception: the example of surrealism, which this paper examines further.

### 3.1 Dyslexia and Phonological Awareness

One pre-requisite to reading is discerning a given sound among the continuous flow of sounds people produce when they speak (Shaywitz, Morris and Shaywitz, 2008) and then mapping the sound to a letter (Byrne, 2005). This phonological awareness is one part of the phonological ability needed to read; thus, a weak phonological ability is considered one explanatory factor in dyslexia (Goswami and Bryant, 1990; Ramus et al., 2003; Vellutino et al., 2004; Everatt and Reid, 2009). In the main study, participants were tested for phonological ability

using a screening test called Duvan (Lundberg and Wolff, 2003). The test is executed in groups and tests for different sub-skills in phonological ability. The results from the main study (Holmqvist Olander, Nyström, Wennås Brante, manuscript) show a significant difference between the groups, supporting the assumption that participants with dyslexia have a lower phonological ability than the rest of the participants do.

### 3.2 Viewing Patterns

In the experiment, pictures were inspected for less time than texts were, yet a difference between groups was found. The control group performed an earlier inspection of the picture, thus rendering a global impression of the material (Holmqvist Olander, Nyström, Wennås Brante, manuscript). Viewing analysed only in the condition of text + picture and the picture was viewed by 95.2% of the controls and 78.3% of those from the participants with dyslexia. The participants spent 45.9 seconds ( $SD = 2.1$ ) looking at the text and 2.2 seconds ( $SD = 2.3$ ) viewing the picture. They were looking elsewhere for 0.8 seconds ( $SD = 1.0$ ). When interviewed about viewing patterns, some respondents with dyslexia had an understanding of the way they processed material containing both text and pictures that was found inconsistent with how they really placed their gazes (Wennås Brante, 2013). They processed the material in a much more random way than they thought they did, thus missing opportunities to gain a global understanding of the material.

### 3.3 Contrasts

The texts from the experiment in the main study contained a contrast formulated in words. The contrast could be explicit (that is, the two values were specified and mentioned) or implicit (that is, one value not was specified). The parts of the texts containing a contrast were the ones most discerned (Wennås Brante, Holmqvist Olander and Nyström, 2013), even when the contrasts were of less importance for learning about the content. If a contrast was implicit—that is, if a counter-value was not specified—it was hard for the dyslexic group to discern it (Wennås Brante, Holmqvist Olander & Nyström, 2013). The micro-analysis of the oral answers revealed also that contrasts are exceedingly effective for discernment (Wennås Brante, Holmqvist Olander and Nyström, 2013).

The experiment also employed different kinds of

pictures that could influence the viewing behaviour. Three pictures differing in motif and color were chosen to test how the viewing behavior differed: a cubistic picture that had a motif that was difficult to see in brown nuances, a romantic picture with a clear motif painted in natural colors, and finally a surrealistic picture with an odd motif and clear colors. No great difference was found in viewing patterns of the cubistic and romantic picture, but participants without dyslexia had significantly higher dwell times on the three pictures ( $p = 0.034$ ), a result that originated from dwell time on the surrealistic picture (Wennås Brante, manuscript). However, most participants with dyslexia inspected the surrealistic picture before they started reading the text, and this had an impact on their reading comprehension: the oral answers from the group with dyslexia contained more inferences regarding the surrealistic image than the same group's answers about the other art genres did (Wennås Brante, manuscript).

## 4 IMPLEMENTATION

The analysis is based on data collected during the main project (Holmqvist Olander, Nyström and Wennås Brante, manuscript; Wennås Brante, Holmqvist Olander and Nyström, 2013, Wennås Brante, 2013; Wennås Brante, manuscript). So far no analysis or results have been presented on the task level regarding the outcomes of the questions in the experiment.

