The Effects of Visual Detail in Images on Metacomprehension Accuracy

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Preface

Before I started my journey in Tilburg three years ago I graduated from Hogeschool Rotterdam. I remember the moment I told my parents that I successfully completed the first year and was able to receive my *propedeuse*. It was essentially my ticket to the university and my parents, as proud as they were, insisted on that I immediately enrolled for a program at a university. However, at the time it felt like a big step and for some reason I did not feel ready. As I continued my education at Hogeschool Rotterdam I constantly felt like I missed out, but it fortunately got to a turning point when I did my internship at a marketing agency. My boss and intern supervisor had inspired and motivated me to enroll for the master program, and so I did. Now three years later I am proud to say that I successfully completed the master program while working at the same marketing agency where I got offered a contract of indefinite duration.

I would like to take this opportunity to thank all the people that helped and supported me through my journey here at Tilburg University. First of all, I want to thank my boss Stijn Mentrop and my then intern supervisor Tessa Cornelisz for giving me the courage and motivation to take the first steps. Secondly I would like to thank my thesis supervisor Dr. Jan Engelen for providing me with his feedback and guidance during my thesis that helped me stay focused. I would also like to thank my best friend Liana and fellow students Yukie and Ivona for simply being ‘there’ for me and supporting me through all the times I was stressed out. Lastly, and most importantly, I would like to thank my parents for always believing in me and supporting me unconditionally.

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Abstract

The purpose of the current study was to determine whether visual detail in representational images affects metacomprehension accuracy. It was expected that text supported with realistic images would lead to weaker learning performance due to the visual richness of this type of images in comparison to texts supported with schematic images and texts without images. In addition to this, this study expected the presence of an image might bias readers, resulting in higher JOLs (judgments of learning) in contrast to weaker learning performance. Due to the expected discrepancy between learning performance and overrated JOLs, this study assumed that participants in the realistic image condition would show weaker learning performance and higher JOLs in comparison to participants in the schematic image and no image condition. A total of 75 participants studied five expository texts with either realistic, schematic or no images. All participants were instructed to make JOLs followed by a test measuring their comprehension score. In contrast to previous research this study does not provide support for the view that images with a higher degree of visual detail negatively affect comprehension or metacomprehension accuracy. Implications for future research regarding JOLs and visual detail in images are discussed.

Keywords: visual detail, visual realism, metacomprehension, metacomprehension accuracy, judgment of learning, image types

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From primary schools to universities, the use of images to support learning from text materials is currently more rule than exception (Gangwer, 2009). For instance, when opening a textbook on any given page it will most likely include some type of image. The increase in the amount of images used for educational purposes has motivated researchers to study the effects of various image types on comprehension and metacomprehension. Many researchers have succeeded in proving that text materials supported with images benefit both comprehension (Carney & Levin, 2002; Eitel, Scheiter, & Schüler, 2013; Maki & Berry, 1984; Pike, Barnes, & Baron, 2010) and metacomprehension (Jaeger & Wiley, 2014; Serra & Dunlosky, 2010; Vössing, Stamov-Rossnagel, & Heinitz, 2016).

In particular representational images (i.e. images that partially or completely reflect the content of the text) have been proven to positively influence the learning process compared to decorative images and text without images. However, much less is known about how particular types of representational images affect (meta)comprehension. For example, a recent investigated what forms of visual discourse are present in biology textbooks on middle, high and undergraduate school levels (Wiley, Sarmento, Griffin, & Hinze, 2016). The researchers found that middle school textbooks used more realistic and depictive images in contrast to college biology texts. Other studies have presented results proving that images that contain more visual detail lead to weaker comprehension scores due to the presence of irrelevant visual detail (e.g., Butcher, 2006; Imhof, Scheiter, & Gerjets, 2011; Moreno, Ozogul, & Reisslin, 2011; Scheiter, Gerjets, Imhof, & Kammerer, 2009; Westerbeek, 2016; Westerbeek, Van Amelsvoort, Maes, & Swerts, 2014).

Nevertheless very little attention has been paid to the effects of visual detail in images on metacomprehension. This study aims to contribute to this growing area of research by exploring to what extent the presence of visual detail in representational images affect metacomprehension accuracy. The purpose of this chapter is to review the literature on the effects of visual detail in images on metacomprehension. It begins by explaining the general cognitive processes of text and image comprehension, followed by reviewing existing literature regarding metacomprehension to obtain a full understanding of what aforementioned terms entail in general. Lastly, the role of visual detail in representational images in relation to (meta)comprehension will be discussed.

1.1 Comprehension

Researchers in the field of cognitive science have shown an immense interest in text comprehension. Kintsch (1994) for example argues that comprehension encompasses three levels of understanding: The surface structure, the text base and the situation model. The surface structure, being the first level of understanding, revolves around encoding the words and phrases and the linguistic relations between them. The second level, which is referred to as the text base level, can be described as the process of encoding semantic and rhetorical structures of the text. Through levels one and two readers are capable of understanding a text. However it is the third and last level that gives readers the ability to obtain a deeper level of understanding. Also known as the situation model, the third level encompasses a process that merges the information in the text with prior knowledge and constructs cohesive mental representations of the events described in the text by storing information in the memory (Gernsbacher, Varner, & Faust, 1990; Zwaan & Radvansky, 1998). Aforementioned levels of comprehension serve as a foundation for successfully understanding information and explain how readers connect information across

sentences. However, this theory focuses solely on reading texts without images and therefore does not fully explain the cognitive processes readers' go through when reading text materials that are supported by images. The processes readers go through while reading texts that are supported with images will be explained in the following section.

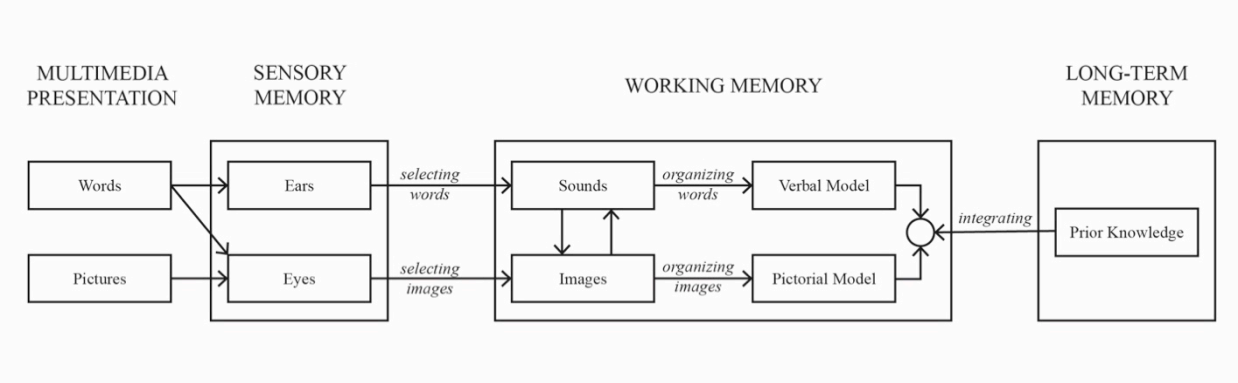

Figure 1. Cognitive theory of multimedia learning. Adapted from "Nine Ways to Reduce Cognitive Load in Multimedia Learning," by R. E. Mayer, & R. Moreno, 2003, *Educational Psychologist, 38*, p. 44. Copyright 2003 by Lawrence Erlbaum Associates, Inc.

A theory that is extensively studied by researchers (Eitel & Scheiter, 2015; Eitel, Scheiter, & Schuler, 2013; Mayer, Bove, Bryman, Mars, & Tapangco, 1996) and explains the process of understanding text materials supported with images is the cognitive theory of multimedia learning (Mayer, 2001). This theory assumes that the implementation of images can contribute to successful processing and efficient learning of text materials based on three main assumptions: The dual-channel assumption, the limited capacity assumption and the active learning assumption. According to the dual-channel assumption people use two channels to process visual and auditory information separately. The limited capacity assumption states that people are not capable of processing unlimited information in each channel at the same time due to the limitations of working memory capacity. The active learning assumption refers to the

ability to organize and select information that is processed into a coherent mental model (i.e., situation model). To give a clear overview of how texts with images are cognitively processed, the cognitive model of multimedia learning is depicted in Figure 1. As can be seen in the model, pictures and words (when written) are both perceived through the eyes in the visual sensory memory, transferred to the working memory to be then organized and integrated in the long-term memory.

1.2 Metacomprehension

Metacomprehension refers to one's ability to assess how well he or she understands information presented in text materials. Many researchers support the notion that metacomprehension accuracy is essential for self-regulated learning (Dunlosky & Lipko, 2007; Jaeger & Wiley, 2014; Wiley, Griffin, & Thiede, 2005). For example, when acquiring new work-related skills or mastering new hobbies successfully self-monitoring one's own learning could increase the chances to achieve the best results in a certain time frame. Particularly in educational settings it is believed that students with stronger metacomprehension accuracy may be more efficient in planning to study course content in a certain time frame and consequently might obtain better study results (Dunlosky & Lipko, 2007).

Numerous studies have focused on text comprehension in context of text materials without images (Carney & Levin, 2002; Eitel, Scheiter, & Schüler, 2013; Maki & Berry, 1984; Pike, Barnes, & Baron, 2010). However, with the large variety of image types used to support effective learning of text materials, it is still of importance to address the effects of particular images on metacomprehension. In general, metacomprehension studies follow a standardized procedure to monitor readers' learning performance. Typically, participants are first asked to read multiple text passages and then judge how well they think they will perform on a test as per

what they have read (i.e. judgments of learning), after which they participate in an actual test related to the content of the text passages to measure text comprehension (i.e., learning performance). Metacomprehension accuracy is then computed by comparing judgments of learning (JOLs) with learning performance. The extent to which JOLs and learning performance correspond to one another indicates the strength of metacomprehension accuracy.

In order to measure metacomprehension accuracy researchers have generally classified three types of accuracy, namely absolute accuracy, confidence bias and relative accuracy (Maki, 1998, as cited in Jaeger & Wiley, 2014). Absolute accuracy can be defined as the mean absolute deviation between the actual and judged performance (Glenberg & Epstein, 1985). In other words, it measures the average distance between a reader's judgments and his or her actual results. According to Jaeger & Wiley (2014), confidence bias is comparable to absolute accuracy but differs on the ground that it gives a direction of misjudgments (e.g. readers can be over or underconfident about their JOLs). In contrast to absolute accuracy and confidence bias, relative accuracy focuses on to what extent JOLs correlate with actual learning performance *across multiple texts* (Dunlosky & Lipko, 2007). In addition, relative accuracy is believed to be independent of non-metacognitive influences, such as text difficulty and prior knowledge (Griffin, Jee, & Wiley, 2009). For this reason, this measure is generally used by metacomprehension researchers and will therefore also be applied in the current study.

Relative accuracy functions as an intra-individual correlation between JOLs and learning performance (Jaeger & Wiley, 2014; Wiley, Griffin, & Thiede, 2005). This means that correlations within a range of -1 and +1, correlations near or below 0 would indicate poor accuracy and, consequently, correlations near +1 would indicate strong accuracy. For example, Person A read three texts about (1) Global Warming, (2) Earthquakes and (3) Windstorms and

has made predictions (JOLs) to what extent he or she thinks to answer correctly to questions about these specific texts. For the purpose of this example we can assume that Person A predicted to perform best on a test about Global Warming, then Earthquakes and least on Windstorms. In case of perfect relative accuracy, Person A's test scores ought to be in line with their predictions (i.e., highest score for Global Warming, followed by Earthquakes and lowest score for Windstorms). However, in case the test scores indicated the opposite (i.e., highest score for Windstorms, followed by Earthquakes and lowest score for Global Warming), Person A would have failed to successfully assess how well he or she has understood a text relative to the other texts resulting in imperfect relative accuracy.

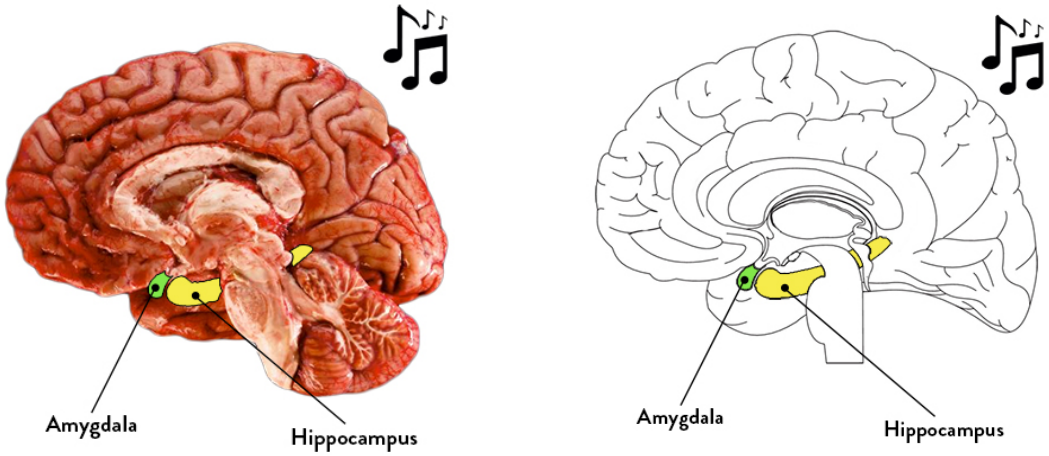

Figure 2. Example images of a human brain: Realistic image (left) and schematic image (right).