### 4.1 Participants and Design

In total, 46 respondents were recruited via an advertisement on two universities' websites and in a residential college for adult education through a teacher, requesting young adult native speakers of Swedish with and without dyslexia and with normal or corrected-to-normal vision. In total, 19 dyslexic and 27 non-dyslexic (control) respondents were recruited. Their ages ranged from 19 to 41, with a mean age of 23.8 years ( $SD = 4.2$ ).

The reading tasks consisted of six different short expository texts which demand somewhat different reading strategies than narrative texts do (Hyönä et al., 2002), such as understanding the topic and the hierarchically related sets of sub-topics and their relationships with one another. Because expository texts are frequently used in schools and education, it is of interest to determine whether pictures contribute to the comprehension of expository texts.

Respondents were presented first with the name of a genre, then with information from either of the two experimental conditions (*text only* or *text plus picture*). The computer-based learning material in the two conditions was identical, except from text only in one condition and text with pictures in the other condition. In total it consisted of six screens; 1. Title of art genre, 2. Text about the art genre (including picture in one condition and without in the other), 3. Blank screen (the researcher asks what information the respondent met on the previous screen – oral post-test), 4. Text question (verbal post-test), 5. Confidence rating and 6. Multiple-choice question illustrated by three paintings (picture post-test). When the respondents had studied the information at the second screen and were ready to answer questions about it, they clicked the mouse, and an empty screen appeared. While instructed to keep looking towards the screen area, respondents were by one researcher asked “What information about [genre] appeared on the last screen?” Their verbal answers were recorded through a webcam. When they had no more information to provide, they were asked to click the mouse and proceed to answer three multiple-choice questions with only one of the alternative answers. The first question offered a choice of five text responses to a question about the genre. In the second question, respondents were asked to estimate how confident they were about their previous answer on a scale of one (very uncertain) to seven (very certain). Finally, they answered the same questions again as they had during the initial test, with the positions of the three pictures randomly shuffled, in order to assess whether learning had taken place during the experiment (Holmqvist Olander, Nyström and Wennås Brante, manuscript).

The eye-tracker used in the main study was an SMI HiSpeed sampling data binocularly at 500 Hz. This speed is sufficient to measure saccades accurately. Stimuli were shown on a 19-inch screen connected to a PC which also collected each subject’s eye-tracking. To ensure that it would be possible to detect which work a person was looking at, text was presented with letters spanning approximately half a degree of visual angle. Rows had double line spacing.

## 5 RESULTS

The results of the main study show significant differences among the two groups of participants regarding both viewing patterns and learning

outcomes (Holmqvist Olander, Nyström, Wennås Brante, manuscript; Wennås Brante, Holmqvist Olander, Nyström, 2013; Wennås Brante, 2013, Wennås Brante, manuscript). However, analysing the computer based learning material at the task level shows one exception regarding an item in which both groups exhibited the same kind of strategy—namely, the task regarding surrealism. This finding was first measured by the eye-tracking equipment (Wennås Brante, manuscript). The results of the analysis indicate that all participants used the same kind of viewing pattern when viewing the painting of surrealism. The analysis of the participants’ answers on the text and picture questions supports this initial indication and demonstrates a correlation between the pattern of eye movements and learning outcome. The result contradicts previous findings as it highlights the impact of the design of the computer-based learning material regarding illustrations. Pictures or not is not a simple question that can be stated to improve or worsen the learning outcome. However, the text material about surrealism did not offer contrasts that are significantly pointed out, resulting in fewer discerned contrasts in the task on surrealism (20–64%) than in, for instance, the task on impressionism (65–77%). Further, this difference between the groups is significant (dyslexic 20–33%, controls 41–64%) for the surrealism task but not for the impressionism task (dyslexic 65–72%, controls 65–77%) (Wennås Brante, Holmqvist Olander, Nyström, 2013). This indicates that contrasts that are not clearly expressed are harder to discern for those with dyslexia than they are for the rest.