In metacomprehension literature, JOLs have been studied extensively with general results showing that monitoring one's own level of understanding is quite poor (Dunlosky, & Lipko, 2007; Griffin, Wiley, & Thiede, 2008). According to Dunlosky and Lipko (2007) it is most likely that people will have difficulties in assessing their understanding if they have not fully

comprehended the text. For example, reading a text once does not necessarily account for lower learning performance on a test. It could simply mean that one was not able to fully process the information and has to read the text multiple times before the information can be successfully placed in a solid situation model. Many recent studies have therefore implemented additional tasks to the standard procedure to enhance metacomprehension accuracy such as rereading, paraphrasing and self-explanation (Griffin, Wiley, & Thiede, 2008; Jaeger, & Wiley, 2014; Kletzien, 2009). Although the aforementioned studies have focused on enhancing metacomprehension accuracy the current study focuses on obtaining more insight in an area of text and realistic image comprehension that has yet to be fully explored. Therefore the standard procedure for measuring metacomprehension will be maintained.

1.3 Type of Image

Over the past decades researchers have investigated the effects of various image types on metacomprehension (e.g., Jaeger & Wiley, 2014; Serra & Dunlosky, 2010; Vössing, Stamov-Rossnagel, & Heinitz, 2016). Particularly, decorative and representational images have been a point of focus. In their study, Jaeger and Wiley (2014) presented participants with either texts without images, or with representational or decorative images. Representational images reflect the content in the text either partially or completely (Carney & Levin, 2002), for example providing a text about the structure of a volcano with a representational image that depicts the various layers of the volcano (i.e., Jaeger & Wiley, 2014). Decorative images on the other hand have the function to simply ‘fill’ the page, such as scenic photographs of a mountain accompanying a text that gives a description about climbing mountains. In this case the type of image does not add value to the process of comprehending the text. Participants were instructed to read the texts and make predictions on how well they understood each text (i.e., JOLs). Finally

they were instructed to take a test for each text to measure their level of comprehension. The researchers found that in comparison to text supported with decorative images and text without images, participants' metacomprehension accuracy was significantly stronger for representational images. This study also provided evidence for the negative influence of decorative images; the presence of decorative images led to poor metacomprehension accuracy.

The current study focuses on representational images that differ in the amount of visual detail presented in an image. Figure 2 shows examples of a more detailed, realistic image and a schematic image of the human brain. Realistic images can be defined as images that depict objects with photographic features and can be categorized within the domain of visual realism. According to Westerbeek (2016), visual realism refers to the extent to which an image is visually similar to the reality it represents. For example, photographs are more realistic in comparison to schematic images due to the high degree of visual similarity of the depicted objects in real life. Schematic images on the other hand consist of simplified line drawings and, thusly, contain less visual detail. Hence the current study aims to address the following research question:

RQ: To what extent does the level of visual detail in representational images influence metacomprehension?

In order to successfully measure metacomprehension accuracy, it is essential to incorporate one's level of comprehension. In context of understanding text supported with images that are either realistic, schematic or solely text, numerous studies have presented varying results. Imhof, Scheiter and Gerjets (2011) examined the effectiveness of dynamic visualizations based on levels of realism and expected that the degree of realism would interact with the

presentation format. However, the results indicate that realism had no main effect. The effectiveness of different presentation formats of visualizations in this study was not affected by the degree of realism. Another study that compared texts with either concrete (i.e., detailed) or abstract illustrations presented somewhat different results; Concrete and abstract illustrations both led to better learning than text alone (Mason, Pluchino, Tornatora, & Ariasa, 2013).

According to Westerbeek (2016), schematic images support making referential connections best in comparison to realistic images. The reason could be that realistic images may disadvantage comprehension due to abundance of visual detail present in this specific image type, which may lead to weaker learning performance. In addition to this, one can assume that when viewing an image with significantly more visual detail to be processed, this may lead to an overload due to too many irrelevant details preventing understanding more important information (Mayer & Moreno, 2002). In the same way Butcher (2006) has found that participants who learned from text accompanied with schematic images acquired more factual knowledge than participants who learned from text accompanied with realistic images. Thusly, the absence of irrelevant visual detail may help readers to focus on information that is essential to learning. However the effects of realistic images on understanding causal relations were not taken into account. Therefore the possibility that realistic images disadvantage understanding factual information but benefit readers to obtain a better understanding of causal relations is not excluded. Overall, the current study assumes that realistic images will lead to overall weaker comprehension compared to schematic images and text without images as proposed in the following hypothesis:

H1: Texts supported with realistic images will lead to weaker comprehension compared to texts supported with schematic images and texts without images.

The aforementioned section hypothesized that realistic images will lead to weaker comprehension. However, the opposite may apply to JOLs. An early study has proved that unnecessary detail in text materials can impair one's ability to learn effectively because detail can lead to selective attention (Harp & Mayer, 1998). This may also apply to images with an abundance of visual detail. This abundance of visual detail could give the reader the impression that he or she understood a text better than he or she actually did. A study conducted by Vössing et al. (2016) for example suggested that the advantages of images for metacomprehension could not be guaranteed for the reason that images may bias JOLs. Supporting this multimedia heuristic, Serra and Dunlosky (2010) have indeed found that the majority of participants strongly believed that multimedia presentations, which included text and diagrams, would have a greater effect on learning than single-medium presentations that included solely text. When they added a third group that read texts with decorative (i.e., non-informative) images they found that JOLs were equal to those in the effective multimedia group. However, their actual learning performance appeared to be lower and did not diverge from the text-only group. In conclusion, aforementioned studies have shown that JOLs are prone to multimedia presentations. This supports the notion that the presence of an image in any form whatsoever might bias JOLs and encourage readers to assign higher JOLs that are not representative of their actual level of understanding.

H2: Texts supported with realistic image will lead to higher JOLs compared to texts supported with schematic images and texts without images.

The current study assumes that text supported with realistic images will lead to weaker comprehension (H1) but will lead to higher JOLs due to the multimedia heuristic (H2). An

explanation for this might be that readers may think they have understood a text better due to the visual richness of realistic images or merely due to the presence of an image. This could be a reason readers think they will perform better on a test (i.e. resulting in higher JOLs). Glenberg, Wilkinson, & Epstein (1982) refer to this as the illusion of knowing, which involves a discrepancy between the actual learning performance and metacomprehension accuracy. Subsequently this means that participants in the realistic image condition will obtain lower comprehension scores and assign higher JOLs in comparison to participants in the schematic image and no image condition. The third and last hypothesis suggests therefore that there is a relation between the type of image and JOLs. In line with the first and second hypothesis, the third hypothesis is therefore as follows:

H3: The correlation between learning performance and JOLs will be weaker for texts supported with realistic images than for texts supported with schematic images and texts without images.