In the condition *text plus picture*, the surrealistic picture itself comprises a contrast with reality as experienced by the participants; moreover, the picture is viewed to a higher degree than the other pictures (Wennås Brante, manuscript). This is true also for the group of dyslexics, and they do not show any similarities with the controls’ viewing pattern regarding the other stimuli. The result shows that the same learning content presented by two different representations, text only or text and picture integrated, is perceived differently as a consequence of the discerned contrasts offered by the computer-based learning material. This is shown by the increased learning outcome regarding the condition *text plus picture*, as the participants’ discernment of the surrealistic painting contrasted with their own views of reality when they observed the aberrant painting. It is more difficult to draw such a strong contrast when present with the text-only stimulus about surrealism. The results of the pre- and

post-tests from the picture question appear in table 1.

The text in the learning material about surrealism describes objects in a way that differs from their ordinary use in reality (e.g., ‘Instead, a connection between, for example, a green hot dog and a gigantic comb wer necessary’). But not until participants see the paintings can they fully grasp how different the image is from what is possible in reality. If the results of the participants’ answers from the text-based questions and the picture-based questions about surrealism are broken out from the material previously presented, a new and different pattern emerges in the group of dyslexics regarding this specific genre in relation to the mean of the remaining five genres.

Table 1: Means of the results from picture-based question about surrealism in comparison to the means of the other five tasks in the two different groups of participants.

Mean points/question	Dyslexic Text only	Non-dyslexic Text only	Dyslexic Text plus picture	Non-dyslexic Text plus picture
Pre-test Surrealism	.44	.38	<b>.10</b>	.21
Post-test Surrealism	.78	.77	<b>.40</b>	.50
Pre-test Other genres	.24	.37	.26	.36
Post-test Other genres	.60	.66	.68	.63

Only three participants in the entire group failed to correctly answer the picture question related to surrealism. Of these three, one came from the group in which the participants did not see the picture (*text only*). The other two were in the group with the condition *text and picture*, but one of those had not fixated at all on the picture (the only respondent to demonstrate that behavior), and the other one had fixated on the picture only once.

The results in table 1 show that there is a learning outcome for the group of participants with dyslexia in the condition *text plus picture* regarding the task on surrealism that differs from the ordinary pattern—a fourfold increase—more than for any other genre or condition. In the condition *text only*, there is no difference in outcomes between the questions for surrealism and the questions on the other art genres; the participants scored roughly twice as high on the post-tests as on the pre-tests.

Regarding the text-based question about surrealism, the group of participants with dyslexia showed slightly higher scores (.80) for the task about surrealism than the mean scores for the other genres

(.68), but this is far from the fourfold increase apparent for the picture-based question (table 2). This supports the assumption about contrast’s impact on learning: there are implicit contrasts in the text, resulting in lower scores for the *text only* condition for both text- and picture-based questions. On the other hand, there was a high increase for the condition *text plus picture* regarding the picture-based question about surrealism.

Table 2: Means of the results from the text-based question about surrealism compared to the mean of the other five tasks in the two different groups of participants.

Mean points	Dyslexic Text only	Non-dyslexic Text only	Dyslexic Text plus picture	Non-dyslexic Text plus picture
Surrealism	.89	1.00	.80	1.00
Other genres	.89	.91	.68	.86

## 6 CONCLUSIONS

The main finding in this study is the importance of purposeful designing computer-based learning materials in relation to content and learner; in particular, it is expedient to offer contrasts embedded in text or pictures in order to make it possible for the viewer to grasp the meaning of the information. The results show that participants with dyslexia are particularly helped by explicit contrasts—for instance, demonstrating what something is by also showing what it is not—and their learning outcomes are also affected to a higher degree than those of individuals without dyslexia. Illustrations in computer-based learning material have to be meaningful and purposeful designed, and not be used as decorations, to influence learning. Findings about decreased learning, when using learning material with illustrations for students with dyslexia, point out the need of further research about how illustrations carefully can be used to improve instead of prevent learning. The results from the eye-tracking data validate the differences in viewing-pattern in between the groups of participants and reveals the strategies used when examining computer-based learning material.

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