Method

2.1 Participants

Initially 79 native Dutch speakers with higher education levels participated in this study. These education levels included students and graduates from higher professional education or university. Participants in this study were recruited via the *Communication and Cognition Proefpersonenpool*, which is an online recruitment tool provided by Tilburg University. Participants who signed up via this tool received 0.5 course credits for their participation. In addition to this a small part of the participants was sampled using convenience sampling. After analyzing the data it turned out that the data of four participants was not successfully processed and was therefore excluded for further analysis. Of the remaining 75 participants, 48 (64%) were

female and 27 (36%) were male. The age of the participants ranged from 18 to 31 years old (M_{age} = 22,56, SD_{age} = 3.07).

2.2 Design

The design used in this study was a 3 (Image type: no image, schematic image, realistic image) × 2 (Test type: inference, memory) mixed design, with image type as a between-subjects variable and test type as a within-subjects variable. Participants were randomly assigned to either the realistic image, schematic image or the no image condition. This resulted in a total of 25 participants per condition. Because the test type was a within-subjects variable, all participants completed the same test that was divided into questions about causal relations (i.e., inference) and factual information (i.e., memory).

2.3 Materials

The materials used in this study were, to a great extent, adapted from Van Loon, De Bruik, Van Gog, and Dunlosky (2014). In the section that follows, these materials will be discussed.

2.3.1 Texts

The texts used in this study were adapted from Van Loon et al. (2014) and consisted of five single-paragraph expository texts on diverse subjects such as “The Suez Canal”, “Music makes smarter”, “Botox”, “Sinking of metro cars”, and “Concrete constructions”. The mean number of words per text was 167.60 (*SD* = 10.92). Because participants were required to read the texts on a computer screen, it was necessary to ensure reading comprehension was not compromised. Therefore, additional measures were taken. Firstly the texts were presented in a format with a 12-point serif font and double spacing to increase on-screen readability (Bernard, Lida, Riley, Hackler, & Janzen, 2002; Neuwirth, Forlizzi, & Regli, 1998). In addition to this,

Jaeger and Wiley (2014) pointed out the importance of eliminating the act of scrolling, as this can negatively impact learning from text on computer screens (Sanchez & Wiley, as cited in Jaeger & Wiley, 2014). Thusly, all texts were presented on separate pages on a computer screen with a minimum resolution of 1280 × 786 pixels so that both the text and, if applicable, the image would fit the page without requiring the participants to scroll while reading. Lastly, all browser toolbars were made unavailable to prevent participants from being distracted by irrelevant visual elements. Examples of the texts used in this study appear in Appendix A.

2.3.2 Images

Each text in the realistic and schematic image condition was supported with one image specifically designed for this study. The purpose of these images was to provide participants visual information equivalent to the content of the texts and contained only information that was mentioned in the texts. For the realistic image condition this meant that participants viewed an image with photographic features to amplify the realistic characteristic of what was depicted. For example the text “Music makes smarter” contained information on how music affects different brain areas. Participants in the realistic image condition viewed the text with an image of a real brain with an emphasis on the brain areas that were mentioned in the text (see Figure 1). The same image was presented to participants in the schematic image condition with the exception that the realistic characteristics of the brain were left out and replaced with solely schematic lines equal to a line drawing of a brain. The differences between the images also applied to the images paired with the remaining texts. In order to ensure consistency in the placement of the images all images appeared strictly on the right side of the texts. See Appendix B for a full overview of the images used in this study. The no image condition served as a control condition and participants in this condition were, consequently, presented with only texts.

2.3.3 Test

In order to measure learning performance participants were instructed to take a test about the content of the texts. Regardless of the condition all participants were presented with the same test questions in the same order and included a total of thirty questions consisting of six questions per text: one question about causal relations and five questions about factual information per text. Questions about causal relations required more elaborate answers (participants were asked to identify four causal relations per text). For questions about factual information short answers (e.g., names, years and numbers) sufficed. Similar to the text materials the test was also adapted from Van Loon et al. (2014). An overview of the complete test can be found in Appendix C.

2.4 Procedure

Participants were welcomed in a room that was suitable for studying without being disturbed by environmental noises. Because the experiment was designed as an online questionnaire the room was equipped with a computer. After being seated participants were requested to turn off their phones and other devices that could cause distraction during the experiment. Prior to the start of the experiment all participants signed a consent form confirming their voluntary participation and giving their permission to use their data for scientific purposes. They then received a brief oral explanation regarding the purpose and duration of the experiment. Participants then carried on with the experiment independently.

Participants were first presented with a general introductory screen stating that the experiment was divided into three section, namely (1) reading five texts, (2) predicting JOLs indicating to what extent they would answer correctly to questions about these texts and finally (3) taking an actual test. They were then presented with an impression of the experiment's

structure based on an example text, example questions and an example of how they would be asked to make a prediction. Participants were instructed to make two JOLs: comprehension-based (inference) and comprehension-based (memory). The reason for this dichotomy was to help clarify on which of the two the reader was relying on during the judgment process. The specific questions at hand were "What percentage of the questions do you expect to answer correctly when tested for understanding causal relations in this text?" and " What percentage of the questions do you expect to answer correctly when tested for understanding factual information in this text?". The JOLs were presented on a 6-point scale ranging from 0% to 100% with points referring to 0%, 20%, 40%, 60%, 80% and 100%. This resulted in a total of ten JOLs per participants.

Before starting with the actual experiment, participants were given the opportunity to ask questions to the experimenter in case the instructions and examples were not clear. After this all participants read the five texts, made ten predictions of JOLs and took the test in the same order. Additionally, all participants were informed that it was not possible to re-read a text once they had moved on to the next page. However, time was not of importance and they could read all texts at their own pace. After completing the test participants were thanked for their participation. The experiment took approximately 30 minutes to complete per participant.

2.5 Scoring of Responses

As mentioned before, the text materials and test questions were adapted from Van Loon et al. (2014). Therefore participants' responses were also evaluated based on the scoring model used in their research to maintain consistent and to ensure validity of the test scores.

2.5.1 Scoring Causal Relations

Following the guidelines of Van Loon et al. (2014) responses for causal relations that included literal ideas or correct paraphrases of ideas inferred from the texts were scored as correct. Points were also given for indirect relations that could not be linked to the text but seemed in line with the general idea because this type of responses indicated valid relations. Questions about causal relations typically required participants to mention four causal relations each equal to one point. Thusly, participants could score a total of four points per question. Despite the availability of a straightforward scoring model the responses about causal relations were open to interpretation. Cohen's Kappa (κ) was run to determine if there was an inter-rater agreement between two independent raters. Analysis revealed that there was a moderate agreement between the two raters ($\kappa = .41$, $p < .001$). Further analysis showed that the differences occurred due to the second reader's less strict way of assessing responses. Thus, the original test scores for causal relations are retained for further analysis.

2.5.2 Scoring Factual Information

For every response on a question about factual information participants could score either 1.0 (correct), 0.5 (partially correct) or 0.0 (incorrect) points. For example, one of the questions about factual information for the text "Concrete constructions" was: "What was the profession of Mr. Nicolas?". Based on the scoring model a correct response would be either 'elevator mechanic' or 'elevator repairman'. Partially correct responses typically contained one of the following: renovates elevators, maintains elevators, elevator maker or elevator builder. Responses that lacked aforementioned terms were scored as incorrect. This resulted in a maximum score of five points per text for factual information.

3. Results

3.1 Visual Detail and Comprehension

To obtain more insight in the extent to which visual detail in images affects comprehension, an overall score was calculated for each participant consisting of the sum of scores for both test types. Then the differences in test scores between groups were compared. Table 1 displays the descriptive statistics for the mean test scores. As can be seen in the table the distance between the mean values is minimal. To determine whether the conditions statistically differed in learning performance a one-way ANOVA was conducted. This revealed a non-significant main effect of image type on test scores, $F(2,74) = .66$, $p = .52$. Hypothesis 1, assuming that participants in the realistic image condition would score lower on the knowledge test compared to participants in the schematic image and no image condition, was therefore not supported.

To determine whether there was an effect of test type on learning performance the scores for causal relations and factual information were standardized for comparison between groups. Using repeated-measures ANOVA no significant differences were found in test type between groups $F(1,72) = .83$, $p = .44$. However, there was a significant interaction between test type and the condition of the participant $F(2,72) = 5.17$, $p < .01$. Participants in the realistic image condition scored statistically significant higher on questions about causal relations but not significantly lower on questions about factual information than participants in the schematic and no image group.

To obtain better understanding of the differences between the groups a one-way ANOVA was conducted within groups for both test type. It was revealed that for causal relations there was a statistically significant difference between groups regarding test scores of questions about

causal relations ($F(2,72) = 3.66$, $p < .05$, $\eta^2 = .092$). A Tukey post-hoc test revealed that participants in the realistic image condition scored statistically higher on questions about causal relations in comparison to participants in the schematic image condition ($p < .05$). There were no significant differences between the realistic image and no image condition ($p = .14$) and schematic image and no image condition ($p = .77$). The between-group comparison for test scores on factual information was non-significant ($F < 1$).

Table 1

Mean Inference and Memory Test Scores for Experimental Groups

Test Type	Experimental Group		
	Realistic	Schematic	No Image (Control)
Causal Relations	13.93 (2.99)	11.52 (3.48)	12.16 (3.26)
Factual Information	11.04 (3.31)	11.40 (4.31)	11.96 (4.33)

Note. Test scores for inference questions are out of a maximum of 20; memory questions are out of 25.

3.2 Visual Detail and JOLs

It was expected that participants in the realistic image condition would make higher predictions of JOLs compared to participants in the schematic and no image condition due to the visual richness of realistic images. As shown in Table 2 mean values of JOLs did not differ between groups. As determined by a repeated-measures ANOVA, there was no main effect for the differences between image type on JOLs, $F(2,74) = .01$, $p = .91$. However, further analysis revealed that there was a difference in test type, $F(1,74) = 5.71$, $p < .025$, $\eta^2 = .079$. Participants generally predicted stronger JOLs for questions related to causal relations ($M_{inference} = 3.79$,

$SD_{inference}$ = .69) in comparison to questions related to factual information (M_{memory} = 3.65, SD_{memory} = .83).

Table 2

Mean Inference and Memory JOLs for Experimental Groups

Test Type	Experimental Group		
	Realistic	Schematic	No Image (Control)
Inference	3.80 (.67)	3.71 (.72)	3.86 (.69)
Memory	3.68 (.73)	3.62 (.80)	3.64 (.97)

Note. JOLs are out of a maximum of 5.

3.3 Visual Detail and Metacomprehension Accuracy

Following previous studies focusing on metacomprehension accuracy intra-individual Goodman–Kruskal gamma correlations were computed between comprehension score and JOL for each participant. Gamma correlations were calculated by measuring the relative differences between comprehension scores and JOLs across all pairs of texts and predictions. For example if one JOL increased from one text to another and the comprehension score also increased, this was considered to be a concordance (C). However, in case one JOL increased from one text to another while comprehension scores decreased and vice versa this was considered to be a discordance (D). The total number of concordances and discordances were then used to compute the correlation coefficient γ, by using the following formula: $\gamma = (C - D)/(C + D)$. In addition to concordances and discordances participants were also able to make the same prediction and/or obtain the same test scores for all texts. If that were the case, this was considered to be a tie (T). As recommended by Nelson (1984) participants with incalculable gamma correlations (ties) were

excluded from further analysis. This resulted in the exclusion of four participants in the realistic image condition, six participants in the schematic image condition and four participants in the no image condition.

Due to the dichotomy in test type (inference and memory) this resulted in two gamma correlations per participant: One for causal relations and one for factual information. In Table 3 an overview of the mean gamma correlations is presented. As mentioned earlier gamma correlations near or below 0 are considered to represent poor accuracy (in contrast to gamma correlations near +1, which indicate strong accuracy). As can be seen in the table the mean values are all near or below 0 showing overall poor metacomprehension accuracy.

Table 3

Mean Gamma Correlations (and Standard Deviations) for Experimental Groups

Test Type	Experimental Group		
	Realistic	Schematic	No Image (Control)
Inference	-.28 (.54)	-.00 (.64)	.02 (.74)
Memory	-.04 (.66)	-.03 (.62)	-.05 (.76)
Overall	-.16	-.02	-.04

Note. Mean gamma correlations range from -1 to +1.

The general expectation of the third hypothesis was that the correlation between comprehension and JOLs would be weaker for participants in the realistic image condition compared to the schematic image and no image condition. As determined by a mixed-design ANOVA there have been statistically no significant differences between the realistic image,

schematic image and no image condition ($F(2,58) = .61$, $p = .55$) and a non-significant interaction between the conditions ($F(2,58) = .62$, $p = .54$). In addition, there was no statistically significant effect of test type $F(1,58) = .12$, $p = .73$. Hence, the third hypothesis was therefore not confirmed.

4. Discussion and Conclusion

The main purpose of the current study was to investigate to what extent the level of visual detail in representational images influences metacomprehension accuracy. It was expected that images with more visual detail would lead to weaker comprehension scores but higher judgments of learning (JOLs) in comparison to schematic images and no images. In contrast to previous literature this study does not provide support for the view that images with more visual detail negatively affect metacomprehension accuracy. This chapter describes and discusses possible explanations for these results followed by a review of the limitations and suggestions for future research.

As discussed in the introduction previous research on this matter has revealed that realistic images might lead to weaker comprehension due to visual detail (e.g., Westerbeek, 2016). In addition to this Mayer and Moreno (2002) implied that too much visual detail goes hand in hand with an overload of irrelevant details, which might prevent the processing of important information. In line with literature, the first hypothesis stated that texts supported with realistic images, would lead to weaker comprehension scores when compared to texts with schematic images and texts without images. However, there were no statistically significant differences found between groups.

Results presented in this study show similarities to the outcomes of Imhoff, Scheiter and Gerjets's (2011) research in which there was also no significant effect of visual realism in

illustrations. Nevertheless further analysis did reveal a significant effect of test type: Participants (specifically those in the realistic image condition) scored higher on questions about causal relations in comparison to questions about factual information. This finding goes against Butcher's (2006) notion that schematic images are better suited than images that contain more visual detail for acquiring knowledge from texts.

The second hypothesis focused on the effects of visual detail in images on predicting JOLs. It was suggested that texts supported with realistic images would lead to stronger JOLs compared to texts supported with schematic images and texts without images. This assumption was based on findings that images might bias JOLs due to the general belief that multimedia presentation would have a greater effect on comprehension than single-medium presentations (Serra & Dunlosky, 2010; Vössing et al., 2016). Unfortunately, these findings could not be ascertained from the results of the current study. None of the three image types differed statistically from one another.

The third and last hypothesis focused on the relationship between comprehension and JOLs. It was expected that images with more visual detail would lead to weaker metacomprehension accuracy. In other words, participants in the realistic image condition had been expected to score lower on test scores but make higher JOLs; leading to a discrepancy between actual learning performance and accurate prediction of JOLs. In addition it was expected that this type of image might create the illusion of knowing (Glenberg, Wilkinson, & Epstein, 1982). Contrary to expectations this study did not find a significant difference between the three image conditions. The results show mean values of gamma correlation, which were below zero for all three groups indicating poor metacomprehension accuracy across all conditions. From these findings questions arise as to why there are no significant differences

between image types. The following section elaborates further on a number of limitations of this study and provides suggestions for future research.

4.1 Limitations and Suggestions for Future Research

A number of limitations need to be taken into account when looking back at the current study. Firstly the sample size was not representative for the entire population. The focus in this study was on students with a higher education background. Additionally, there was an unequal distribution of gender. Although results are not as expected, it can be of importance for future research to further investigate the differences between realistic and schematic images with a more representative sample.

Secondly, participants were not able to re-read the texts once they moved on to the next page. Even though this was a deliberate decision to maintain focus on the initial comprehension process it is important to note that it does not comply with real life circumstances. It may be uncommon for students to be restricted to reading a certain text on solely one moment without having the opportunity to re-read the content for better comprehension. Especially because in real life the process of studying texts for a test involves repetition and practice during various time points which are two study methods that were not present in this research design.

Another drawback of the current approach is that there was no information collected about the study styles of the participants. It may be important to know how students study for tests considering different study styles may possibly affect initial comprehension scores. Furthermore it may be of importance to observe to what extent participants perceive themselves as good or poor comprehenders. When analyzing JOLs this could be of essential knowledge since better comprehenders are expected to be better at assessing their metacomprehension

accuracy. Measuring whether one thinks he or she is a good or poor comprehender may also help to reduce judgment errors.

It can be interesting for future studies to include eye movement analysis. By incorporating eye-tracking methods participants' visual engagement with the texts and images could be measured more precisely. In context of the current study eye movement analysis could be of value because it may be easier to analyze the cognitive process when reading texts with images. This method may also contribute to the question whether there is an interaction between reading speed and type of image (e.g. if schematic images are perceived as easier to process, it could be possible that readers are able to read through texts more quickly or even assign higher JOLs). In addition, eye movement analysis could be useful in comparing how long readers look at different types of images. For example if readers are taking more time to process realistic images than schematic images this could be an indication that realistic images are more difficult to understand. Future research could focus on comparing the differences between time spent looking at certain types of images in relation with comprehension scores and metacomprehension accuracy.

This study also made no attempt to address participants' attitudes towards the images. Future research should consider developing a post-questionnaire in which participants' can express their attitude and/or opinions about the relevance of the images. A question that could be asked is for example: "To what extent did you feel like the images helped you understand the text?". Another area that could give rise to improvement is the design of the images that are used in this study. Results have shown that there were no significant differences between groups. A possible explanation for these findings is that the level of detail in realistic images was not perceived as different from images in the schematic image condition. However this is an

insufficient explanation as to why participants in the text-only group also obtained poor metacomprehension accuracy. Future research should therefore consider pre-testing the images in order to ensure that the images are perceived as different from each other. By doing so it may be prevented that between-subject variables obtain similar results, as was the case in this study.

Even with these possible limitations the current study adds to a growing body of literature on visual realism in images and the effects of metacomprehension accuracy. As stated throughout this study many researchers have been successful in providing support for the notion that in general detailed images harm metacomprehension accuracy. Although the outcomes of this study did not support this general belief it is recommended that future research continue to explore the differences between various image types and the effects of visual realism.

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Appendix A

Text: Het Suezkanaal

Het Suezkanaal, dat de Indische Oceaan en de Middellandse zee met elkaar verbindt, is van groot belang voor de wereldhandel. Er is van oorsprong geen natuurlijke waterverbinding tussen de Atlantische en de Indische oceaan. Tussen deze twee zeeën ligt een woestijn. Hierdoor moesten handelsschepen die van de havenstad Jeddah in Saoedi-Arabië naar Europa reisden, een lange tocht rond het hele Afrikaanse continent maken. Daarom werd besloten dat er een kortere waterweg nodig was die de twee oceanen met elkaar zou verbinden. Om deze reden werd het Suezkanaal gegraven, dat was ontworpen door de Oostenrijkse ingenieur Alois Negrelli. Jarenlang waren arbeiders bezig om dit kanaal te graven en uiteindelijk werd het kanaal in 1869 geopend voor de scheepvaart. Door het graven van het Suezkanaal is de afstand van de havenstad Jeddah naar de havenstad Rotterdam met 40% verkort. Via het Suezkanaal is de afstand tussen deze twee steden 6337 zeemijl, als men rond het Afrikaanse continent vaart is deze afstand 10.743 mijl.

Text: Muziek maakt slimmer

Leren om een instrument te bespelen kan veel voordelen hebben. Dit komt omdat voor het lezen van bladmuziek en het spelen van noten men gebruik moet maken van verschillende gebieden in de hersenen. De hersenen verbinden muziek met geheugen in verschillende hersengebieden, zoals de amygdala en de hippocampus. Canadees onderzoek toonde aan dat als gevolg van het gebruik van deze verschillende hersengebieden, 12-jarige kinderen die muziek leerden spelen, hogere scores haalden op een IQ-test. Ook kan het gebruik van de hersenen tijdens het leren van muziek ruimtelijke vaardigheden verbeteren die nuttig zijn bij het oplossen van wiskundetaken zoals breuken. Daarnaast kan muziek helpen met het ophalen van herinneringen. Zo kan een oud liedje je herinneren aan iets dat lang geleden gebeurde. Ook kunnen bijvoorbeeld patiënten met de ziekte van Alzheimer door muziek geholpen worden om herinneringen op te halen. Dit werd aangetoond in onderzoek van de wetenschapper Polk. Hij testte een oude vrouw met Alzheimer, zij bleek alle muziek die zij vroeger geleerd had nog te herkennen.

Text: Botox

Botox is de afkorting van botulinetoxine, het is een gif dat door de bacterie Clostridium Botulinum wordt geproduceerd. Dit middel blokkeert het aanspansignaal tussen de zenuwen in de huid en de huidspieren. Sinds 1989 is dit middel toegestaan. Er is wel strenge controle in Nederland. In Amerika is er in 2004 een ongeluk geweest met de dosering van Botox, waaraan 28 mensen overleden. Vanwege het blokkeren van het aanspansignaal tussen de zenuwen en de huid werd het middel Botox oorspronkelijk vooral gebruikt tegen samentrekkende spieren, bijvoorbeeld bij patiënten die vaak hard met hun oogleden knipperen.

Door het inspuiten van Botox in de spieren rond de ogen, worden de spieren verlamd en verdwijnen deze spiersamentrekkingen. Omdat Botox het aanspansignaal tussen de zenuwen en de huidspieren blokkeert, wordt dit middel in de plastische chirurgie ook gebruikt om rimpels naast de ogen en op het voorhoofd glad te strijken. Het effect van een behandeling houdt meestal tussen de 1 en 6 maanden aan. Door zo'n behandeling zien mensen er jonger uit. Maar omdat de rimpels tussen de ogen en op het voorhoofd verdwijnen, kan iemands gezichtsuitdrukking ook ongewenst veranderen.

Text: Metrowagons tot zinken gebracht

Het grootste gedeelte van de oceaanbodem ligt rond de 3 tot 4 km diepte en heeft relatief weinig reliëf. Dit wordt de abyssale vlakte genoemd. Voor de oostkust van de Verenigde Staten zijn in de Atlantische Oceaan zevenhonderd uitgerangeerde, rode wagons van de New Yorkse metro tot zinken gebracht. De oude, rode metrowagons van de New Yorkse metro worden ook wel redbirds genoemd. Door deze wagons tot zinken te brengen hoeft het afval van de oude rode metrowagons niet meer op een andere manier verwerkt te worden. Tegelijkertijd is door het zinken van deze wagons een kunstmatig rif aangelegd. Sinds het afzinken van de eerste wagons in 2001 is door dit kunstmatige rif de hoeveelheid plankton en zeefauna vierhonderd maal zo groot. De zandige zeebodem voor de oostkust van de Verenigde Staten biedt normaal gesproken niet zo veel leefruimte voor zeedieren. Maar door deze toename van plankton en zeefauna worden nu veel makreel, baars en andere zeevissen aangetrokken.

Text: Beton

Beton is nog steeds een veelgebruikt bouwmateriaal, al bijna zeventig jaar worden veel grote gebouwen van betonnen materialen gemaakt. In Nederland moet beton sinds 1962 een KOMO-certificaat hebben, wat aangeeft dat het geschikt is voor constructie van gebouwen. Bij het bouwen van betonnen gebouwen is het belangrijk om rekening te houden met de gevolgen van het gebruik van centrale verwarming. Door het gebruik van centrale verwarming kan beton uitdrogen. Wanneer het beton uitdroogt zorgt dat voor betonkrimp, dat betekent dat betonnen gebouwen krimpen en dus kleiner worden dan ze oorspronkelijk waren. Doordat de gebouwen waarvan het beton uitdroogt kleiner worden, blijven de liften op een gegeven moment hangen. Daarom moet men dan vaak de liften kleiner maken en de liftschachten inkorten. In 1952 werd het Mazzo gebouw gemaakt van betonnen panelen. Door het effect van centrale verwarming is het Mazzo gebouw 12 cm gekrompen. De heer Nicolas, een liftmonteur, vertelt dat er uitgebreide renovatiewerkzaamheden nodig waren om de liften van het Mazzo gebouw aan te passen.

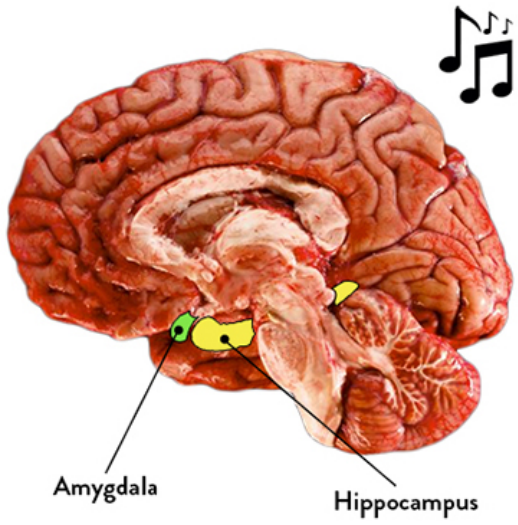
Appendix B

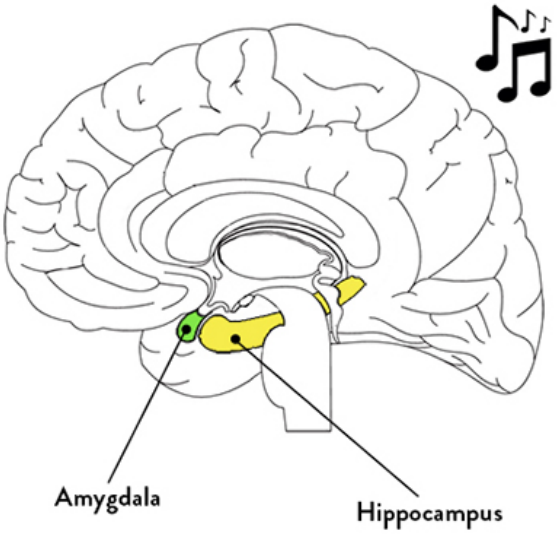
Images used in realistic image condition

Text: "Het Suezkanaal"

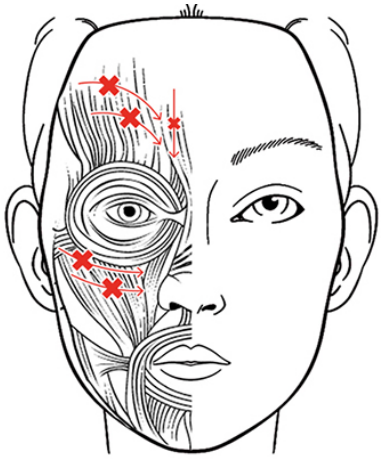
Images used in schematic images condition

Text: "Muziek maakt slimmer"

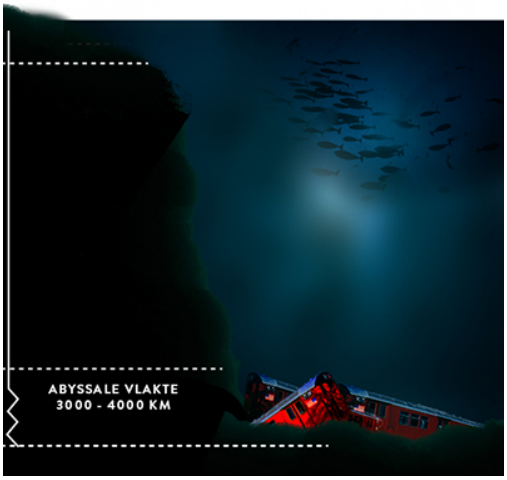


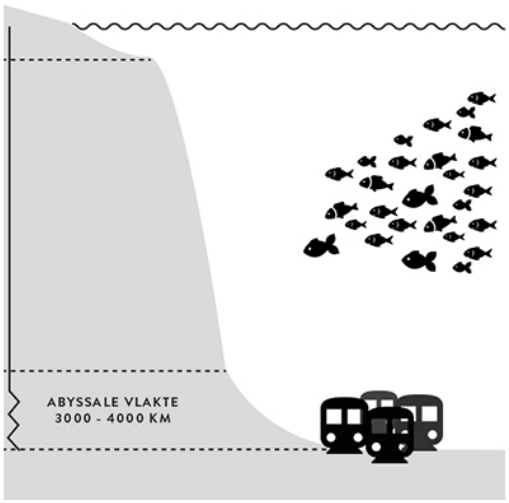


Text: "Botox"

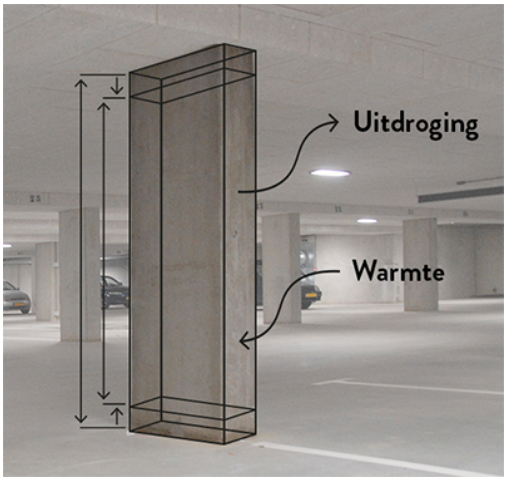


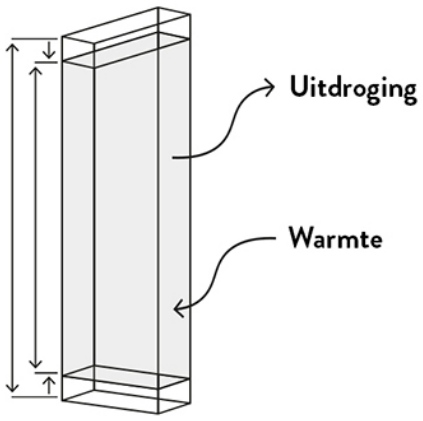
Text: "Metrowagons tot zinken gebracht"





Text: "Beton"





Appendix C

Het Suezkanaal:

1. De afstand voor zeeschepen die varen tussen Jeddah en Rotterdam is een heel stuk verkort. Om welke redenen is de afstand tussen Jeddah en Rotterdam korter geworden? Geef een zo volledig mogelijk antwoord, noem hierin 4 verbanden.
2. In welk jaar werd het Suezkanaal geopend voor scheepvaart?
3. In welk land ligt de havenstad Jeddah?
4. Uit welk land kwam de ingenieur die dit kanaal heeft ontworpen?
5. Met hoeveel procent is de afstand tussen Jeddah en Rotterdam verkort door het Suezkanaal?
6. Wat is de afstand tussen Jeddah en Rotterdam via het Suezkanaal?

Muziek maakt slimmer:

1. Er zijn verschillende positieve gevolgen van het leren lezen en spelen van muziek? Beschrijf welke gevolgen dat zijn. Geef een zo volledig mogelijk antwoord, gebruik hierin 4 verbanden.
2. In welk land werd onderzoek gedaan met een IQ test?
3. Hoe oud waren kinderen in dit onderzoek met de IQ test?
4. Noem een hersengebied dat wordt gebruikt bij het leren van muziek.
5. Noem nog een hersengebied dat wordt gebruikt bij het leren van muziek.
6. Bij welke ziekte kan muziek patiënten helpen?

Botox:

1. Botox blokkeert het aanspansignaal tussen de zenuwen en de huid. Wat zijn de gevolgen hiervan? Geef een zo volledig mogelijk antwoord, noem hierin 4 verbanden.
2. Van welk woord is Botox de afkorting?
3. Sinds wanneer is dit middel toegestaan?
4. Waardoor wordt Botox geproduceerd?
5. Hoeveel mensen overleden in Amerika door een ongeluk met Botox?
6. Hoe lang houdt het effect van een behandeling meestal aan?

Metrowagons tot zinken gebracht:

1. In de Verenigde Staten zijn metrowagons tot zinken gebracht. Het tot zinken brengen van de metrowagons heeft verschillende gevolgen. Wat zijn deze gevolgen? Geef een zo volledig mogelijk antwoord, noem daarin 4 verbanden.
2. Hoe wordt de vlakte waaruit het grootste gedeelte van de oceaanbodem bestaat genoemd?
3. Hoe worden oude, rode metrowagons ook wel genoemd?
4. Uit welke stad kwamen de gezonken metrowagons?
5. Hoeveel wagons zijn tot zinken gebracht?
6. Hoeveel maal groter is de hoeveelheid plankton en zeefauna, vergeleken met voorheen?

Beton:

1. De liften in betonnen gebouwen moeten vaak gerenoveerd moeten worden. Wat zijn de oorzaken waarom deze liften gerenoveerd moeten worden? Geef een zo volledig mogelijk antwoord, noem hierin 4 verbanden.
2. Sinds welk jaar moet beton in Nederland een certificaat hebben?
3. Hoe heet dit certificaat voor beton?
4. In welk jaar werd het Mazzo-gebouw gemaakt?
5. Hoeveel centimeter is het Mazzo-gebouw gekrompen?
6. Wat is het beroep van de heer Nicolas?